Meat Science Tutorial for QA Managers

The Colmslie, Cnr Junction & Wynnum Roads, Morningside, QLD 4170

Agenda

1. **Meat Colour (Dr Robyn Warner- CSIRO)**
   - Background theory and the importance of meat colour
   - Measurement of meat colour – Subjective and Objective methods
   - Factors influencing meat colour and colour faults
   - Browning colour and metmyoglobin, Pale colour and rapid pH decline
   - Options available to improve meat colour
   - What is Dark Cutting and causes of DFD
   - How can it be better managed on plant
   - Economic impacts and livestock handling
   - Strategies for reducing dark-cutting
   - MAP (Modified atmosphere packaging) and impact on Meat Quality
2. **Meat Flavour (Dr Robyn Warner- CSIRO)**
   - Theory and Background
   - Grass vs grain
3. **Theory of Meat Tenderness (Dr John Thompson- UNE)**
   - Background theory and the importance of meat tenderness
   - Measurement of meat tenderness
   - Factors affecting meat tenderness
   - Live animal
     - HGP
     - *Bos indicus* content
     - Gene markers
   - Post mortem
     - pH temperature window
     - tenderstretch
     - ageing
4. **MSA model (Dr John Thompson- UNE)**
   - Numbers graded
   - Economic returns of MSA
   - Problems with boning groups
   - Optimisation
   - Where to from here?
5. **Scientific Panel Discussion (Q&A session)**

MINTRAC Meat Science Tutorial for QA Managers

Robyn Warner

April 19, 2013

ANIMAL, FOOD AND HEALTH SCIENCES
www.csiro.au

Topics Covered

WHAT IS MEAT QUALITY?

MEAT COLOUR

MAP AND IMPACT ON MEAT QUALITY

MEAT FLAVOUR

DARK CUTTING AND CAUSES OF DFD

What is meat quality?

Point of sale

- Meat colour
- Packaging
- Visible drip
- Visible fat

Point of consumption

- Tenderness
- Juiciness
- Flavour

Meat Colour

- Background theory and the importance of meat colour
- Measurement of meat colour – Subjective and Objective methods
- Factors influencing meat colour and colour faults
- Browning colour and metmyoglobin, Pale colour and rapid pH decline
- Options available to improve meat colour

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Theory and the importance of meat colour

<u>Conditions</u>

- Dark-cutting
- Pale, weepy meat (PSE)
- Browning, Greening

<u>Factors</u>

- Content of myoglobin, varies with age of animal, muscle
- Chemical state of myoglobin, ultimate pH, oxidation
- Structure of the muscle, rate of pH fall, ultimate pH

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MEAT COLOUR

Myoglobin (purplish red)

Oxygenation →

← Deoxygenation

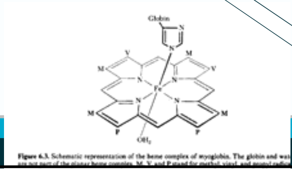
Oxymyoglobin (bright red) Fe^{+2}

Reduction + Oxygenation

Oxidation

Reduction

Oxidation

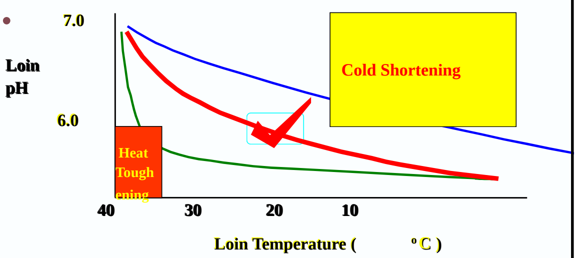


Metmyoglobin (brown) Fe^{+3}

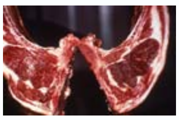
•Pale, weepy meat (PSE)

- Pale, weepy meat (PSE)
  - AUSMEAT colour score 1B and 1C
  - Exudate on surface
  - Weep in bag
  - Failure to tenderise in vacuum bag
  - Caused by rapid pH fall

The MSA abattoir window

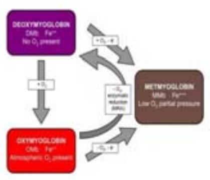


Dark-cutting – high pH meat



- Dark colour
- Variable tenderness
- Bland flavour
- High water-holding capacity
- Greening in vacuum bag (sulphomyoglobin, H_2S from bacteria)

Browning and Greening



Browning
- Caused by oxidation
- Metmyoglobin
- Off flavour and odours (rancid)
- Possible toughening of meat (see MAP)

Greening
- Formation of sulphomyoglobin from H_2S byproduct of bacterial growth in dark-cutting meat

LIPID OXIDATION – anything that promotes lipid oxidation will promote browning

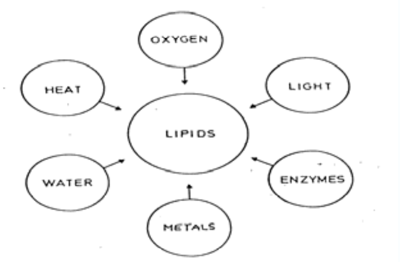
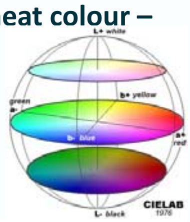
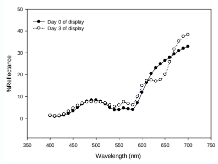


FIG. 1. Factors affecting lipid stability.

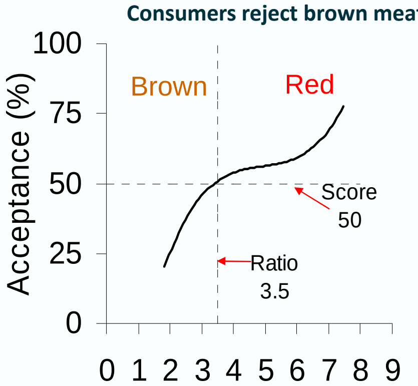
The measurement of meat colour – Subjective and Objective methods

The measurement of meat colour – Objective methods





Consumers reject brown meat



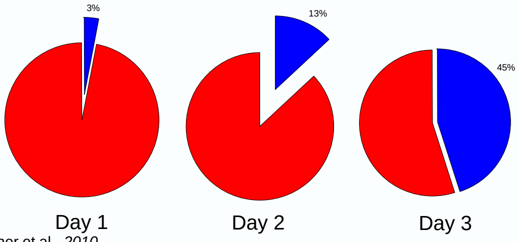
Jacob and Jose, 2009

Oxy/met

Use cutoffs for objective measurements, to establish % unacceptable; eg. fresh colour of lamb meat from sheep CRC flocks

- Very acceptable (>85%)
- Very little high pH meat (1.1%)

Percent of lamb loins from sheep CRC with brown meat (oxy/met <3.5) at 1, 2, 3 days of display (after 5 days ageing)



Warner et al., *2010*

Factors influencing Retail Colour

Trait (Range)	Retail Colour
Iron (8 to 45 mg/kg)	↓ 0.3
Copper (1 to 3.5 mg/kg)	↓ 0.8
Intramuscular fat (2 to 9%)	↓ 0.5
pH at 18C (5.4 to 6.8)	↓ 1.0

Acceptable if retail colour ratio >3.5

Effecting of feeding system on retail colour - Experiment in Victoria (Geelong)

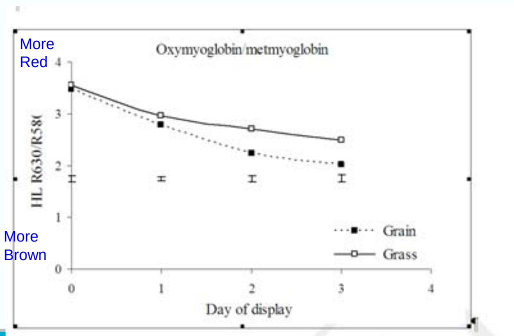
- Eric Ponnampalam, DPIV

- 37 lambs
- 19 sheep on pasture for 5 weeks
- 18 sheep on pasture and grain for 5 weeks
- Measured fatty acids and retail colour

Fatty acids

	Grain	Pasture	*P*-value
Polyunsaturated fats (PUFA)	**245.6**	**216.9**	0.001
Saturated fats (SFA)	1741	1399	0.03
Omega-6/omega-3	**1.58**	**1.37**	0.003

Grain feeding produced more brown meat

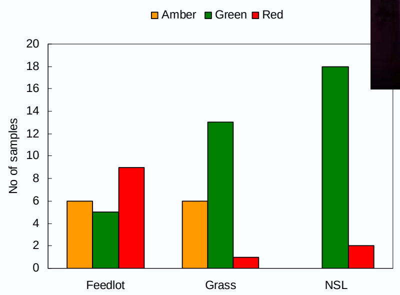


Seasonal changes in the colour stability of lamb meat

Potential causes and solutions for a major supply chain

- Aim: Investigate the cause of poor colour stability of lamb in spring of 2009 for a major supply chain.
- Meat samples collected from 30 lambs in 5 consignments;
  - feedlot, pasture, new season lambs.
- Topside subjected to a display period for during which they were measured and visually scored for colour.
- Meat samples were also assayed for vitamin E and selenium concentration.

Visual colour rating done of colour by supply chain QA on day 7 of display



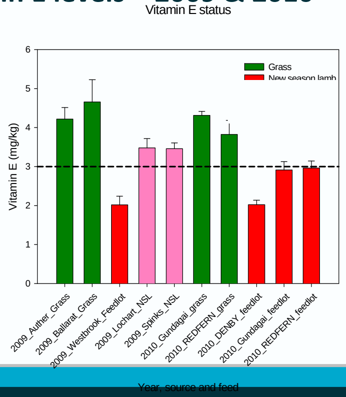
Vitamin E and selenium concentrations in topside

Assay	Feedlot	Grass	NSL	Signif.
Vitamin E	2.02[a]	4.44[b]	3.47[c]	**
Selenium	0.64	0.37	0.28	NS

Seasonal changes colour stability

- The differences between finishing systems for meat colour were related to muscle vitamin E concentrations.
- Addition of vitamin E supplements should be considered for lambs finished on feedlot rations. **This was implemented by supply chain.**
- A further 50 samples of topsides were collected from two abattoirs in 2010, from five different consignments, representing both grass-fed and lot-fed lambs and these were assayed for Vitamin E concentration.

Vitamin E levels – 2009 & 2010



Options available to improve meat colour

Pale meat

- Usually linked to excess water loss
- reduce electrical inputs into carcass, turn off electrical stimulation, reduce time rigidity probe at hide puller, make sure immobiliser is operating effectively
- use rapid chilling, run carcasses off kill floor during breaks

Options available to improve meat colour

Premature browning

- Manage factors known to induce oxidation; temperature abuse, light, oxygen, unsaturated fat levels
- Feed Vitamin E to feedlot lambs or if no green feed (beef?)
- Use MAP to extend colour

Greening

- caused by high pH in beef
- Do not vacuum pack high pH beef
- Lamb – no data – study underway, likely to be similar

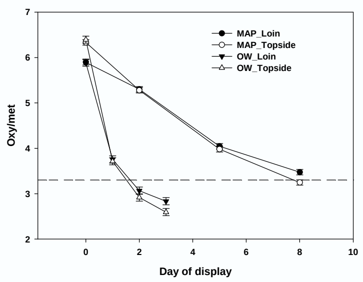
Options available to improve meat colour

Dark-cutting

- Investigate stressors from farm to slaughter and consider on-farm nutrition
- Ensure carcasses in rigor when graded
- (see later section)

MAP (Modified atmosphere packaging) and impact on Meat Quality

Why MAP?



Typical retail shelf-life of beef and lamb in over-wrap and high O_2 (80%) MAP

Storage time in the vacuum pack (weeks at 0C)	0	2	4	6	8
Retail display life (days)					
Overwrapped trays	3	3	2	2	1
High-O_2 MAP	10	5-6	4	3	2

Does packaging method affect the eating quality of beef? Geert Geesink (UNE)

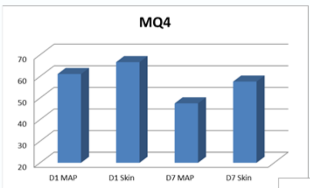
- MAP: 80% O_2, 20% CO_2
- Skinpack: vacuum

Hypotheses:
- MAP will be detrimental to sensory quality
- Ageing will be affected by packaging method

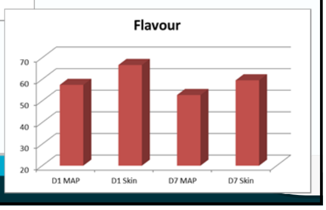
Experimental design

- Striploins - 1 day aged (n = 10), then packed
  - 7 days aged (n = 10), then packed
- Skinpack and MAP pack: displayed for 7 days
- Consumer panel
  - 40 consumers
  - 9 pieces of meat per person
  - Grilled to medium rare
  - Palatability scored

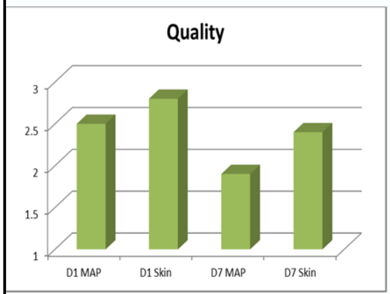
Meat Quality



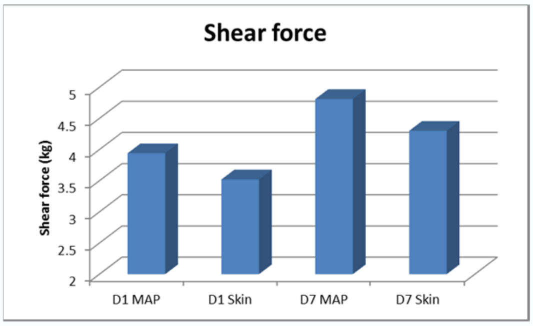
8.8 points difference!



Descriptive quality



1 = Unsatisfactory
2 = Good everyday
3 = Better than everyday
4 = Premium quality



Conclusions

- •Small study with students on beef show negative effect of MAP on eating quality
- •Needs to be replicated using MSA consumer panel
- •Lamb needs to be tested
- •MAP – same as DARFRESH bloom?

Beef Colour at Grading

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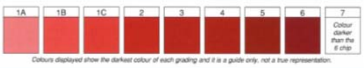
Investigation of beef colour at grading

Joanne Hughes

•N= 1512, 7 plants over Feb to June.

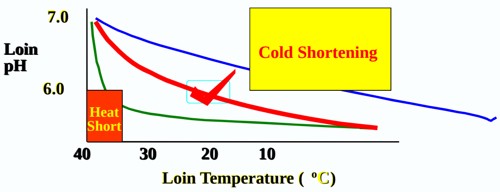
Attributes significant in model:

- Category of cattle
- Days in feedlot
- Temperature at pH6
- Ultimate pH (pHu)
- Time from slaughter to grading

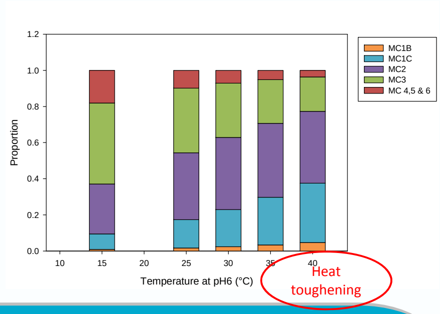


The MSA abattoir window

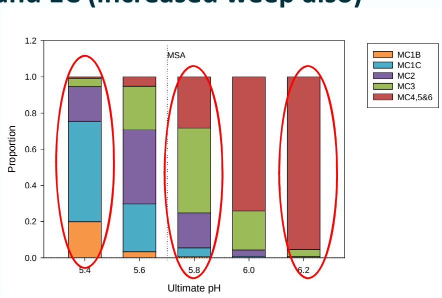
Temperature at pH 6 >35C, heat-toughening



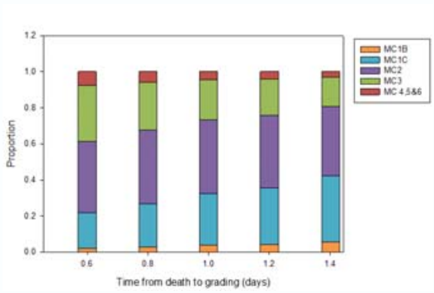
Key Findings – higher temperature at pH 6 results in paler colour scores



Effect of ultimate pH - Carcasses with a low pH have more colour scores 1B and 1C (increased weep also)



Key Findings – Meat that is graded earlier has more dark coloured meat (too early?)



Implications & Future directions

Optimise conditions at grading:

- Heat-toughened (high temp at pH 6 and low pHu) carcasses will have more pale meat (but probably greater weep/purge)
- Ultimate pH, implement systems to prevent dark-cutting
- If grading < 24 hrs, will have more dark-cutters

Meat Flavour

Theory and Background
Effect of feeding systems

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Flavour

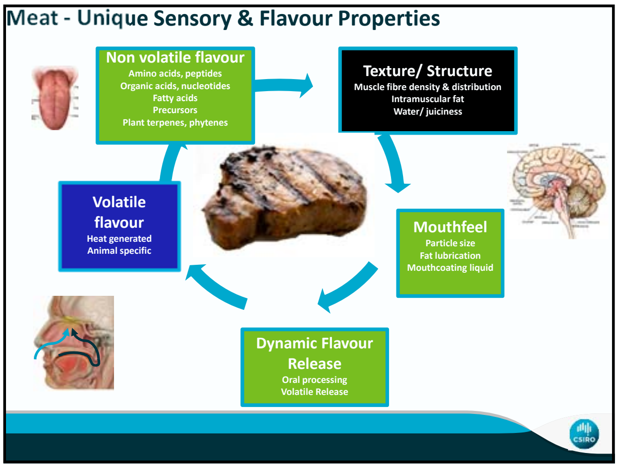
Flavour, along with other attributes, is an important component of meat eating quality

Flavour comprises two components – aroma and taste

- Aroma is perceived by olfactory receptors in the nose
- Taste is perceived by olfactory receptors in the mouth and throat

Volatile compounds largely contribute to aroma profile

Non-volatile compounds are main contributors to taste



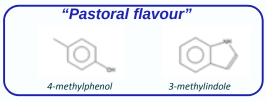
Flavour development during cooking

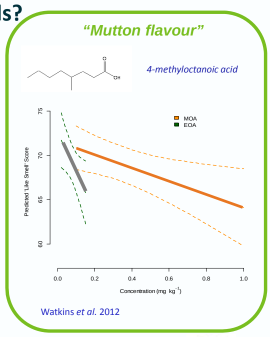
- Raw meat is generally quite bland

- Meat flavour develops only as a result of cooking. During cooking, non-volatile components undergo complex series of reactions that generates volatile aroma products
- Two distinct reactions occur during cooking
  - **Maillard reactions** between amino acids and reducing sugars
  - **Thermal degradation** of lipid components → volatiles
- Resulting characteristic flavour is regarded as typical for given species

Study #1: Pastoral & Mutton Flavour in Grilled Lamb – what are the chemical compounds?

- 180 lambs (215 – 362 d) – Information Nucleus Flock CRC for Sheep Industry Innovation
- No effect on MSA 'Flavour' score
- MOA and EOA impacted on 'Like Smell'
- ↑ BCFAs ↓consumer acceptance
- 3-MI & 4-MP no affect





Watkins *et al.* 2012

Study #2: Influence of Diet on Lamb Flavour & Texture

72 Male lambs

↓

Growing diet

Finishing diet regime (3 months)

Lucerne | Ryegrass | Plantain

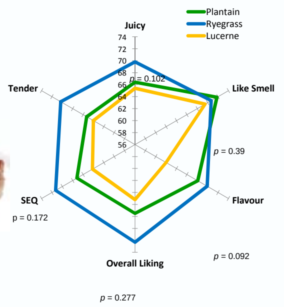
MSA consumer testing

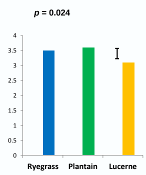
CSIRO- sensory & flavour chemical analysis

CSIRO trained sensory panel

Standardised grilling & serving protocol

Study #2: MSA Consumer Data



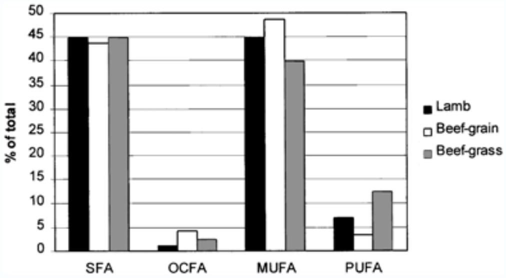


CSIRO is presently analysing a larger data set comparing sensory quality of high-glucosinylate and low-glucosinylate brassica fed sheep compared to lucerne and ryegrass

Effect of forage on lamb flavour

- The vast majority of feeding systems produce highly acceptable sheep meat.
- Some feeding systems can have a positive or negative influence on sheepmeat flavour. These need to be identified to ensure domestic/export markets.
- Sheep fed brassica crops to be removed 2 weeks prior to slaughter.
- Sheep grazing pastures high in protein (e.g. clover, lucerne) can increase the occurrence of 'pastoral' flavour in meat. The perception of 'pastoral' flavour as unacceptable may depend on habituation and prior experience.

Effect of grain *vs* grass



Grain-Fed vs. Grass-Fed Beef.

USA -- majority of consumers are able to detect the difference in flavour between grain-fed and grass-fed beef and prefer the flavour characteristics of beef produced by grain-finished cattle -

Sensory panellists often characterize the less desirable flavour of pasture-fed beef as “grassy,” “dairy/milky,” “gamey,” or “fishy” compared with the “beef fat” flavour normally associated with grain-fed beef

Difference in flavour between grain and grass-fed beef due to the higher levels of oleic acid in grain-fed beef compared with higher levels of linolenic acid in grass-fed beef.

(Flavour/odour develops during cooking of the meat as these fatty acids generate different products. Eg. Lactones (milky aroma/taste) are associated with grain feeding.

CSIRO presently undertaking a study on IMF, grain/grass feeding and flavour release in the mouth

Dark-cutting

How can it be better managed on plant

Economic impacts and livestock handling

Strategies for reducing dark-cutting

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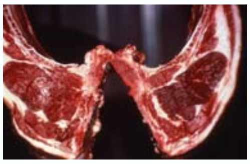
Dark-cutting meat



Ultimate pH > 5.7

Variable tenderness (tough at intermediate pHu)

Dark colour

Reduced shelf-life

Greening in vacuum pack

Cost - $200/carcass, in MSA alone, incidence is 5-7% (10-15% in pasture –fed cattle), costs industry about $35 million annually

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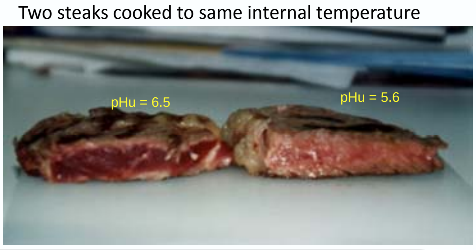
Dark-cutting beef- longer time to cook to desired internal colour

Two steaks cooked to same internal temperature



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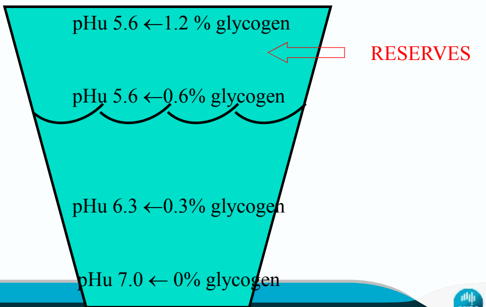
Glycogen and pHu

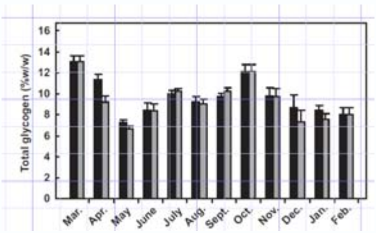


2 strategies

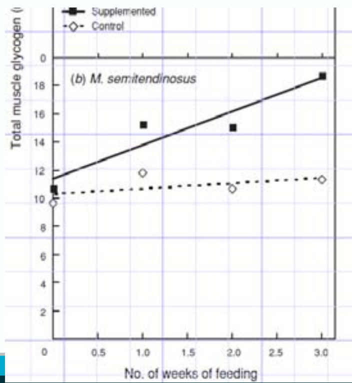
Muscle glycogen is a bit like a water trough

- Fill the trough up - vital for cattle to have high plane of nutrition prior to leaving farm/feedlot.
- Stop the trough leaking - minimise stressors between farm and slaughter

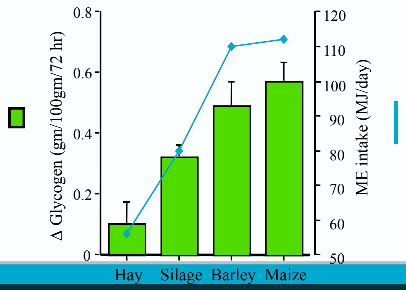
Reducing dark-cutting – seasonal variation



Reduce dark-cutting by feeding onfarm



SM Glycogen repletion & ME intake (72 hours)



Pethick et al (1999)

Farm to Slaughter

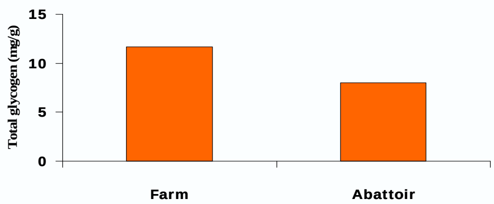
Farm - Mustering, penning, loading, curfews

Transport - distance/time, mixing, conditions

(Saleyards - loading/unloading, handling, time)

Abattoirs - Unloading, lairage conditions, time, mixing, handling to slaughter

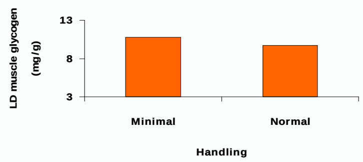
Muscle glycogen loss occurs between farm and slaughter



Pethick et al

Pre-slaughter washing

Industry practice of overnight lairage, washing and 'normal' handling depletes glycogen by 10% relative to no washing, <4 hr lairage and gentle handling



Questions

- Is washing always essential?
- Can overnight lairage be avoided?
- How can handling be minimised? (no prodders)

Walker et al (1999)

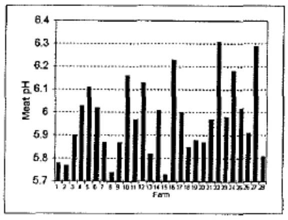
Marketing Method

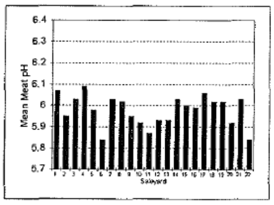
Effect of Marketing method and Nutrition on dark-cutting

Specification	DC	Feedlot	SY
Meat Colour	7%	1%	9%
Meat pH	9%	3%	15%
	8 abattoirs		
Meat pH	12%	1%	9%

Warner et al (1988)

Variation between farms and saleyards

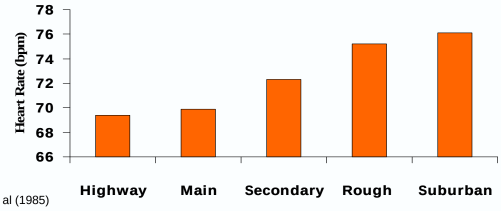




HPP for value-adding | Anita Sikes | Page <#>

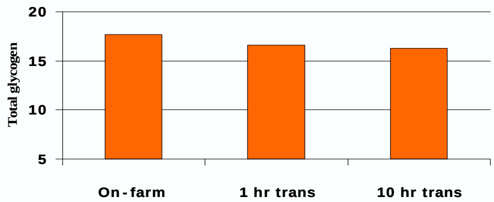
Transport / Curfews

Road type influences heart rate and therefore stress levels during transport



Eldridge et al (1985)

Little effect of extended transport on muscle glycogen - stress is in loading-unloading

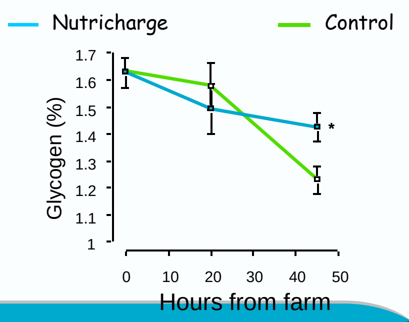


Pethick et al (1999)

Electrolytes

- Simple preps are a mixture of salts (NaCl, KCl,$NaHCO_3$) plus dextrose/sugar
- Either 'in feed' or 'in water'
- Do they effect glycogen?

Nutricharge may assist in preventing glycogen loss from farm to slaughter if lairage > 1 day



Pethick et al (1999)

Summary of electrolytes

- Small positive effect of ‘Glucotrans’ in cattle (in water preparation)
- Nutricharge also showed positive effect in cattle in WA but not in Vic – not available
- Magnesium Oxide (MgO) had a positive effect in lambs

Summary of electr es

- Small positive effect of ' cattle (in water preparati
- Nutricha in catt vailable
- Mag O) had a positive effect in lan

▪Forget about it
▪Costly, often has little effect
▪Focus on prevention

Conclusions

Normal abattoir practice (washing, overnight lairage, normal handling) lead to a 10% decline in muscle glycogen content.

Washing pre-slaughter resulted in 7% glycogen loss.

Overnight lairage or longer resulted in 9% glycogen loss.

Heifers and pasture-fed cattle are at risk.

Conclusions (cont.)

Nothing beats eating high energy diet (good roughage or grain)

No food, no glycogen repletion

Care at all stages with pasture animals

Mg/electrolytes supplements pre/post consignment show promise BUT no substitute for good nutrition

Acknowledgements

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AUSTRALIAN MEAT PROCESSOR CORPORATION

Meat Quality Short Course

AMPC

Muscle structure and factors affecting meat tenderness

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Summary

- Background theory and the importance of meat tenderness
- Measurement of meat tenderness
  - Factors affecting meat tenderness
    - Live animal
      - HGP
      - *Bos indicus* content
      - Gene markers
    - Post mortem
      - pH temperature window
      - tenderstretch
      - ageing

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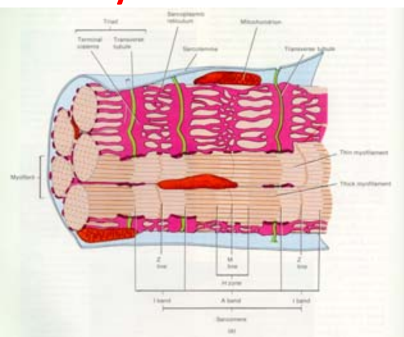
Composition of Muscle

Constituent	%	Form	Changes
Water	70-78	Free and bound to proteins	Decreases with age and fat content
Protein	15-22	Myofibre, sarcoplasmic stromal	Decreases with fat
Lipid	1-30	Depot fat, membranes lipids etc	Highly variable, inversely related to water content
Carbohydrate	1-2	Glycogen Monosaccharides	relatively constant

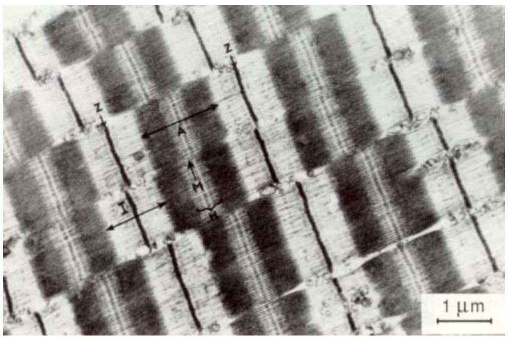
Muscle components impacting on tenderness

- Myofibre structure
- Connective tissue structure

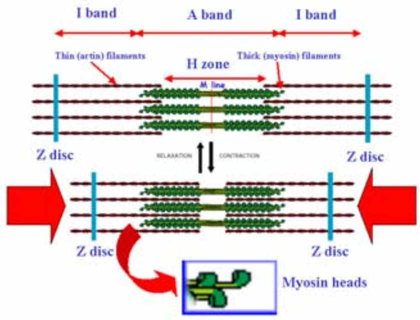
Myofibre structure



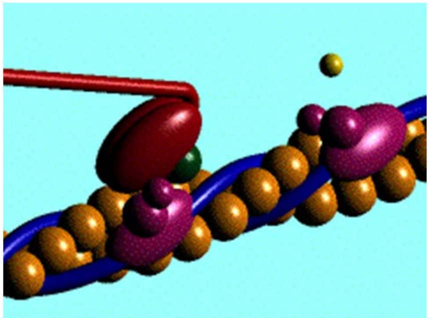
Myofibre structure



Muscle contraction



Muscle contraction



ATP breaks actin/myosin linkages

- enables muscles to relax again.

- no ATP… rigor mortis!

ATP →	ADP	+ Pi	+	energy
adenosine triphosphate	adenosine diphosphate	inorganic phosphate		

Rigor Mortis

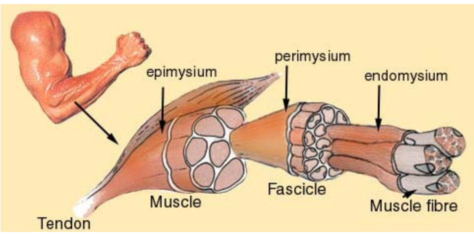
- 3 Definitions
  - **Biochemical** – ATP insufficient to break actin/myosin linkages.
  - **Chemical** – post mortem muscle pH is lower than 6.0
  - **Practical** – muscle has "set". Stiff to the touch.

Connective tissue

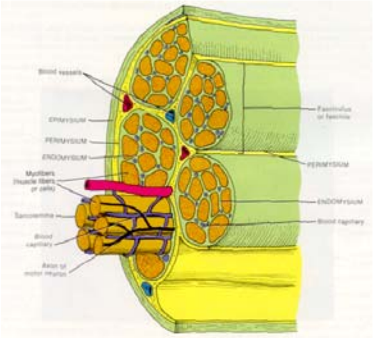
- Structural tissues in body.
- Include bone, ligaments, tendons etc.

- Three levels of muscle connective tissue (ie extracellular matrix).
  - Endomysium (covering muscle fibres)
  - Perimysium (covering muscle bundles)
  - Epimysium (covering entire muscles)

Types of connective tissue



Connective tissue matrix



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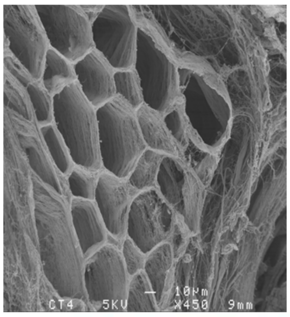
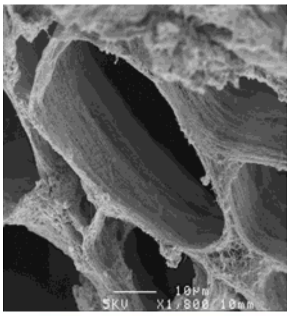
Connective tissue matrix





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Connective Tissue – Visual Example

- Silverskin = Epimysium

Collagen is major muscle connective tissue

- **Major constituent of endo, peri, and epimysium.**
- **Most abundant protein in body.**
- **Shrinks when heated.**
- **Breaks down to gelatine at higher temperatures.**

Elastin

- **Less prevalent in muscle.**
  - **Eye round elastin comprises 2% of muscle on a DFF% and ca. 40% of total CT**
  - **Loin cuts elastin is 0.2% of muscle wt on a DFF basis and ca. 5% of total CT**
- **Important in arteries**
- **Does not break down when heated**

Collagen Crosslinks

- Chemical bonds linking collagen fibres.
- Stabilise collagen molecule.
- Provides tensile strength to connective tissue.
- Increases with age, increasing strength and rigidity.
- Varies between muscles (ie LD has less).

Crosslinking and meat tenderness

- More crosslinks = tougher meat

Therefore…

- LD is more tender than SM
- Younger is more tender than older

Circulatory failure

Muscle continues using energy (ATP)

↓

Localised oxygen consumed (ie in blood)

↓

Aerobic metabolism stops

↓

ATP conc. falls stimulating anaerobic metabolism

→

Glycogen catabolised as fuel producing lactic acid

↑

pH declines due to lactic acid build up

↑

Rigor mortis

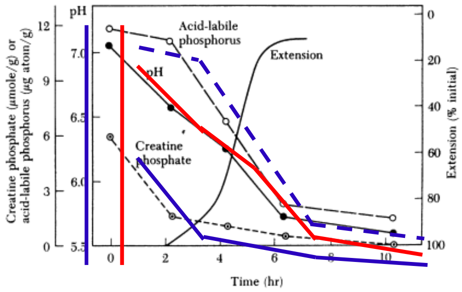
↑

Ultimate pH (pHu) 5.5 stops metabolism

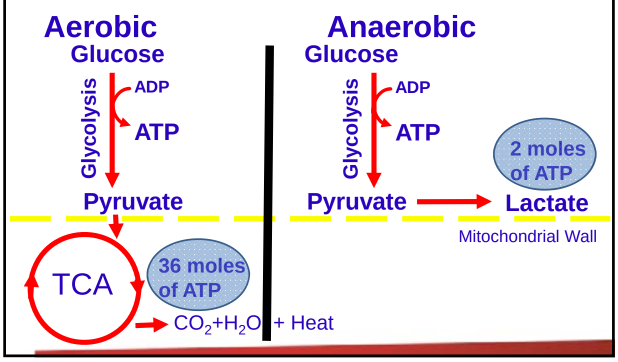
Post Mortem Muscle Metabolism

- Two sources of energy (ATP)
  - Creatine Phosphate
  - Glycolysis

Changes in metabolite concentrations post-mortem



Glycolysis



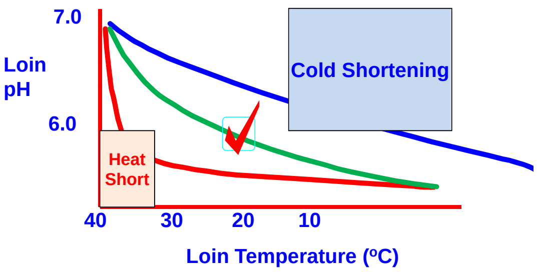
Rate of pH decline/ultimate pH

- These are separate events
  - Rate of pH decline is a function of temperature and glycogen reserves
  - Ultimate pH depends upon there being a threshold level of glycogen

Rate of pH decline

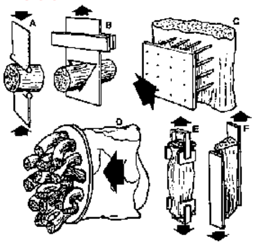
- Too rapid – pale soft exudative meat (PSE, or heat shortening).
- Too slow – cold shortening
- Not enough glycogen
  - pHu (5.5) not reached
  - dark cutting meat (DFD meat)

The pH/temperature window

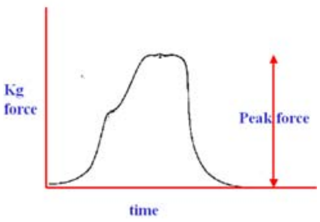


Objective measurement of tenderness

- When consumers eat meat they perform a number of actions.
  - a biting shearing action
  - a squeezing action
  - a stretching tearing action



Shear Force



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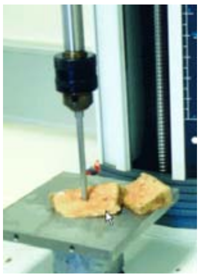
Compression



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Sensory Attributes

- Tenderness
- Juiciness
- Flavour
- Overall acceptability

Consumer Sensory testing of meat

- Advantage
  - you get a direct quantification of a human's perception of meat attributes.
  - Can give preferences
- Disadvantage
  - time consuming,
  - expensive,
  - variation, both between and within individuals, therefore experimental design is critical

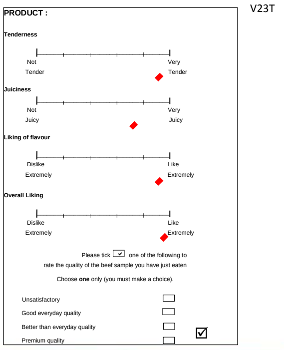
Factors to consider

- number of samples per consumer
- number of assessments per sample
- presentation order of samples
- quality range in session
- whether or not link product is used
- coding of samples (transcription error)
- recording of panellists scores

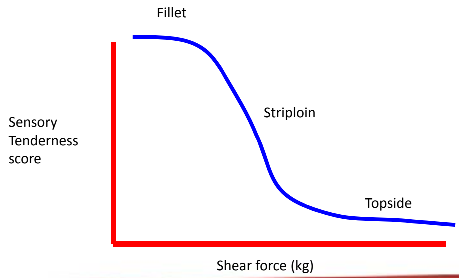
MSA consumer panels

- Panel comprises 20 tasters.
- Each taster receives 7 samples to taste.
- The first sample is a link
- Each sample of meat assessed by 10 consumers.
- The tasters scores recorded on a linear scale for tenderness, juiciness, liking of flavour, and overall liking
- Consumers then 'grade' the sample
- Pre-cooking treatment of samples, thickness and weight were standardised.
- All cooking methods standardised as to equipment used, temperature and time of cooking and resultant degree of doneness.

MSA Consumer Score Sheet

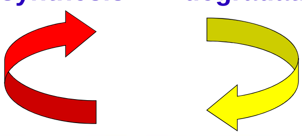


Relationship between objective and subjective measurements of tenderness



Ways to get increased muscle in the body

Net muscle accretion = muscle synthesis – muscle degradation

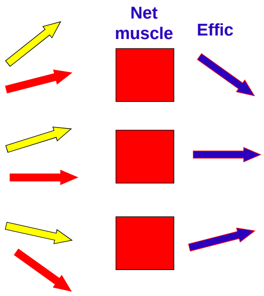


How can an animal increase muscle?

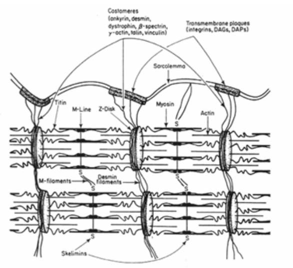
a) increased synthesis
   increased degradation

b) increased synthesis
   no change degradation

c) decreased synthesis
   decreased degradation



Myofibre structure



What impact does synthesis/ degradation in the live animal have on meat quality in the carcass?

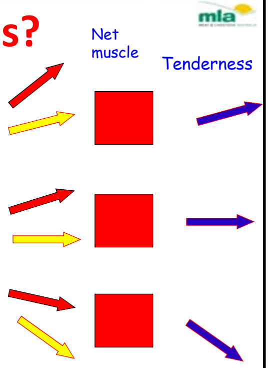
- Synthesis
  - events to synthesize new muscle have little relationship with meat quality
- Degradation
  - Calpain degrades muscle in the muscle (accelerator)
  - Calpastatin is an inhibitor (brake)

Implications?

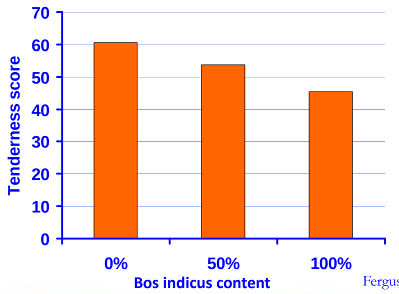
a) increased synthesis
   increased degradation

b) increased synthesis
   no change degradation

c) decreased synthesis
   decreased degradation

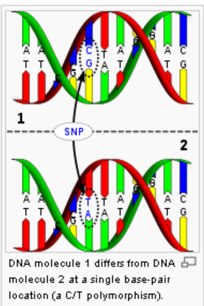


Bos indicus effect on tenderness of the striploin



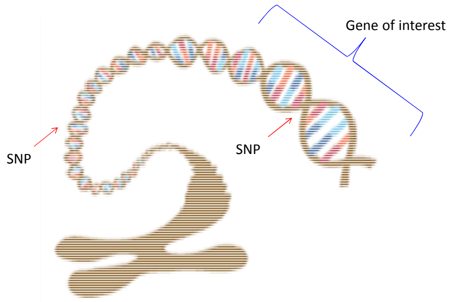
Ferguson et al (2000)

What are gene markers?



SNP
Single Nucleotide Polymorphism

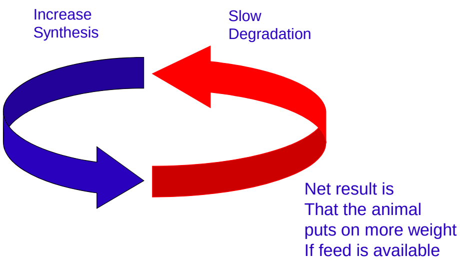
What are gene markers?

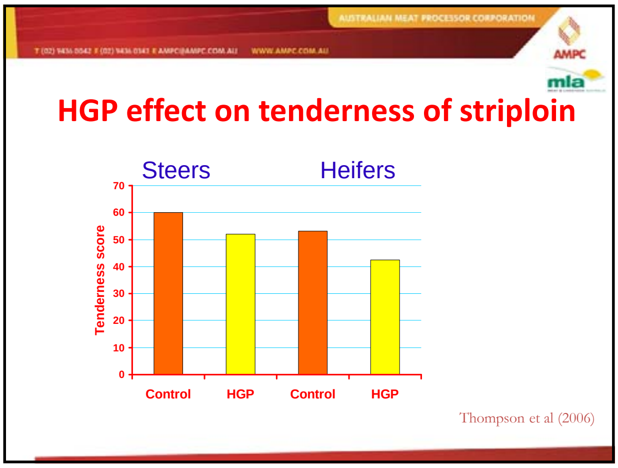


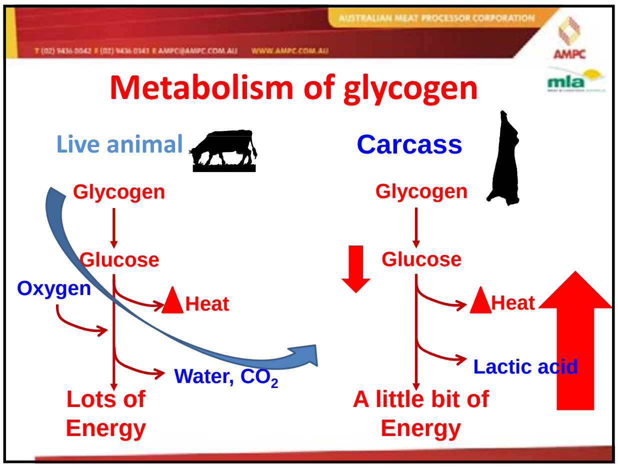
Sensory Results (MQ4)

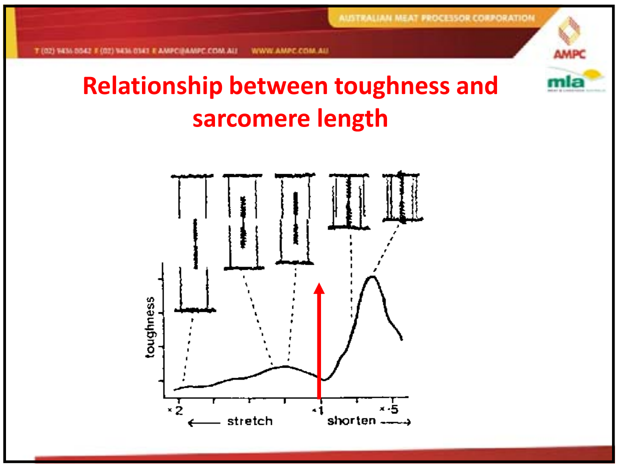
Muscle	Unfavourable Calpastain/ Calpain	Favourable Calpastatin/ Calpain	Diff
TS Strip	54	64	10 ***
AT Strip	42	54	12 ***
AT Rump	47	57	10 **
AT Oyster	70	74	4 ns

How do HGPs work?

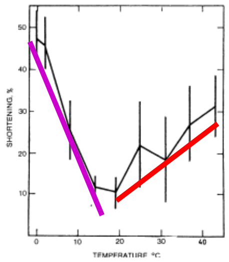



HGP effect on tenderness of striploin
Steers
Heifers
Tenderness score
70
60
50
40
30
20
10
0
Control
HGP
Control
HGP
Thompson et al (2006)


Metabolism of glycogen
Live animal
Glycogen
Glucose
Oxygen
Heat
Water, CO_2
Lots of Energy
Carcass
Glycogen
Glucose
Heat
Lactic acid
A little bit of Energy


Relationship between toughness and sarcomere length
toughness
stretch
shorten

The effect of temperature at rigor on shortening



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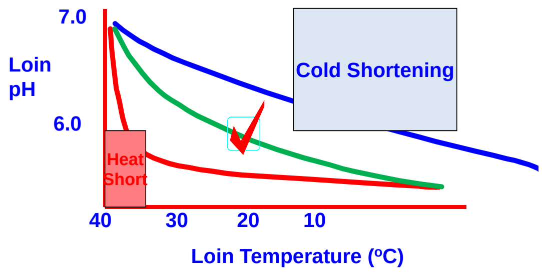
The pH/temperature window



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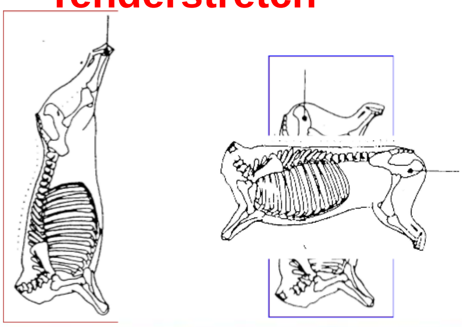
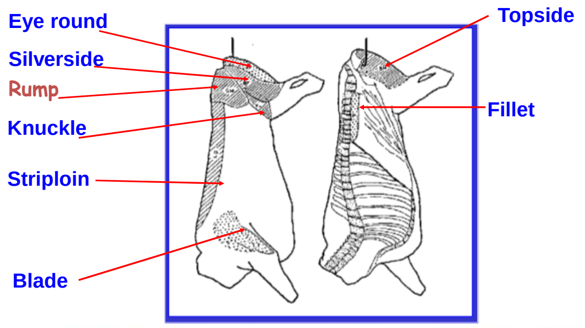
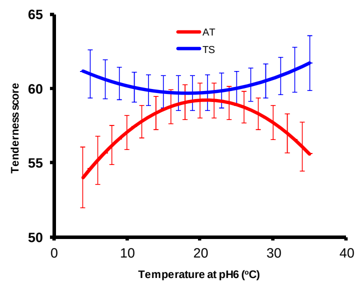
Tenderstretch



Muscles affected by Tenderstretch



The effect of tenderstretch in sheep carcasses on tenderness score



Thompson et al (2005)

The ageing process

- Ageing commences in individual muscle fibres after rigor is complete
- At rigor ATP disappears, calcium levels rise and activate the calpains as a consequence of the inability of the sarcoplasmic reticulum to bind calcium

The ageing process

- Ageing meat post-rigor will
  - improve tenderness
    - thru degradation of the Z-disks and transverse crosslinks between myofibres
  - change flavour components
    - Flavour changes occurs thru oxidation (rancidity) and breakdown products of protein degradation. Therefore flavour will generally improve with ageing, then as the cut is overaged it will decrease
  - Ageing has little impact on connective tissue

Conclusion

- Eating quality of meat can vary enormously
  - Live animal factors
    - *Bos indicus*
    - Gene markers
    - HGPs
  - Processing factors
    - Cold shortening
    - Heat toughening
    - Tenderstretch
    - Ageing
- Can we predict quality and so provide the consumer a better eating experience?

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Meat Quality Short Course

AMPC

The MSA grading scheme

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Summary

- MSA model
  - Background
  - Numbers graded
  - Economic returns of MSA
  - The MSA Quality Index
  - Problems with boning groups
  - Optimisation
  - Where to from here?

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Each Cut is Different!

- Breed differences
- Carcass hanging differences
- Ageing differences
- Sex differences
- Marbling differences
- Cooking differences

We must grade cuts, not carcasses to be useful to the consumer

The Pathway Process gave consumer protection

But was becoming too complicated
- multiple pathways
- multiple cuts
- cooking variation

How could the decision tree be made workable?

SP6 – The First MSA Model (1999)

enter values of the variables in the shaded cells below

to modify days_aged for any cut, enter in the shaded cells below (else previous entry is assumed)

		d.aged
hang (AT, TS)	AT	
sex (M, F)	M	
feed (F, G, M)	M	
epbi (est %)	0	
cwt	280	
uoss	100	35
umb	600	
ulean	200	
pHu	5.6	
d.aged	5	
wam	1.9	

don't enter wam: it will be calculated)

Note: if you leave a cell blank, it assumes the common or mean value.

		st	G	st	R	st	SF	st	SC*	st	C	st
brisket	60	3							42	x		
outside flat	58	3			46	3			47	3	56	3
topside	56	3			49	3	45	x	42	x		
eye round	60	3			55	3			53	3		
knuckle	63	3	56	3	68	4	64	4	50	3		
blade	70	4	71	4	73	4			73	4		
rump*	60	3	60	3	69	4						
striploin	64	4	70	4	66	4						
oyster blade	68	4	74	4	72	4	77	4				
cube roll	66	4	75	4	76	4						
tenderloin	69	4	88	5	86	5						
spinalis	68	4	87	5			86	5				

The MSA Prediction Model

MSA Parameter	Individual Carcase Input
%Bos Indicus	0
Sex	M
HGP	N
Milk Calf	N
Carc Wt	300
Hang	TX
Ossification	150
Marbling	320
Rib Fat	5
Ult pH	5.58
Ult Temp	3
Days Aged	14

cut	muscle	GRL	RST	SFR	TSL	YAK	SSB	SCT	CRN
spinalis	SPN081	79	69	79	75	80			
tenderloin	TDR034	83		77					
tenderloin	TDR062	78	77	80	75	71	67		
tenderloin	TDG062	76							
cube roll	CUB045	66	66	66	66	67			
striploin	STA045	60	61	62	59	62	54		
striploin	STP045	58	59	62	58	59	52		
oyster blade	OYS036	68	65	71	72	72			
blade	BLD095			44	49				
blade	BLD096	57	61	63	63	65	50	63	
chucktender	CTR085		51	53	58			62	
rump	RMP131	55	64	62	66	61	53	58	
rump	RMP231	58	66	65	65	69			
rump	RMP005	62	67	70	71	73			
rump	RMP032			68	70				
rump	RMP087		56	61	61			59	
knuckle	KNU066	49	63	58	61	60		50	
knuckle	KNU098			57	62			60	
knuckle	KNU099	39	50	47	54	50		55	
knuckle	KNU100			64	67	65		58	
outside flat	OUT005	46	46	49	59	60	47	62	55
outside flat	OUT029			62	69			63	
eye round	EYE075	50	53	51	53	55		54	52
topside	TOP001	43		54	56	61		53	
topside	TOP033	39		56	61	61		63	
topside	TOP073	38	46	46	56	57	48	56	
chuck	CHK068			48	52			65	
chuck	CHK074	60	56	61	67	59		72	
chuck	CHK078	55	57	58	62	58		69	
chuck	CHK081			60	64	60		75	
chuck	CHK082			52	56				
thin-flank	TFL051			62				62	
thin-flank	TFL052			70	63			67	
thin-flank	TFL064			65	61			64	
rib-blade	RIB041			53					
brisket	BRI056			43	57	52		59	37
brisket	BRI057			40	48	48		64	
shin	FQshin							65	
shin	HQshin							68	
intercostal	INT037			57					

Maximising Value from MSA

- *Utilise **ALL** the technology to capacity.*
- *Move beyond cut description to cooked result.*
- *Create the ultimate FMCG product - BEEF.*
- *Link grade and yield to Value Based payment.*
- *Become the global standard.*

Current MSA Model Application

Grading Inputs

↓

Differentially Applied at MUSCLE Level

↓

Animal Parameters
- BI%, Uoss, HSCW, HGP, Mb, Ribfat, pHU

Processing Parameters
- Hang, pH/temp decline

Post Processing Parameters
- Days Aged
- Cooking Method (Domestic)

↓

MSA Grade for single meal portion derived from predicted MQ4

Potential Process Additions

Grading Inputs

↓

Differentially Applied at MUSCLE Level

↓

Animal Parameters
- BI%, Uoss, HSCW, HGP, Mb, Ribfat, Phu
- Gene markers

Processing Parameters
- Hang, pH/temp decline
- Needle, Inject, Massage, HPP

Post Processing Parameters
- Days Aged
- Cooking Method (Domestic)
- Commercial Cooking Methods
- Hot, cold, slice thickness

↓

MSA Grade for single meal portion derived from predicted MQ4

Potential Capability of MSA

To accurately grade

- *any cut*
- *from any carcass*
- *for any cooking method*

to any consumer in the world

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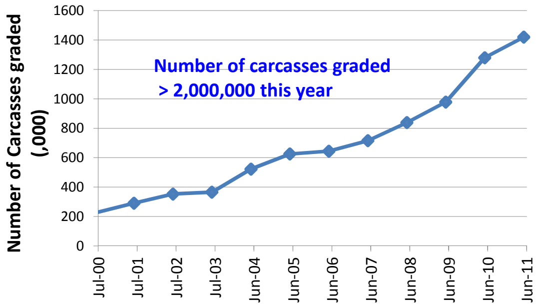
Number of MSA carcasses graded per year



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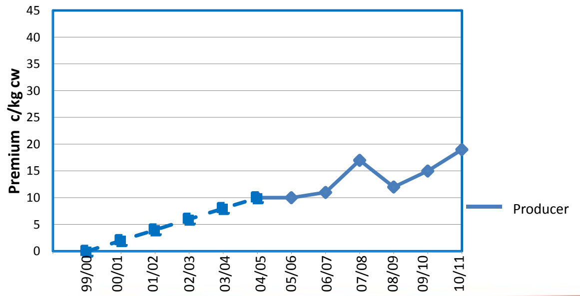
Current Usage of MSA

- Rather than using the three grades most wholesalers and retailers simply use 3 star as a threshold trait, ie the cut graded 3 star or better

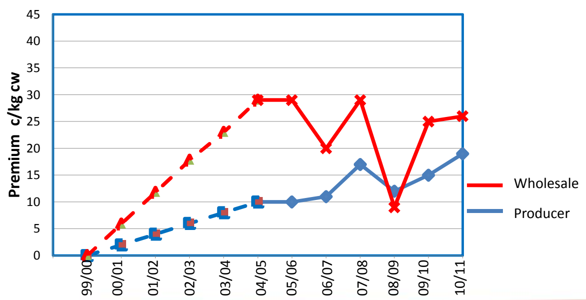
Economic benefits of MSA

- From 2005 the retail, food service and wholesale sectors were surveyed for prices of MSA and non-MSA cuts
  - 25,000 prices collected annually by phone and visits across all states (5) for 13 cuts
  - Cut premiums converted to a whole carcass basis
- Over the hooks prices (OTH) for MSA and non-MSA carcasses were collected by NLRS

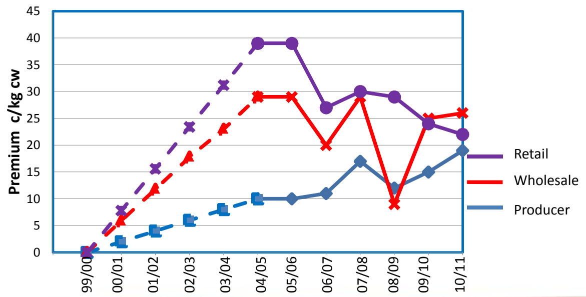
Economic returns (c/kg cwt)



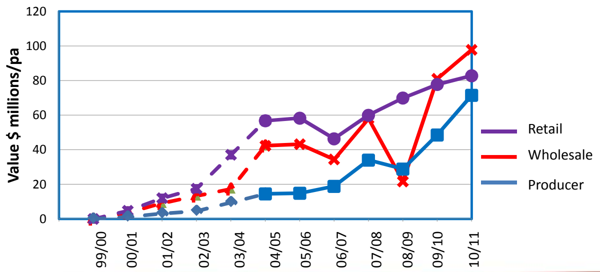
Economic returns (c/kg cwt)



Economic returns (c/kg cwt)



Economic returns ($m/pa)



Future developments

- The MSA model describes a complex biological system
  - The downside is that any model needs to be complex to describe the biology
  - The upside is the complexity results a vastly more accurate model compared to competitors around the world
- 2 priorities
  - Communication of quality information back along the supply chain to producers
  - Segregation of product at boning to harvest different qualities

Why have an MSA Index?

PURPOSE: To provide a standard measure over time to compare cattle against an eating quality base.

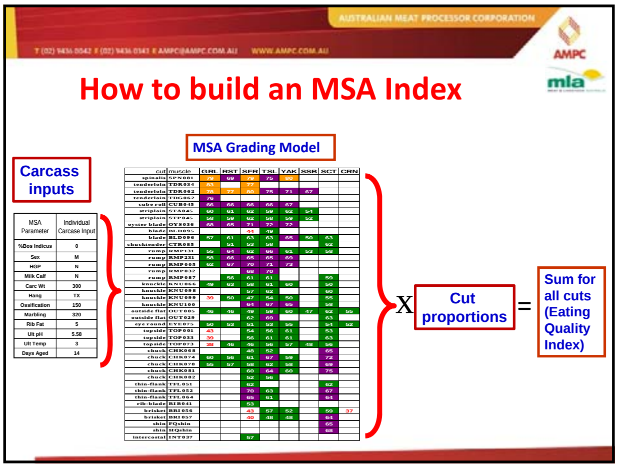
- The Index will be an **alternative** to boning groups for feedback
- A sound basis for evaluation of on-farm genetic progress & management strategies.
- Similar in concept to a management adjusted EBV.
- **May** provide a basis to develop individual company commercial indexes & VBP.

MSA Quality Index

- There is no single indicator muscle for quality
  - estBi, Hang and HGP have different effects on different muscles
  - Uoss and Umb have different coefficients for different muscles
- Need to summarise changes into a simple index

MSA Base/Customised add-ons

- Using the **MSA base index** the producer can
  - -plot changes over time to monitor
    - -management
    - -genetic progress
- Using the **customised add-ons**
  - - Producers can ask "what if" questions on the changes in production systems
  - - Processors can modify
    - -processing (Hang and ageing)
    - -questions what they harvest (cut/cook options)
    - -Calibrate it against value for their supply chain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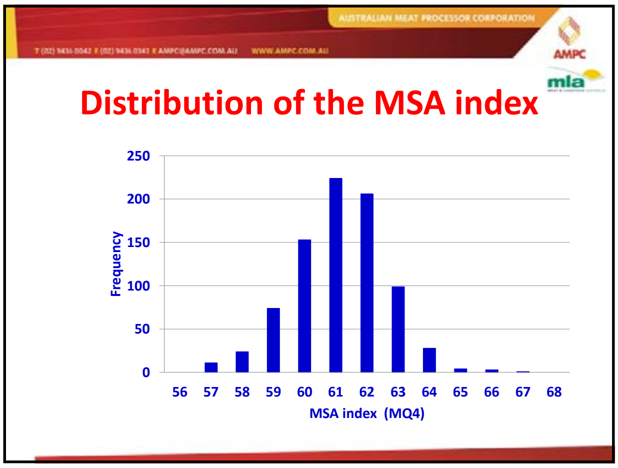
How to build an MSA Index
MSA Grading Model
Carcass inputs
X
Cut proportions
=
Sum for all cuts (Eating Quality Index)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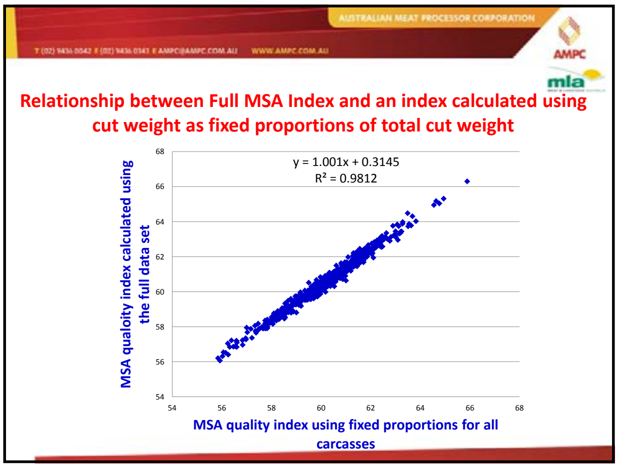
Distribution of the MSA index
250
200
150
100
50
0
Frequency
56
57
58
59
60
61
62
63
64
65
66
67
68
MSA index (MQ4)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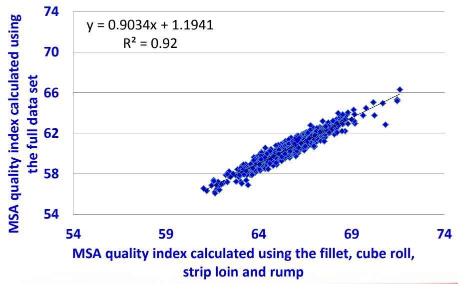
Relationship between Full MSA Index and an index calculated using cut weight as fixed proportions of total cut weight
y = 1.001x + 0.3145
R² = 0.9812
MSA qualoity index calculated using the full data set
68
66
64
62
60
58
56
54
54
56
58
60
62
64
66
68
MSA quality index using fixed proportions for all carcasses

What if the processor is only harvesting the sweet cuts?



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Setting the base line for the MSA Quality Index

- The MSA Quality Index is a weighted MQ4 score for the carcass
- Need to set a base line for the 39 MSA cuts
  - Boned 40 sides from Angus high and low muscling lines
  - CT scanned

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Boning Room Management

- Chiller space & carcass sorting constraints.
- Marshalling area constraints.
- Changeover complexity – specifications, product segregation.
- Multiple market specifications.
- Inventory management

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The problem with Boning Groups (BG)

- Boning groups originally set to allow the harvest of different quality cuts. The initial concept was to customise the groups to particular plants
- Instead current BGs applied as a national standard.
  - BG can grossly misrepresent many cattle.
  - BGs grade everything to the **lowest** quality in the boning group
- The problem is driven by inherent inconsistency in cut relationships eg; estbi, HGP, hang
- BGs not suitable (and potentially badly misleading) as a genetic or management tool.
- BGs grossly inefficient as a payment tool

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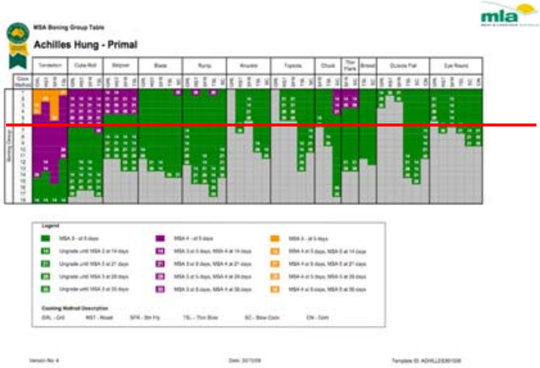


Optimisation for individual abattoirs

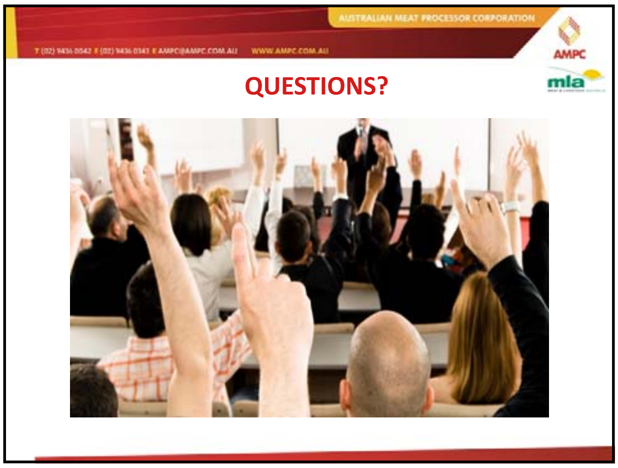
- Abattoirs will sort carcasses onto rails which group different quality carcasses
- An example sort
  - Rail 1 - 5* Fillets, 4* Strips and Cubes, 3* Rumps
  - Rail 2 – 5* Fillets, 4* Cubes, 3* Strips and Rumps
  - Rail 3 – 5* Fillets, 3* Cubes, Strips and Rumps
- Carcasses on rail 1 > rail 2 > rail 3
- Abattoirs will be assisted in setting customised rails to harvest cattle delivered to their abattoir

Conclusion

- MSA uses a PACCP approach to grading
- Unique in the world
- Currently returning good value to all industry sectors
- Future innovations
  - The MSA Quality Index
  - Optimisation for specific works/markets

Will consumers pay a premium for higher grades in eating quality?

- Wholesale and retail sectors have been slow to move on this question
- Interest from branded products/supermarkets in marketing different quality levels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QUESTIONS?

Meat Science Tutorials Feedback Form

SUGGESTIONS AND FEEDBACK

(AGENDA, SPEAKERS, CONTENT, DELIVERY ETC.)

FUTURE MEAT SCIENCE R & D ACTIVITY AREAS OF INTEREST

(COLOUR, SENSING & SCANNING, MEASUREMENT OF MEAT QUALITY ATTRIBUTES ETC.)

WHAT ADDITIONAL INFORMATION WOULD YOU BE INTERESTED IN RECEIVING FROM AMPC

(FACTSHEETS, REGULAR UPDATES ON INDUSTRY RELATED R&D, TUTORIALS, E-LEARNING TOOLS ETC.)

CONTACT DETAILS

Meat Science Tutorial – MTU Handouts

Summary of material contained in this folder

General

1. ***Oxy torches and their effect on meat colour (2002)***

Hot flames and oxyacetylene torches produce nitrogen dioxide gas. Internal combustion engines also produce it. Nitrogen dioxide is an energetic oxidising agent and the gas can rapidly oxidise the purple or red forms of myoglobin in meat to brown metmyoglobin.

2. ***UV light and its effect on fresh meat (2002)***

UV radiation can be extremely effective in killing or damaging microorganisms. Bacteria on carcases and primals 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.

3. ***Tenderstretch (2004)***

Toughness caused by muscle contraction can be prevented by accelerating the onset of rigor mortis using electrical stimulation; or by hanging the carcase in a way that will stretch the muscles and not allow them to contract, hence the name 'Tenderstretch'.

4. ***Colour defects in meat, Part 1: Browning of fresh meat (2006)***

Fresh meat eventually turns brown (sometimes interpreted as grey-brown); its acceptability to customers usually determined by loss of red colour ('bloom') rather than onset of bacterial spoilage. Display life is reduced by several factors that hasten discolouration. This article gives some realistic expectations for display life, discusses the basis for meat colour, and some reasons for premature loss of bloom.

5. ***Colour defects in meat, Part 2: Greening, pinking, browning and spots (2006)***

Part 1 discussed the development of a brown colour in fresh meat as a result of oxidation of the pigment myoglobin to metmyoglobin, Part 2 describes other undesirable colours and appearances.

6. ***Prevention of fresh meat colour defects (2006)***

At retail level, customers are most influenced by eating colour in their decision to buy. Colour is perceived to be a valuable guide to the overall quality of meat; if a visual appraisal raises any doubts it is unlikely that purchase of that particular time will be considered further. Conditions of primary importance to meat colour are temperature, pH and the amount of available oxygen.

Beef

7. ***High rigor temperature and toughening in beef (2002)***

Inappropriate application of electrical stimulation can contribute to toughening and changes in colour and texture similar to that observed in PSE pork.

8. ***Production factors affecting beef eating quality (2006)***

This newsletter focuses on the on-farm, or production-based factors, that have been shown to affect beef palatability. The production factors covered include: within-breed and between-breed variation; sex; fatness; age; nutrition and growth path.

9. Pre-slaughter aspects of beef eating quality (2006)

Losses of both product quality and quantity during the critical pre-slaughter period are inevitable. These losses are the result of social, physical, environmental and nutrutional stresses imposed on the animal between the farm/feedlot and the abattoir knocking box. In the interests of animal welfare and beef quality, it is essential that effective management strategeis be implemented to minimse adverse pre-slaughter effects.

10. Electrical inputs during beef processing (2006)

During slaughter and dressing, beef carcases may be subjected to a range of electrical inputs. These are used to: limit the danger to slaughterers from kicking; assist rapid bleeding; prevent broken backs from hide pulling; and optimise meat quality. Each of these applications may require a specific current, waveform and frequency. Use of incorrect electrical parameters may result in damage to the carcase, poor meat quality and safety risks.

11. High pH/Dark Beef (2006)

The pH scale is used to measure the degree of acidity or alkalinity present in meat. The 'ultimate' pH of meat, i.e; the final pH achieved by the muscles when the rigor processes have ceased, influences meat tenderness, colour, flavour and shelf-life.

12. Very fast Chilling (2011)

The chilling rate after slaughter is a critical part of producing meat that is of high quality and safe to eat. From a shelf-life and food-safety perspective, carcases should be chilled as quickly as possible; however, from an eating-quality perspective, fast chilling can cause cold toughening. So, with meat processing, the optimal chilling rate represents a balance between the control of microbiological growth and meat tenderness.

13. Sources of contamination on beef carcases during dressing (2012)

During carcase dressing, contamination can arise from the workers, the equipment and from the bodies being processed. The animals are the most significant source of contamination of the resulting carcases. In most cases, the deep tissues of healthy livestock at the time of slaughter are bacteriologically sterile and contamination is introduced onto the meat surfaces during the dressing process.

14. Heat toughening—Part 1: Effects of heat toughening on quality of beef, and the incidence in Australia (2011)

When the consumer buys meat, visual cues for quality include a bright red colour, low fatness levels and the absence of weep in the tray. On consumption, the consumer expects the meat to be tender, juicy and flavourful, with no abnormal flavours or odours. Understanding the factors that contribute to variations in these quality traits assists in determining strategies to optimise the quality traits. The concept of a pH/temperature window was one of the initial specifications for the Meat Standards Australia (MSA) grading scheme in Australia, and was designed to minimise the detrimental effects of extremes in processing i.e. heat toughening and cold shortening.

15. Heat toughening—Part 2: Strategies for reducing the incidence of heat toughening in beef carcases (2011)

Heat toughening in beef carcases is caused by rapid pH fall in the pre-rigor period, while muscle temperatures are still high. This was discussed in the previous Meat Technology Update titled 'Heat toughening—Part 1: Effects of heat toughening on quality of beef, and the incidence in Australia'. This MTU discusses the effects of on-farm, pre-slaughter and post-slaughter factors which contribute to heat toughening in beef carcases. It also presents strategies to reduce the incidence of heat toughening.

16. The causes of drip in meat (2002)

Lean fresh meat has a water content of approximately 70%. One of the major challenges of meat processing is concerned with preventing loss of liquid from lean meat tissue during storage. When meat is cut, a red solution of proteins that is known as drip (or weep or purge) oozes from the cut surfaces.

17. Shelf life of Australian chilled vacuum-packed boneless beef (2009)

Studies undertaken over 25 years ago led to process guidelines for Australian exporters of vacuum-packaged beef to help them achieve storage lives of 10 to 12 weeks at 0°C. Since then, cumulative commercial evidence, supported by recent scientific studies, indicates that a rather longer shelf life—20 weeks or more—is now regularly achieved. This paper provides information on the principle of vacuum-packaging, shelf life and consumer acceptance of meat, and suggests some reasons why the shelf-life extension has occurred. For those readers who seek a more detailed understanding of the science of vacuum packaging, the paper also discusses meat colour, meat spoilage and the role of bacteria, and describes the recent Australian scientific study of vacuum-packaged beef that supports the industry observations.

18. Hormonal Growth Promotants and Meat Quality (2009)

Hormonal growth promotants (HGPs) are used extensively in northern Australia and the feedlot industry. They are used to a lesser extent in southern Australia and are banned in Tasmania. HGPs are used to improve the rate of liveweight gain and the feed efficiency of cattle by producing a hormone that is very similar in structure to the animal's natural hormone. In excess of 2.5 million doses are sold annually in Australia and, of these, about half are used in pasture-fed steers in northern Australia. The industry currently uses a wide range of HGPs that can be implanted at the different stages of production such as at weaning, at back grounding on pasture, and at entry to the feedlot. The implants can have a functional life of up to 400 days and contain either oestrogenic or androgenic compounds or combinations of both.

Sheep Meat

19. Sheep meat eating quality (2006)

All consumers who buy sheep meat expect it to be tender and flavoursome. Toughness is caused by four major factors: advancing age of the animal; 'cold shortening' (the muscle fibre contraction that can occur during chilling); animal stress (unfavourable eat acidity, or pH); and the cut (i.e. connective tissue content/structure). Meat quality can be improved by careful selection of pastures, correct pre-slaughter handling and carcase processing.

20. Processing factors affecting sheep meat eating quality (2005)

Post-slaughter factors have a significant influence on the eating quality of sheep and lamb meat. This Meat Technology Update provides information for processors on how to optimise sheep meat eating quality and covers factors such as electrical stimulation (ES), hanging and cooling, and meat ageing. Some factors that influence retail display life are also discussed.

21. Producing quality sheep meat (2007)

This Meat Update presents recent findings on some slaughter floor influences on sheep meat eating quality.

New electrical inputs during slaughter and dressing help to deliver better quality sheepmeat. Medium voltage electrical stimulation enhances meat quality by improving tenderness and meat colour. High frequency immobilisation of bodies at slaughter reduces involuntary movement and permits abattoir workers to begin processing sooner. Medium voltage stimulation at low frequency (10Hz) hastens blood release.

Also discussed is the 'eating quality window' and its application by sheepmeat processors. Results show that without electrical stimulation, that proportion that falls within the window is about 5%. With optimal stimulation, the proportion rises to 90% based on a revised window of pH 6.0 between 18-45°C.

22. The effect of diet on sheep meat flavour (2012)

Flavour is an important sheepmeat quality trait. Flavour is comprised of aroma (volatile) and taste (non-volatile) compounds. Aroma is perceived during eating by olfactory receptors in the nose, and taste is perceived by receptors in the mouth and throat. Fresh, uncooked meat is quite bland; it is only as a result of cooking that meat flavour develops. The resulting characteristic flavour is regarded as typical for a given species, e.g. lamb, beef, pork etc. During cooking, the non-volatile components of lean and fat tissues undergo a complex series of heat-induced reactions that generate a large number of volatile aroma products. The compounds formed are mainly derived from two distinct reactions that occur during the cooking process: Maillard reactions between amino acids and reducing sugars; and thermal degradation of the lipid components to produce volatiles.

23. Effect of slaughter method on animal welfare and meat quality (2011)

The manner in which livestock are mustered, yarded, handled, transported, restrained, slaughtered, and exsanguinated can affect their welfare and final meat quality. Welfare requirements dictate that animals should be insensible to noxious, potentially painful, stimuli during slaughter. In abattoirs, pre-slaughter stunning is usually applied to induce rapid desensitisation of animals to the pain of slaughtering, and to minimise bodily injury risks to abattoir personnel. This is important as the neck region contains a number of sensory nerve fibres that are capable of triggering powerful reflex reactions upon throat cut; therefore, stunning should be done effectively.

24. Shelf life of Australian chilled, vacuum-packaged lamb (2010)

The process guidelines for Australian exporters of vacuum packaged beef—to help them achieve storage lives of 10 to 12 weeks at 0°C, developed from studies undertaken over 25 years ago—have also been successfully applied to lamb cuts by many Australian processors. The application of these guidelines has allowed lamb processors to achieve storage lives of six to eight weeks at 0°C. Recent commercial evidence has indicated that shelf lives in excess of this can be successfully achieved, but are not necessarily understood, or accepted, by key markets.

Other Materials/AMPC Factsheets

25. Dark Cutting Beef and Animal Temperament: Peter McGilchrist- Murdoch University (2012)

Dark cutting syndrome more - commonly referred to as DFD - is an important issue for both producers and processors. DFD results in meat which is dark in colour (figure 1), is less tender, less juicy and spoils rapidly due to the high pH making the environment more favourable for bacterial growth. The economic impact in 2009 as a result of DFD alone resulted in over $35million in lost revenue due to reduced quality of saleable product. In the 2011/12 FY, DFD affected approximately 75,000 MSA graded carcases.

26. Dark, Firm and Dry Beef: Mark Millar- Texas Tech University (2007)

Beef characterized as dark cutting will have an abnormally dark purplish red to black colored lean as shown in Figures 1a and 1b. Dark cutting beef is most often known as dark, firm, and dry (DFD). DFD beef can also be called “high pH” beef as a result of an animal’s depleted muscle glycogen reserves prior to slaughter. The carbohydrate (sugar) glycogen is used as an energy source for muscle contraction and relaxation. Lactic acid is a by-product of glycogen utilization by the muscle when energy is produced in a stress event. After death, lactic acid accumulation in the meat is responsible for the pH decline from 7.0 to about 5.7 (Figure 2) during normal rigor mortis development.

Oxy torches and their effect on meat colour

September 2002

Results for today; Ideas for tomorrow

Hot flames from oxyacetylene torches produce nitrogen dioxide gas. Internal combustion engines also produce it. Nitrogen dioxide is an energetic oxidising agent and the gas can rapidly oxidise the purple or red forms of myoglobin in meat to brown metmyoglobin.

Oxyacetylene torches

Oxyacetylene torches are sometimes used in loaded chillers, freezers or stores, either for welding or for emergency thawing. This can sometimes have disastrous effects on the colour of the meat, due to the production of a brown or yellow pigment.

The association of discolouration with the use of an oxyacetylene torch in the confined environment of a chiller was confirmed by CSIRO some years ago. Briefly, two beef sides were boned out and placed in a chiller (5°C), which had a volume of approximately 27 cubic metres. An oxyacetylene torch was ignited and adjusted to give a neutral flame. The torch was left burning in the closed chiller for 30 minutes. Next morning all cut tissue surfaces were severely discoloured. There was a significant amount of brown metmyoglobin pigment in the surface tissue.

After the test, a member of staff identified the odour of nitrogen dioxide in the chiller. The concentration of nitrogen dioxide in the chiller was measured with test strips sensitive to nitrite or nitrogen dioxide. Operation of the torch for 30 minutes in a chiller of the above size resulted in a nitrogen dioxide concentration in excess of 50 ppm. The nitrogen dioxide seemed to be stable at the low temperatures in the chiller, and even after nearly five hours, the concentration was still 20-25 ppm.

In further tests, it was found that operation of the oxyacetylene torch in the chiller for a period of five to six minutes resulted in a nitrogen dioxide concentration of approximately 25 ppm, a concentration which caused significant discolouration of beef and mutton carcases. Carcases held in a chiller for 48 hours prior to exposure to nitrogen dioxide discoloured to a greater extent than carcases that were exposed a few hours post-slaughter.

The colour of meat resulting from the operation of oxyacetylene torches can range from dark brown to yellow. Affected carcasses in New Zealand were once described as having the appearance of extreme freezer burn.

The evidence shows quite clearly that welding torches should never be operated in the vicinity of meat (loaded chillers, freezers or stores, either for emergency thawing or for welding operations) unless very good ventilation is provided.

Internal combustion engines

Internal, combustion engines also produce nitrogen dioxide. A New Zealand company, which had a severe problem of carcase yellowing in a new bulk store, found that it was using forklifts powered by liquefied petroleum gas (LPG) within the store. This practice was discontinued.

Forklifts, other than electric, must be suspect when used for lengthy periods in unventilated areas such as meat chillers and freezers. In simple terms, the amount of nitrogen dioxide produced by an engine will be least at idling, and greatest when the engine is working hard (say, accelerating under heavy load). The only way that the amount of nitrogen dioxide produced can be controlled is by limiting the running time in the confined area, and ensuring adequate ventilation.

Careful tuning will minimise emissions of hydrocarbons, carbon monoxide and oxides of nitrogen. Emissions from engines of recent design are primarily controlled by catalytic converters. Three-way converters will reduce oxides of nitrogen to nitrogen and oxygen however they must be well maintained and replaced in accordance with instructions from the manufacturer.

Case studies of some occurrences

Butcher's shop chiller

The blower unit had iced up and needed repair. The refrigeration mechanic thawed it with an oxyacetylene torch and repaired it.

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Within a few hours all the exposed meat surfaces and mince in the chiller were brown.

The discolouration extended about 6-8 mm into the muscle and 12-16 mm into the mince. The discoloured areas were trimmed and discarded. About 130 kg in all was condemned as unsaleable.

Meatworks chiller

A LPG motor was run all day in an empty export chiller, and in another empty chiller several sections of rail were welded into place. A meat chiller next to these was charged with veal and mutton carcasses from the slaughter floor, and silversides from the boning room. Doors of all chillers were open all day.

The report of what was found next day is graphic:

'On entering the wholesale meat department I observed a number of veal and mutton carcasses, and a number of silversides which were pale greenish yellow in colour and dark in appearance.

The subcutaneous connective tissue and fat of the mutton and veal had a distinct greenish-yellow colouration like jaundice. The muscle had lost its bloom and it appeared as though the carcasses were a few days old and had been subject to incorrect handling and poor refrigeration.

Bruises, where they appeared, were clearly defined, being much darker than the surrounding tissue. Internal blood drip and clots were a distinct brownish colour and the surface had a dried out parchment-type appearance'.

Clearly the welding torch and the LPG motor produced nitrogen dioxide, which contributed to the discolouration.

Safety

It is widely accepted that carbon monoxide emission from internal combustion engines used in confined spaces is dangerous to man. There is also a danger from nitrogen dioxide. From a safety viewpoint, short exposure to concentrations of nitrogen dioxide greater than 5 ppm. is considered hazardous. The current standard limit for nitrogen dioxide is 0.12 ppm for one hour. The gas has an odour but is only slightly irritating to the respiratory tract. Therefore, dangerous amounts of the fumes may be breathed before any real discomfort is noticed. Toxic effects may occur after exposure to concentrations of 10 ppm for 10 minutes and include coughing, chest pain, and difficulty in breathing. Brief exposure to 200 ppm can cause severe lung damage, which may be fatal.

Results for today; Ideas for tomorrow

UV light and its effect on fresh meat

August 2002

UV light and its effect on bacteria

Ultraviolet (UV) light lamps are sometimes used in meat chillers. They differ physically from fluorescent lamps in that they do not contain phosphor and are constructed with a special type of glass to permit maximum emission of ultraviolet energy. The glass used in ordinary fluorescent lamps filters out much of the UV energy.

UV radiation, in the 200-300 nanometre (nm) wavelength range, is extremely effective in killing or damaging microorganisms. The most lethal wavelength is at 265 nm. At this wavelength, certain nucleic acid molecules in the nuclei of microorganisms absorb the radiation in this range and break, causing either death or inhibition of growth.

Bacteria on carcases and primals 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.

The effectiveness of UV light in inhibiting bacteria is proportionate to its intensity. This means that bacterial growth on meat surfaces that are near the UV source - within one metre – is less than on surfaces that are more distant. Although reflected UV light has some effect, there is less inhibition on surfaces that are shaded from direct UV irradiation. UV radiation does not penetrate meat surfaces and is therefore only capable of killing or injuring bacteria on smooth surfaces.

A substantial extension of storage life of chilled carcases is possible when UV light is used continuously in chillers to delay the onset of microbiological spoilage. For instance, there was an increase of 50% in the storage life of mutton carcases in a 1970 CSIRO investigation. Storage life in that investigation was limited by spoilage of areas of carcases shaded from direct irradiation.

Stermer *et al*. (1987) found UV light was effective in reducing bacteria on the surface of round beef steak, but the authors found that the rough surfaces of fresh meat, tended to shield the bacteria from the radiation. Kim *et al.* (2002) also found greater reductions in bacteria on smooth surfaces such as stainless steel, rather than on chicken meat. Neither study examined the effect of UV light on meat colour.

UV lamps that are used for their bactericidal effect have a limited life. The output of UV light in the wavelength range that is effective gradually declines, until after around 7000-8000 hours use, when the output has declined to a level where they are only marginally effective (Fig. 1).

The tubes should be replaced when they have been used for their rated life. The rated life for tubes will be available from the supplier but as a guide, tubes that are used for 12 hours or longer each day should be replaced about every 12 months.

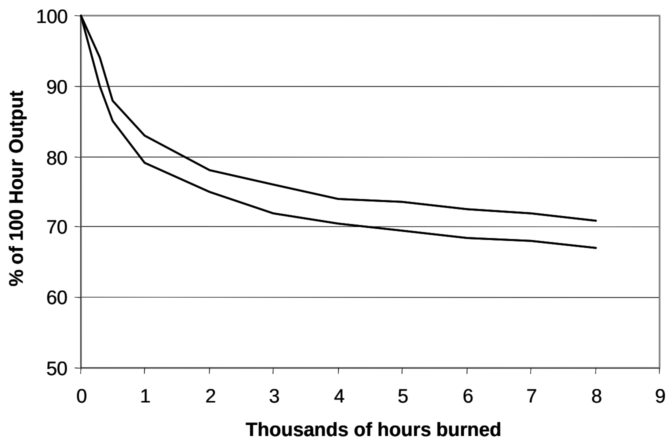

Figure 1. Typical maintenance characteristics for ultraviolet lamps (From: Mpelkas, C. Sylvania Engineering Bulletin 0-342).

UV light and its effect on meat colour

The principal pigment of fresh meat is myoglobin, which can exist in various forms. Deoxymyoglobin is the form responsible for the purple colour of freshly cut meat or meat stored in the absence of oxygen, such as with vacuum packaged meat. When meat is exposed to oxygen, the bright red form, oxymyoglobin, rapidly develops. This form of myoglobin is responsible for the attractive bright red colour of meat typically associated with freshness by consumers. A third form, metmyoglobin, is brown and is irreversibly formed through the oxidation of myoglobin. Consumers relate the presence of this brown colour to the loss of freshness and are reluctant to purchase that particular product.

UV light can play a critical role in brown discolouration of meat, since it encourages metmyoglobin formation. The rate of product discolouration depends on the intensity of light and wavelength distribution used for retail display, in combination with the light permeability of the packaging material. Hood (1980) found that fluorescent light produced only a minor accelerating effect in fresh, pre-packaged beef but UV light produced serious discolouration in product displayed at 5°C and even at 0°C.

Renerre (1990) found that wavelengths within the visible part of the spectrum did not contribute to the production of metmyoglobin. However, even a short exposure to UV light was found to be detrimental to meat colour.

Djenane *et al*. (2001) studied the effect of lighting conditions on the retail display life of modified atmosphere packed, fresh beef steaks. The lighting conditions studied included:

- conventional supermarket fluorescent light;
- supermarket fluorescent light with a UV filter;
- low-UV, colour-balanced lamp; and
- darkness

Meat spoilage was assessed by:

- surface colour (redness indices and metmyoglobin percentage);
- lipid oxidation (rancidity);
- bacterial counts; and
- sensory evaluation (discoloration and odour)

The results showed that the elimination of UV radiation by using either the UV filter or a low-UV lamp can significantly extend the display life of meat, to one similar to that of meat held in the darkness.

Key points

Use of ultraviolet lamps to slow growth of bacteria, and to delay the onset of microbial spoilage of meat, may actually shorten the meat's retail display life. Even the smallest amount of UV radiation should be avoided in lighting devices for the retail display of fresh meat.

Where UV lights are used in holding chillers to extend the storage life of carcases and primal cuts, it is important to replace the tubes after the time specified by the suppliers. In most situations they should be replaced at least annually. If they are not, their bactericidal effectiveness will have dramatically diminished but they will continue to have a detrimental effect on meat colour.

References

Djenane, D., Sanchez-Escalante, A., Beltran, J. A., Roncales, P. (2001) Extension of the retail display life of fresh beef packaged under modified atmosphere by varying lighting conditions. Journal of Food Science, 66: 181-186.

Hood, D. E. (1980) Factors affecting the rate of metmyoglobin accumulation in pre-packaged beef. Meat Science, 4: 247-265.

Kaess, G and Weidemann, J (1971) Extending storage life of chilled mutton by continuous irradiation with ultraviolet light. Food Technology Australia, 23: 62-66.

Kim, T., Silva, J. L., Chen, T. C. (2002). Effects of UV irradiation on selected pathogens in peptone water and on stainless steel and chicken meat. Journal of Food Protection. 65: 1142-1145.

Mpelkas, C. C. Germicidal and short-wave ultraviolet radiation. Sylvania Engineering Bulletin 0-342.

Renerre M. (1990) Review: Factors involved in the discoloration of beef meat. International Journal of Food Science Technology. 25: 613-630.

Stermer, R. A., Lasater-Smith, M., Brasington, C. F. (1987). Ultraviolet radiation – an effective bactericide for fresh meat. Journal of Food Protection, 50: 108-111.

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Meat Technology Update

Newsletter 1/04

February 2004

Tenderstretch

Tenderness is one of the most important attributes of the eating quality of meat. The major animal/carcase factors that affect the tenderness of meat are:

- selection of cut;
- animal age;
- cold shortening (muscle contraction that can occur during chilling);
- animal stress leading to high pH;
- the extent of ageing; and
- breed.

Contraction of the muscles during chilling can lead to increased toughness in meat. Carcases are chilled rapidly soon after slaughter to prevent the growth of bacteria and to minimise weight loss during chilling. The muscle fibres tend to contract when a muscle is chilled rapidly to below 12ºC before the onset of rigor mortis. In those muscles that are free to shorten, this contraction may be sufficient to cause commercially significant toughness. Lean, light carcases chill more rapidly than do fat, heavy carcases, and yield tougher meat in muscles free to shorten.

Toughness caused by this muscle contraction can be prevented by accelerating the onset of rigor mortis using electrical stimulation; or by hanging the carcase in a way that will stretch the muscles and not allow them to contract, hence the name 'Tenderstretch'.

Electrical stimulation involves the application of a suitable electrical current to the carcase either immediately after slaughter, or at the end of the dressing line. This rapidly converts the muscle glycogen to lactate, lowering the pH and speeding up the onset of rigor mortis so that by the time the muscle temperature is reduced, the fibres are unable to contract (cold shorten) and toughen. The degree of electrical stimulation must be controlled however, so that the pH does not fall so rapidly that there is the danger of heat shortening.

Figure 1. Tenderstretch beef sides in a chiller

Tenderstretch

Many of the valuable muscles are in the butt and loin of a carcase. For beef sides, these can be restrained from shortening during the rigor process by suspending the side from the eye of the aitch bone (*obturator foramen*) or the pelvic ligament (Figure 1). Whole carcases of sheep, lamb or veal can be suspended from the pelvic girdle.

In a small throughput beef plant the transfer to the aitch bone or ligament can be done using an extended S hook and a hoist. At higher line speeds a continuous process can be employed where the hook is inserted into the suspension point and the roller is placed on a separate rail at a lower height which rises to the level

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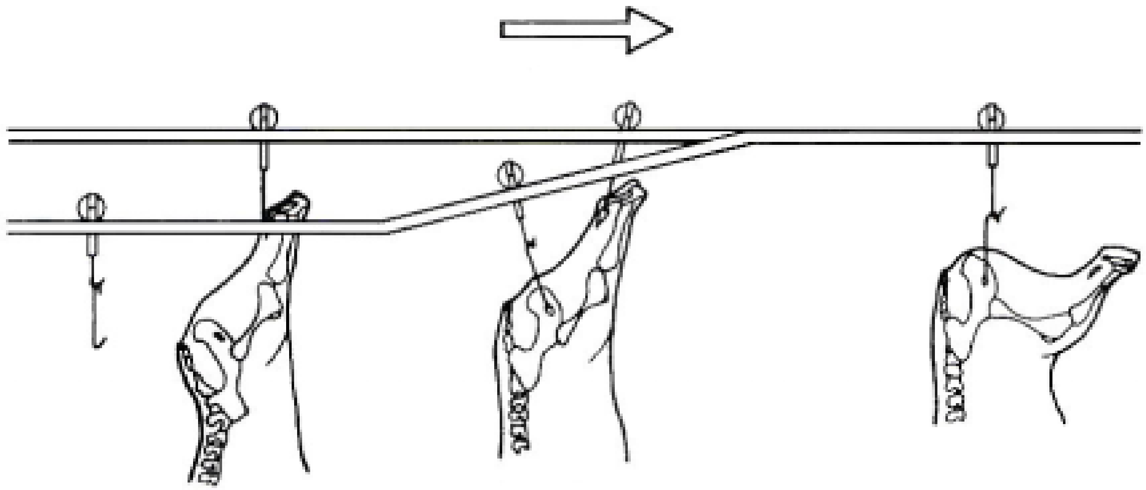

Figure 2. Changeover to tenderstretch

of the main rail (Figure 2). Capital cost can be reduced by replacing the stainless steel hook with a disposable rope of suitable length to hang the side at the same height. These procedures will normally require one additional person on the process line.

The sides must be left hanging in this manner during chilling or until rigor mortis is established. After this period, the side or quarter can be again hung from the Achilles tendon for transport or boning. Experience with trade cattle has shown that they return to close to the original shape even after weekend chilling.

Table 1: Effect on meat quality scores of suspending beef cuts by the Achilles tendon or aitch bone (assessment by panel after grill cooking)

	Achilles Hung	Tenderstretch	Change in Meat Quality
Hindquarter			
Tenderloin	73.5	70.9	Decreased
Rump	56.9	63.9	Improved
Striploin	55.3	61.2	Improved
Eye Round	47.3	48.3	No difference
Outside Flat	46.7	50.4	Improved
Topside	37.8	44.9	Improved
Forequarter			
Cube Roll	62.9	65.9	Improved
Blade	55.8	55.3	No difference
Brisket	34.7	31.9	No difference

The application of tenderstretch results in more tender meat for most cuts from the major leg muscles than does conventional Achilles-tendon hanging. The effect is most marked in the topside, loin, rump and outside flat (Tables 1 and 2).

Table 2: Effect on meat quality scores of beef cuts suspended by the Achilles tendon or aitch bone (stir fried)

	Achilles Hung	Tenderstretch
Tenderloin	76.0	75.2
Striploin	54.8	56.8
Topside	43.8	47.6
Outside Flat	41.0	47.6

The meat quality score is derived from consumer test results and includes an assessment of tenderness, juiciness, flavour and overall liking. Higher scores indicate superior eating-quality satisfaction.

Tenderstretch allows the fibres of the muscles of some cuts, such as the tenderloin, to shorten. Any adverse effect on tenderness is small and usually not apparent to consumers. There is also no effect on forequarter cuts other than the cube roll as no extra tension is applied to these muscles.

Tenderstretch sides can be hung by either the aitch bone or the ligament (Figure 3).

The position effect on the striploin in normally hung carcases (whereby the cranial portion had a higher palatability than the caudal portion), was reduced by suspension from the ligament (Table 3). When evaluated over several hindquarter muscles and

Figure 3. Sides can be hung by the aitch bone (L) or the ligament (R).

the loin muscle, there was a trend for suspension by the aitch bone to produce meat that was more palatable than the ligament method.

The results plotted in Figure 4 indicate that tenderstretching has almost the same effect on tenderness of cube rolls as ageing for 3 to 4 weeks at 0 to 1ºC. This suggests that there is little need for ageing of this cut from tenderstretched sides beyond 7 to 14 days. In contrast a significant improvement in tenderness occurs with ageing this cut from Achilles-hung sides right through to 4 weeks from processing. This relationship differs for different cuts. In some cases, the tenderness of a two-day-aged tenderstretch cut is equivalent to that of a two-week-aged cut from an Achilles-hung side.

Table 3: Effect of hanging method on meat quality scores at various positions along the LD muscle

Position	Achilles	Tenderstretch Aitch Bone	Tenderstretch Ligament
Cranial end	54.8	60.0	59.2
Centre	54.8	56.8	53.3
Caudal end	49.6	48.4	56.1

Tenderstretch hanging is an alternative to electrical stimulation for achieving good sheepmeat eating quality; it is best suited to the domestic short-aged market.

An advantage of tenderstretch lies in the uniformity of eating quality between cuts. For example, if older sheep are Achilles-hung there are marked differences between the different cuts, to an extent not seen with lamb; however, if they are tenderstretch-hung, the marked differences between cuts are eliminated.

In some cases the economic advantage for tenderstretching beef sides may be reduced by the fact that, with some chiller designs, fewer tenderstretch than Achilles-hung sides can be accommodated in a chiller. A rail spacing of 900 mm is normally sufficient to accommodate tenderstretched carcases from local trade cattle.

Tenderstretch is a process that has been proven effective in improving the tenderness of the commercially valuable cuts from carcases of both cattle and smallstock. Although there is an increased cost with the process, MSA grading offers the potential for tenderstretch to increase returns to processors from the sale of beef with improved eating quality.

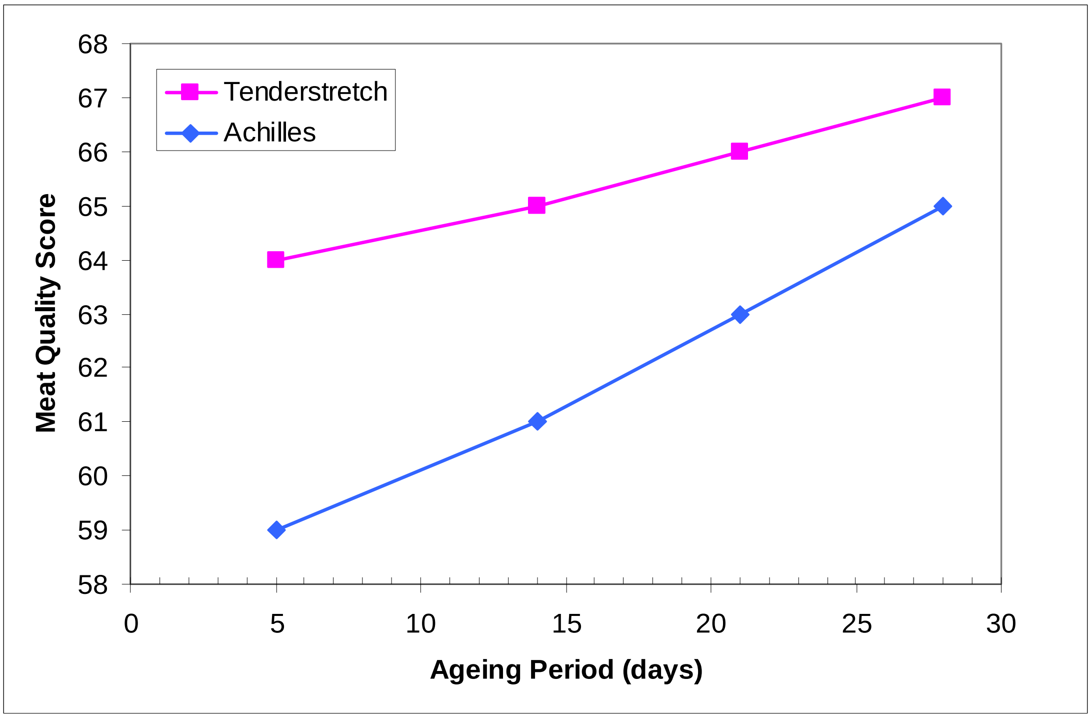

Figure 4. Effect of ageing on tenderness of cube rolls

Further information

Meat Standards Australia. MSA11 – How tenderstretch affects beef eating quality. MLA tips & tools.

Thompson, J (2002). Managing meat tenderness. Meat Science 62, 295–308.

Maximising lamb and sheepmeat eating quality – a guide for Australian lamb and sheepmeat processors (2003). Meat & Livestock Australia.

For more information, contact one of the Meat Industry Services staff listed below.

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The Meat Industry Services (MIS) section of Food Science Australia is an initiative supported by Meat and Livestock Australia (MLA) and the Australian Meat Processor Corporation (AMPC) to facilitate market access for, and support world-class practices in, Australia's meat industry.

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Meat technology update

5/06 – October 2006

MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Colour defects in meat
Part 1: Browning of fresh meat

Fresh meat eventually turns brown (sometimes interpreted as grey-brown); its acceptability to customers usually determined by loss of red colour ('bloom') rather than onset of bacterial spoilage. Display life is reduced by several factors that hasten discolouration. This article gives some realistic expectations for display life, discusses the basis for meat colour, and some reasons for premature loss of bloom.

Retail display life

It is the colour of meat that first influences the potential retail customer and also affects the decisions made by wholesale and institutional customers. There is a strong preference for meat that has the bright red colour that consumers associate with freshness and quality.

Because the bright red colour is enhanced by high concentrations of oxygen, most displayed meat is either open to air (in which case there is a risk of drying of the meat surface), packed in an oxygen-permeable wrap, or sealed in a modified atmosphere high in oxygen—normally around 80%. Meat displayed in these ways usually becomes discoloured through browning before bacteria have grown sufficiently to cause spoilage.

Incorrect storage or handling at any stage of the distribution chain will reduce retail storage life. The principal factor affecting the shelf life of meat on display is temperature. In order to obtain the longest possible shelf life for meat on display, the storage temperature should be as close to 0°C as possible. As well as keeping microbial growth to a minimum, it will prolong retention of the bright red colour. As it is impossible to maintain a steady 0°C in open meat display cabinets, a realistic optimum temperature range is 0–5°C. Meat should be cooled to below 5°C before it is prepared for retail display, and it is best cut just prior to packaging for display.

The basis of meat colour

In the absence of oxygen (O_2), fresh meat is purplish-red. This is the colour of the pigment myoglobin. On exposure to air, myoglobin absorbs oxygen. The oxygenated form of the pigment is called oxymyoglobin. It is bright red and produces the 'bloom' expected by the consumer. Since the oxygenation occurs progressively, blooming takes up to 30 minutes; it is for this reason that colour appraisal of meat should not be carried out until after it has been exposed to air for 30 minutes. The oxygenated layer is only 3–4 mm at 0 °C, even less at higher temperatures.

Figure 1: Loss of bloom (oxymyoglobin) and development of brown discolouration (metmyoglobin) after 3 days on retail display.

After prolonged exposure to air (up to several days, but the rate is influenced by factors described below), the meat turns grey-brown or brown. The brown pigment is known as metmyoglobin. Browning starts under the surface at the interface between the oxygenated layer of oxymyoglobin and the deoxygenated myoglobin. The layer of metmyoglobin gradually expands and, when it is visible at the surface, the meat is brown.

Enzyme systems in the meat and environmental factors both influence the rate at which the pigments change from one state to another. Generally speaking, pigment changes are

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caused by factors that reduce the oxygen available at the meat surface or cause dissociation of the oxygen from oxymyoglobin. With this in mind, conditions of primary importance to meat colour are temperature, pH, the age of the meat and the amount of available oxygen.

Retail storage after ageing

Some enzymes can convert metmyoglobin back to myoglobin and hence oxymyoglobin. The enzyme system in meat becomes less active with ageing, and discolouration is faster. When these enzymes lose activity, the concentration of metmyoglobin increases. After three weeks in vacuum packs, meat that is then exposed to air or a high-oxygen atmosphere discolours faster than fresh meat. The longer meat is aged, the faster it will discolour after being exposed to air. The longer the period of storage in the vacuum pack the shorter the display life of the consumer portions, because of more rapid conversion of oxymyoglobin to the brown metmyoglobin.

Storage time in the vacuum pack (weeks at 0 °C)	0	2	4	6	8
Retail display life (days)					
*Overwrapped trays	3	3	2	2	1
High-O_2 MAP	7-10	5-6	4	3	2

This table indicates the retail display life of consumer cuts of beef (stored at about 5°C) in conventionally over-wrapped and oxygen-enriched modified atmosphere packs (MAP) as a function of the meat storage time in the vacuum pack at 0°C.

Beef and lamb stored in high levels of carbon dioxide (CO_2) appear to retain their retail display life better than vacuum-packed beef and lamb. For example, products prepared from lamb primals or carcases that have been stored at 0°C in a CO_2 atmosphere for 12 weeks have a retail display life in over-wrapped packs of about 2–3 days.

Dark cutting meat

Stress prior to slaughtering can play a significant role in meat colour since it affects meat pH, which in turn affects colour. Meat colour gradually darkens with an increase in ultimate pH through the pH range 5.4 to 7.0. If beef has a pH of 6.0 or more, it is usually classified as 'dark cutting' or 'high-pH' beef; however, meat with an ultimate pH of 5.8 may be regarded as dark-coloured by some customers.

High-pH meat is dark-coloured because, with low acid levels in the meat, there is less oxymyoglobin formation at the surface. The reduced myoglobin under the surface gives a dark appearance to the meat. There is less light reflected from the surface. This, coupled with the fact that there is a light-scattering effect, causes the eye to perceive the colour differently.

Browning of dark cutting meat occurs more slowly than in meat of 'normal' pH; however bacterial spoilage occurs sooner at high pH, and the meat may be spoiled by microbial activity rather than by discolouration.

Two-toned (pale and dark) meat

Two-toning usually refers to meat in which there are undesirable gradations in meat colour within a cut, usually with the deep meat tissue being paler than the normal red meat closer to the surface. Pale-coloured meat will discolour more quickly than normal-coloured meat in the presence of oxygen because its enzyme system has been affected, leading to faster progression of the metmyoglobin reaction.

The paleness leading to two-toning is caused by denaturation of meat proteins at relatively high temperatures (30–40 °C) when the pH is low due to the acidity that results from the accumulation of lactic acid during the early stages of rigor mortis. The paleness normally occurs in the deep muscle (e.g. topsides) of heavy carcases where chilling is slow. It is not seen in smallstock carcases to any extent because there is a more even chilling rate throughout the carcase.

Fast chilling of heavy beef sides after slaughter gives more evenly coloured meat, and firmer muscles. It also minimises the subsequent unsightly weep (drip) in display or vacuum packs; however, where rapid chilling is applied and no electrical stimulation is utilised, the rate of pH decline can be quite slow and carcases may be incorrectly assessed as dark cutting.

Effective electrical stimulation (ES) will overcome the two-toning effect in many carcases by accelerating the rate of pH decline. ES tends to even up the colour, making it more uniform and lighter; however, in heavy carcases, ES may aggravate two-toning. It is important not to overstimulate. The way in which slaughter floor electrical inputs influence meat quality was discussed in some detail in previous Meat Technology Updates 3/04 and 1/06. As a guide, if the pH is at, or below, 6.0 while the temperature is still at or above 35 °C, then the electrical inputs have been excessive, and there may be undesirable paleness of the slow-cooling muscles.

Two-toning can also refer to browning of some parts of the cut surface of a piece of meat. Different muscles have different biochemical activities, so the rate of discolouration differs between muscles, and this can lead to different colours in a single cut (Figure 2).

Figure 2: Evidence in lamb leg steaks of a muscle-to-muscle difference in colour stability.

Colour of vacuum-packaged and (100% CO_2 or N_2) MAP meat

From a colour point of view, the aim of vacuum-packaging or packing in CO_2 is to prevent the production of undesirable brown metmyoglobin during storage, by reducing the concentration of oxygen in the pack to below 0.2%. To achieve this, the meat should be packed and sealed as quickly as possible after boning or cutting the carcase. Inside a vacuum package, residual oxygen is consumed and carbon dioxide (CO_2) is produced as a result of metabolism by the muscle tissue. The bright red oxymyoglobin colour of fresh meat disappears in vacuum packs and in CO_2 flushed packs as the pigment reverts to its purplish-red form. This is the normal and desirable colour of vacuum-packed meat. Within a short time of the pack being opened, the purple myoglobin at the meat surface changes to oxymyoglobin and the meat blooms again to a bright red colour, in response to the oxygen present in air.

Not all the air will be evacuated from a vacuum pack, but any residual oxygen should be used up by respiration of the meat tissue. How well this residual oxygen is used up is dependent on the age of the meat when packed because its respiration ability declines with time. The rate of decline varies between muscles. The tenderloin, for example, loses the ability to respire quite quickly. If the meat is older than around 48 hours post-slaughter at the time of packing, there may be insufficient meat respiration to consume the residual oxygen. If there is residual oxygen in the pack, metmyoglobin will form, and this browning problem will be exacerbated by high storage temperatures.

Browning of meat while stored in a vacuum package indicates that there is too much oxygen in the pack. Browning occurs fastest at about 1% oxygen. If the packaging film allows too much oxygen to permeate through, or if there are poor seals, pinhole punctures, or poor air evacuation at the time of packing and sealing, the meat will turn brown during storage. The oxygen transmission rate of the films used for vacuum packaging is very important.

Colour problems will also occur with beef and lamb stored in high concentrations of carbon dioxide, unless oxygen is excluded from the pack. As with vacuum packs, if a critical 0.5 to 1 per cent of oxygen is present, the rate of browning will be higher than in air. In addition to discolouration of the lean surface, problems with the appearance of fat surfaces may occur (grey-brown discolouration). With lamb, a brownish discolouration of the fascia (connective tissue) surfaces may develop after several weeks' storage at 0°C if there is too much oxygen present.

Note that this type of browning should not be confused with cooked meat browning which can be caused by excessive heat during shrinkage of the packaging film.

There is documented evidence of what is termed 'transient discolouration', where metmyoglobin increases during the first 3 days or so of storage under low-oxygen conditions, and then decreases. It then may or may not increase again to an unacceptable level. This has been observed with striploins and particularly in trays of tenderloin beef in low-oxygen master packs. The use of oxygen scavengers as part of the packaging system can prevent the transient discolouration. In a Canadian study, beef tenderloins were aged in vacuum packs for 2 to 3 weeks. Steaks were then prepared in N_2 master packs and stored for a further week, after which the individual trays were removed from the master packs and placed on retail display. Unless oxygen scavengers were in the trays when they were prepared in the master packs, the steaks discoloured rapidly. Meat in trays with sufficient scavengers had retail lives in excess of 4 days after being removed from the master packs.

Bone-in retail cuts

Bone-in cuts that are packed in high-O_2 gas mixtures are prone to rapid discolouration. Modified atmosphere packaging (MAP) with high levels of oxygen predisposes bone marrow to discolouration. There is evidence that high oxygen is detrimental to bone marrow colour stability because the haemoglobin that accumulates on cut bone surfaces after cutting is oxidized in the presence of oxygen to dark brown methaemoglobin, resulting in significant discolouration within 24 hours after packaging. There is also evidence that packaging in atmospheres devoid of oxygen (e.g. CO_2/N_2 mixtures) will limit marrow discolouration during storage and display.

Tunnel-boned legs

It is likely that two factors contributed to the discolouration of the tunnel-boned lamb legs seen in Figure 3: residual air in the cavity after vacuum-packaging; and diminished enzyme activity in legs boned 3 to 4 days after slaughter of the lambs.

Figure 3: Evidence of browning of lamb surface created when bone was removed.

Discolouration of frozen product

On occasions, discolouration has been observed in frozen beef and lamb. It is unclear, though, whether the discolouration occurred during frozen storage or before the meat was frozen. The main focus of recent studies in this area has been on frozen restructured beef steaks, where mixing and grinding contribute to colour instability; however, the results for intact steaks used in these studies as controls indicated that steaks stored at –23 °C after being vacuum-packaged, developed more metmyoglobin over three months than did steaks that were not vacuum-packaged before being frozen. This suggests that the phenomenon of maximum browning associated with the critical 0.5 to 1% oxygen discussed earlier for chilled meat also applies for frozen meat.

Some points about meat colour

- The greater the concentration of myoglobin, the darker the colour of the meat. Myoglobin concentration varies from species to species: beef contains about nine times as much myoglobin as pork. Also, older animals have a higher concentration, and different muscles contain varying concentrations of myoglobin, and so differ in darkness.
- Aged meat has poor colour stability compared with fresh meat. Enzymes in fresh meat can prevent the formation of brown metmyoglobin, but these enzymes lose their activity as the meat ages.
- The rate and extent of metmyoglobin formation (browning) are related to the oxygen content of the atmosphere around the meat, as well as temperature and the balance between the various biochemical reactions that occur—those that promote metmyoglobin formation and those that slow it. The rates of these reactions are determined by enzyme systems.
- Metmyoglobin formation is slower at low temperatures because the low temperature slows the biochemical reaction and preserves the activity of enzymes in aged meat.
- At extremely low concentrations of oxygen (such as in vacuum packs and modified atmosphere packs containing pure carbon dioxide), the development of the brown pigment is prevented; however, at medium to low oxygen levels (about 1%, such as in poorly prepared vacuum packs), metmyoglobin development is greatest. There can be increased browning when unwrapped cuts are stacked in contact with each other, and this browning occurs because of the low oxygen levels at the points of contact.
- The red colour of meat is brighter and deeper at low storage temperatures because oxygen is able to penetrate the meat more easily. The layer of oxymyoglobin at the surface of the meat is thicker at 0°C than at 15 °C (3–4 mm compared with 1–2 mm).
- pH (acidity) has an influence on retail display life in air. High-pH (dark cutting) meat discolours at a slower rate than normal pH (5.5) meat.
- Beef from grass-fed cattle contains high levels of natural antioxidants such as vitamin E and beta-carotene, which slow down the browning discolouration. Beef from cattle raised on good-quality pasture has Vitamin E content and lipid stability equivalent to that from grain-fed cattle supplemented with over 2500 international units (I.U.) of Vitamin E per day for four months. Dietary beta-carotene supplementation will extend retail display life.
- Localised areas of discolouration on the surface of fresh meat can be caused by any of: spoilage bacteria; contaminating substances; partial contact with other meat or packaging surfaces; or from by-products of fat oxidation (i.e. rancidity development).
- Differences in biochemical activities in different muscles cause colour stability variations from cut to cut and also within a cut. It is possible to see red and brown parts within one cut. Some cuts, such as rumps and tenderloins, are more susceptible to browning than others such as striploins.
- Various antimicrobial interventions affect meat colour and colour stability – some positively, some negatively. Organic acids sometimes decrease redness and colour stability, probably because they reduce the meat pH where they contact the meat surface.
- Contamination of meat with multivalent ions such as copper, iron and aluminium and oxidising agents such as peroxide, hypochlorite and common salt (NaCl), greatly accelerates the rate at which meat discolours.
- Lighting will influence the colour appearance of meat. Certain types of lighting accelerate colour deterioration e.g. incandescent lights and those fluorescents with a UV component. Exposure of meat to intense light, as in display cases in supermarkets, also increases the discolouration rate. It does this mainly by increasing the surface temperature of the meat.
- In low-oxygen modified atmosphere packs (carbon dioxide or nitrogen), there can be a condition termed transient discolouration where discolouration becomes evident during the first three days of chilled storage, then disappears.

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Meat technology update

6/06 – December 2006

Colour defects in meat—Part 2: Greening, Pinking, Browning & Spots

The previous Meat Technology Update (Issue 5/06, October 2006) discussed the development of a brown colour in fresh meat, as a result of oxidation of the pigment myoglobin to metmyoglobin. Other undesirable colours and appearances are described in this issue.

Greening

Green colour may develop in meat through reaction of the meat pigment myoglobin with certain compounds. When myoglobin reacts with hydrogen sulphide (H_2S), the resultant pigment is sulphmyoglobin, and when myoglobin reacts with hydrogen peroxide (H_2O_2), a number of pigments are produced. These pigments are green. The compounds H_2S and H_2O_2 are produced by certain microorganisms under specific storage conditions.

Sulphmyoglobin greening is associated with growth of the bacterium *Pseudomonas mephitica*. This organism requires low oxygen levels and pH greater than 5.9 for production of hydrogen sulphide from sulphur-containing amino acids. Greening is associated with poor barrier films used for vacuum packaging, which allow a small amount of oxygen into the pack. The good barrier provided by most modern films has led to sulphmyoglobin greening being quite uncommon. The organism can produce greening even if the cells are less than 5% of the total microbial population. If oxygen is absent, or the level is high, or the pH is below 6, it cannot produce hydrogen sulphide and greening will not occur. To avoid green discolouration at low oxygen levels (e.g. in vacuum or low-oxygen MAP with some residual oxygen), high pH meats should not be used. When sulphmyoglobin green packs are opened, the green colour often disappears because the pigment is oxidised to a red form.

Other green pigments result from the interaction between myoglobin and hydrogen peroxide. Their formation is favoured between pH 4.5 and 6. The source of the hydrogen peroxide may be bacterial, may result from the interaction of ascorbic acid (vitamin C) with the oxygen molecule of

Figure 1: Two packs of lamb showing greening, compared with a normal pack above.

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oxymyoglobin, or may be produced by the muscle itself. Hydrogen peroxide greening has been associated with cooked cured meats under aerobic conditions. In vacuum-packaged fresh meat, the meat enzyme catalase breaks down hydrogen peroxide, so production of the green pigments is limited, and greening due to sulphmyoglobin is much more important.

Brown and black spots

Brown discolouration in the form of spots on fat surfaces has been attributed to the yeasts *Yarrowia lipolytica* (formerly *Saccharomycopsis lipolytica*) and *Candida zeylanoides*. Yeasts can survive and grow on chilled meat stored in air; and in vacuum-packed meat if the oxygen transmission rate of the packaging film is too high. Brown spot was a problem on vacuum-packaged beef in the 1970s, but is a rare occurrence today.

Yeasts and moulds require oxygen to grow, and can grow at temperatures from just below zero to up to 40°C, dependent on the species. Most tolerate reduced water activity, and prefer a slightly acidic environment of pH 4.4 to 5.5. Yeasts and moulds survive well in chillers, and incidents of brown spot on carcasses and corresponding packaged meat have been associated with contaminated condensate dripping onto the meat.

Black spots may develop on frozen meat stored at –5 °C for 40 days or more, and this has been associated with a number of yeasts and moulds including *Cladosporium cladosporoides*, *Cladosporium herbarum*, *Penicillium hirsutum* and *Aureobasidium pullulans*. These organisms penetrate into the meat surface, and must be trimmed off.

Figure 2: Brown spots on beef fat.

Spots on cured and fermented meats

Some moulds are considered desirable in cured and fermented meats because they impart certain flavours, and assist in the fermentation process; however, some are undesirable. The mould *Cladosporium* causes unsightly, deep-seated black spots on cured hams, which cannot be washed off. It has strong proteolytic activity, allowing it to break down the product surface and burrow into it. *Scopulariopsis* causes white spots on the skin of hams, and a number of other moulds cause whiskers on fermented meats. Lightly smoking the product during curing or before packaging can help to reduce mould growth.

A Gram-negative bacterium, *Carnomonas nigricans*, has also been found to cause black spots on cured meats. These spots begin as small rust-coloured areas which blacken over a few hours. Adding sodium nitrite to the cure prevented the formation of these spots; while adding dextrose, maltose or dextrin encouraged formation.

Bones and marrow

The marrow of bones contains a high proportion of blood, and when bones are cut, red blood cells may be ruptured, releasing haemoglobin which gets smeared onto the surface of the bone. Haemoglobin is the red pigment in blood, and it responds to oxidation in the same way as myoglobin. Initially, on exposure to oxygen, it is bright red, but brown methaemoglobin develops rapidly in response to low oxygen levels in packaged product. When packaged in a high oxygen-modified atmosphere (e.g. 80% O_2, 20% CO_2), bones discolour significantly within 24 hours. Alternatively, if the oxygen in the gas mixture above is replaced with nitrogen, a stable purplish marrow colour will remain for 1–2 weeks at 4°C or less.

Ground and comminuted meats

The colour stability of meat is partly dependent on aerobic-reducing enzymes. The aerobic-reducing systems prevent browning by converting metmyoglobin back to myoglobin. When the myoglobin and reducing enzymes are contained within the muscle-cell membrane, the meat has relatively good colour stability.

When meat is minced, the cell structure is disrupted (see diagram below). This increases the exposure of myoglobin to oxygen, and destroys some of the muscle's innate aerobic-reducing system. This partly explains the accelerated browning observed in minced versus whole muscle. In addition, the oxygenation of meat during mincing followed by restricted access to oxygen in the middle of a pack, creates low oxygen levels at the surface of particles. At low oxygen levels myoglobin is oxidised to metmyoglobin; but, whereas in intact meat the aerobic-reducing system is active, in minced meat the system is inactive and the meat turns brown from the inside of a pack.

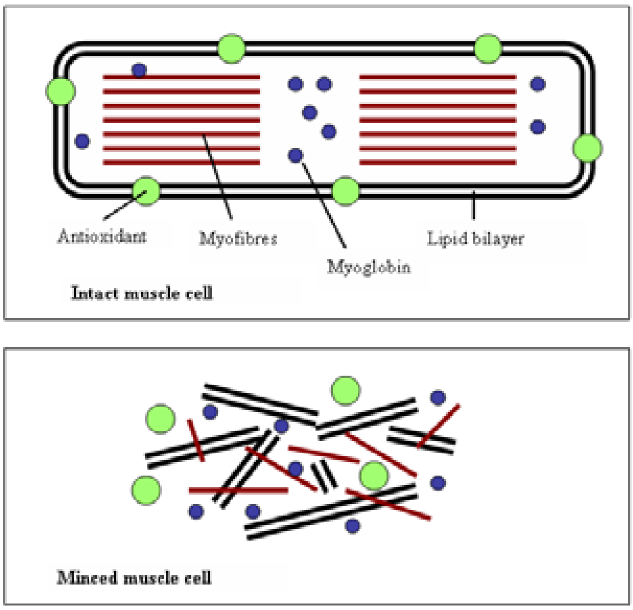

Figure 3: Destruction of muscle cells by mincing.

Researchers have found that antioxidants can inhibit myoglobin oxidation and improve colour stability, but are more useful in controlling other aspects of oxidation such as rancidity. For example, EDTA is an antioxidant and, although it decreases lipid oxidation and rancidity, it increases myoglobin oxidation and browning; vitamin C is an antioxidant, but it can sometimes react with meat and produce hydrogen sulphide, and cause greening. At present, such additives are not permitted in Australia.

Feeding vitamin E to cattle seems to decrease lipid oxidation and myoglobin oxidation and thereby improves fresh meat colour stability and shelf life. One study showed that while control packs of mince were okay up to 48 hours, those from cattle fed 500IU Vitamin E for 120 days were okay up to 67 hours, and those fed 2000IU for 120 days were okay up to 92 hours. This was in PVC overwrap displayed under fluorescent light.

Frozen meat

The colour of frozen meat is affected by: freezing rate; storage temperature and fluctuation in temperature during storage; intensity of light during display; and method of packaging. Very slowly frozen meat is excessively dark, while meat frozen in liquid nitrogen is unnaturally pale. Such extremes are unlikely to be seen under commercial conditions, but faster freezing regimes will give a paler product than slower freezing regimes. The large variation in lightness is a result of differences in the rate of ice-crystal growth. Small crystals formed by fast freezing scatter more light than large crystals formed by slow freezing; so fast-frozen meat is opaque and pale, while slow-frozen meat is translucent and dark. To optimise frozen-beef colour, fresh beef should be exposed to air for 30 minutes before freezing to allow optimum bloom to develop prior to freezing. This can result in frozen beef that is similar in appearance to fresh beef.

During storage of frozen meat, if it is exposed to air, slow thawing and refreezing of the exposed surface leads to dehydration of the meat. This leads to the development of freezer burn which appears as a grey-white area on the exposed surface where the fibres of the meat are visible. Freezer burn areas stay dry and pale when the meat is defrosted, and is tough and dry to eat.

The major colour problem during retail display of frozen meat is photo-oxidation. Frozen meat under direct illumination oxidises from the surface inwards (compared with fresh meat which oxidises from the subsurface outwards). Oxidation of frozen oxymyoglobin is temperature dependent—the rate increases from –5 to –12°C and then decreases to a minimum at –20°C. The rate of oxidation is affected also by muscle type—*Longissimus dorsi* (loin) will fade more slowly than *Gluteus medius* (rump). Frozen-beef colour remains attractive for at least 3 months in the dark, but only 3 days in the light.

Cooked meat

Thorough cooking causes denaturation (unfolding) of the globin part of myoglobin. This makes the pigment much more prone to oxidation. In the presence of air, the grey-brown cooked meat pigment (denatured globin haemachrome), is formed. Under anaerobic conditions (canned meats, vacuum bag in water), the pink denatured globin haemochromes can be formed. Owing to heat denaturation of the globin protein, these proteins coagulate and are not soluble in water, so meat juices don't look red.

Variation in the colour of precooked meat products cooked to the same internal temperature has been a problem in the meat industry for over 30 years. The problem occurs sporadically and is characterised by variation in redness in highly pigmented muscles. There are two possibilities:

1. The myoglobin has been converted to a pink haemochrome during heating. This seems to occur at higher temperatures (>76°C);
2. The myoglobin has not been completely denatured. This seems to occur at lower temperatures (<76°C).

There seems to be some relationship between pH and cooked colour, but other factors are involved. High pH (above 6.0) stabilises myoglobin against the effects of heat, so decreases the percentage of myoglobin denatured during cooking, and this can be sufficient to produce obvious colour differences.

Pinking and premature browning when cooking

Pinking in cooked meat

Although cooked meats are typically grey-brown, pinking is not uncommon. Several conditions other than undercooking may result in pink or red colour of cooked meat. Some of these are:

- incomplete denaturation of myoglobin, as described above. This is associated with high pH and high pigment concentration;
- contamination with nitrite/ nitrate/ ammonia, or exposure to carbon monoxide or nitric oxide gases can lead to red pigments;
- the grey-brown pigment is not 100% stable: it can slowly be reduced to the pink haemochrome, and the interior of large roasts may slowly turn pink during refrigerated storage due to this effect.

Pink colour after cooking patties is due to incomplete denaturation of myoglobin. It is much more likely to occur in patties that have been frozen. Most frozen patties will brown when cooked to 71°C, but a few may retain a red to pink colour. A higher internal temperature (around 81–84°C) will be needed to completely remove the pink/red colour from these patties. Red internal colour at 71°C seems to be more frequent in products containing less than 20% fat. One study showed that the internal colour of patties cooked to 71°C within 12 hours of thawing at 7°C remained red-pink. Only after 18 hours or more of thawing did cooking to 71°C result in a well-done appearance. The cooked colour of patties which were thawed while vacuum-packed, was redder than patties thawed non-vacuum packed. The conclusions were that the best ways to prevent pinking was (i) to produce patties immediately prior to cooking, and not frozen, or (ii) if frozen, patties should be thawed in air for 18 hours prior to cooking. Thawing in air allows oxygenation of the myoglobin, and thus the grey-tan denatured globin haemachrome forms. When the patties are cooked from frozen, and are not fully oxygenated, the pink denatured globin haemochromes can form, so the interior of the patty looks pink. It is not, however, possible to apply the findings of the above study to a commercial situation.

Pink cured colour may result if meat is exposed to nitrite in ingredients, or nitrogen dioxide (NO_2) during cooking (surface pinking). The nitrogen dioxide may be present in the combustion gases in gas ovens. Meat cooked in a gas oven, or heavily smoked, frequently develops surface pinking. Upon slicing, a pink ring is observed to a depth of

~8–10mm from the surface. Pink ring is a traditional and desirable attribute in some products, e.g. 'Texas BBQ' beef roasts, but in most cases, the surface pinking is undesirable since consumers may associate pinking with undercooking. It was thought that carbon monoxide (CO) or nitric oxide (NO) produced by gas combustion was the cause of the pinking, but research has shown that nitrogen dioxide (NO_2) is probably the culprit. During cooking, the presence of up to 149ppm CO or 5ppm NO did not cause pinking, but as little as 0.4ppm NO_2 caused pinking of turkey rolls, and 2.5ppm caused pinking of beef roasts. Nitrogen dioxide has a much greater reactivity than nitric oxide with moisture at meat surfaces.

Premature browning

This is the other extreme, where ground beef appears thoroughly cooked at internal temperatures as low as 55°C. It is particularly associated with unaged ground beef that is stored in air. Premature browning appears to be related to frozen storage, but this is not the primary cause. It seems that if the meat is more oxidised, it is more likely to show premature browning, so any factor that promotes oxidation of myoglobin, or limits the reducing capacity of the meat, can result in premature browning. For example, aged meat has less reducing capacity than fresh meat. There have been some studies on the effect of the animal or diet (young animal or old animal, Vitamin E supplemented or not), but it seems that while it affects display life (see above), it has little effect on the internal colour of cooked patties.

Premature browning is particularly associated with patties that are frozen and thawed before cooking. Some researchers have managed to manipulate the thawing process to prevent premature browning—by thawing patties in vacuum packs, then giving them 4.5 hours anaerobic reduction by holding at 22°C before bringing them back to chill temperature (3°C) before cooking. If the patties were cooked from frozen, without thawing, premature browning did not occur.

When cooking patties, the juice produced becomes less red and more yellow as the endpoint temperature increases, but it doesn't tend to run clear, as suggested in a number of cooking guidelines. Visual evaluation of patty colour is not an accurate indicator of doneness, and a more appropriate guideline would be 'cook until the juices lack redness'. Cooking to a recommended internal temperature (e.g. 71°C) to achieve destruction of live pathogens remains the most reliable indicator, however.

Uneven surface browning of roasts

The Maillard reaction is a non-enzymatic reaction between amino acids and reducing sugars, which occurs during cooking. This reaction is responsible for the production of many of the flavours and odours associated with cooked meat. It also results in browning of the meat through production of pigments called melanoidins. These contribute to the dark brown colour on the surface of roasted meats, which is a key factor in consumer acceptance of the product. The actual products formed from the Maillard reaction depends on the duration and temperature of cooking, moisture content and pH, as well as the nature and concentration of the sugars and amino acids involved. There is a significant correlation between the temperature of cooking and increasing production of melanoidins. It also proceeds more rapidly at low moisture levels (optimum aw 0.65-0.75), which is why browning is greater at the surface, which has become dehydrated during cooking. Where the roast is in contact with the pan, or in contact with wrapping, the surface remains moist and there is less browning.

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Meat Industry Services is supported by the Australian Meat Processor Corporation (AMPC) and Meat & Livestock Australia (MLA).

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

00/2 – April 2000
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Prevention of fresh meat colour defects

Consumers usually assess meat quality in terms of colour, tenderness, juiciness, flavour, fat cover and marbling. However, at retail level, customers are most influenced by meat colour in their decision to buy. Colour is perceived to be a valuable guide to the overall quality of meat; if a visual appraisal raises any doubts it is unlikely that purchase of that particular item will be considered further.

Although there are conflicting scientific studies about colour relevant to eating quality, it is the colour of meat that first influences the potential customer and also affects the judgement of wholesale and institutional purchasers. It is therefore necessary to have an understanding of the variations in meat colour and how it is affected by various conditions and handling practices.

The basis of fresh chilled-meat colour

In the absence of oxygen (O_2), fresh meat is purplish-red. This colour is caused by the presence of a pigment called myoglobin, which, on exposure to air, absorbs oxygen and becomes bright red. Since this occurs progressively, colour appraisal of the meat should be carried out after it has been exposed to air for approximately 30 minutes. The oxygenated form of the pigment, called oxymyoglobin, causes the bright red meat colour expected by the consumer. The red meat layer occurs to a depth of only 3-4 mm at 0°C (Figure 1A).

After the meat's prolonged exposure to air, the pigment turns grey or brown just under the surface. This brown pigment is known as metmyoglobin (Figure 1B).

Systems in the meat and environmental factors control the rate at which the pigments change from one state to another. Generally speaking, pigment changes are caused by factors that reduce the O_2 tension at the meat surface or cause dissociation of the O_2 from oxymyoglobin. With this in mind, conditions of primary importance to meat colour are temperature, pH and the amount of available oxygen.

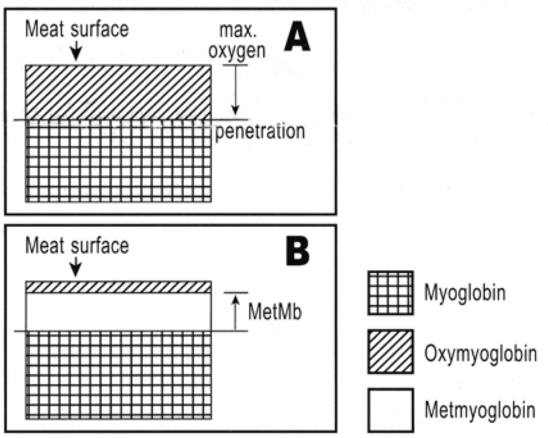

FIGURE 1 A simplified representation of the formation of pigments at the surface of meat

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General points

- The rate of metmyoglobin formation is related to the balance between systems in the meat that promote metmyoglobin formation and those that slow it, as well as the oxygen content of the atmosphere around the meat.
- At extremely low concentrations of oxygen (such as in vacuum packs), the development of the brown pigment is prevented. However, at medium to low oxygen levels (about 1%, such as in poorly prepared vacuum packs), metmyoglobin development is greatest. There can be increased browning when unwrapped cuts are stacked in contact with each other and this browning occurs because of the low oxygen levels at the points of contact.
- Low temperatures slow the rate of the chemical and enzymic reaction leading to brown metmyoglobin pigment formation.
- The red colour of meat is brighter and deeper at low storage temperatures because oxygen is able to penetrate the meat more easily. The layer of oxymyoglobin at the surface of the meat is thicker at 0°C than at 15°C.
- Differences in the chemical and enzyme activities of different muscles cause colour stability variations from cut to cut and also within a cut. It is not uncommon to see red and brown parts within one cut. Some cuts, such as rumps and tenderloins, are more susceptible to browning than others such as striploins.
- pH (acidity) has an influence on retail display life in air. High-pH meat (dark cutting) discolours at a slower rate than low-pH meat. Meat discolours at a slower rate as its pH increases above normal pH (5.5).
- Beef from grass-fed cattle contains high levels of natural antioxidants, such as vitamin E and beta-carotene, which slow down the browning discolouration. Beef from cattle raised on good-quality pasture has Vitamin E content and lipid stability equivalent to that from grain-fed cattle supplemented with over 2500 international units (I.U.) of Vitamin E per day for four months.
- Exposure of meat to intense light, as in display cases in supermarkets, also increases the discolouration rate. It does this mainly by increasing the surface temperature of the meat.
- Contamination of meat with multivalent ions such as copper, iron and aluminium and oxidising agents such as peroxide, hypochlorite and common salt (NaCl) also greatly accelerates the rate at which meat discolours.
- Localised areas of discolouration on the surface of meat, sometimes referred to as 'spot' discolouration, may result on fresh meat surfaces from bacteria, contaminating substances, partial contact with other meat or packaging surfaces or from by-products of fat oxidation (which lead to fat rancidity).
- Lighting will influence the colour appearance of meat. Adequate quantity of light (or illuminance) is only one of the necessary elements of a satisfactory lighting system, particularly for such tasks as inspection for meat colour. Failure to achieve adequate light quality can reduce the efficiency of assessment and thereby increase the likelihood of customer complaint. In chiller assessment AUS-MEAT require that the exposed meat be evaluated after at least 20 minutes of cutting (provided blooming is complete) using a light with 1400-3000 lux (recommended 1800-2600 lux) and a colour temperature of 3000 degrees Kelvin (K).

Other aspects of fresh chilled-meat colour

Pigment concentration

For meat at any particular pH level, the greater the concentration of myoglobin, the darker the colour of the meat. Its concentration varies from species to species. Beef contains about nine times as much myoglobin as pork and this partly explains why beef is red and pork is pink. Meat colour is also affected by the sex and age of the animal, with older animals having a higher concentration of pigment. Within a carcase, different muscles contain varying concentrations of myoglobin, and so vary in darkness of colour. Meat from bulls typically has a higher myoglobin (muscle pigment) content than that from steers, heifers or cows at the same age. Similarly, meat from rams has a higher myoglobin content than that from wethers and ewes.

Drying out

Drying of the meat surface affects the way that light is reflected and absorbed. The drier the meat surface, the greater the reduction in reflected light. During drying, the concentration of meat pigment increases at the surface and produces a darkening effect. Drying out also leads to increased brown pigment formation. This darkening, due to dehydration, can often be seen on the cut surface of the topside on sides of chilled beef.

'Dark cutting' meat

Stress prior to slaughtering also plays a significant role since it affects meat pH, which in turn affects colour. High-pH meat is dark because, with low acid levels in the meat, there is less oxymyoglobin formation at the surface. The reduced myoglobin under the surface gives a dark appearance to the meat. As a result, there is less light reflected from the surface. This, coupled with the fact that there is a light scattering effect, causes the eye to perceive the colour differently.

Meat colour gradually darkens with an increase in ultimate pH right through the pH range 5.4 to 7.0. If beef has a pH of 6.0 or more it is usually classified as 'dark cutting' or 'high-pH' beef. However, meat with an ultimate pH of 5.8 may be regarded as dark by some consumers but would not be classed technically as 'dark cutting' meat. Dark cutting meat has a shorter shelf-life than meat of 'normal' pH.

Two-toned (pale and 'dark') meat

In two-toned meat there are undesirable gradations in meat colour within a cut, with the deep meat tissue being paler than the normal red meat closer to the surface. Pale-coloured meat will discolour more quickly than normal-coloured meat in the presence of oxygen because of the effect on its enzyme system and the faster progression of the metmyoglobin reaction.

The two-tone effect is sometimes evident in beef (particularly heavy carcases), but is not seen in smallstock carcases to any extent because of their more even chilling rate. The paleness causes a ring effect in the meat, sometimes called a 'heat ring and is due to the comparatively slow cooling of the deep meat compared to that of the surface meat.

The undesirable paleness leading to two toning is due to denaturation of meat proteins at relatively high temperatures (30-40°C) and acidity resulting from the natural development of lactic acid during the early stages of rigor mortis (acid production is also faster at higher temperatures). The paleness normally occurs in the deep muscle where slower chilling conditions are experienced.

Electrical stimulation tends to even up the colour, making it more uniform, and lighter. However, it is important not to overstimulate and measuring muscle pH and temperature as the beef side enters the chiller will indicate the effect of the combined electrical inputs. As a guide, if the pH is at or below 6.0 while the temperature is at or above 35° C, then the electrical inputs have been excessive, and there may be undesirable paleness of the slow cooling muscles and heat shortening. Subsequent pH and temperature measurements will indicate whether cold shortening is a possibility. If at any time the pH is at or above 6.0 when the temperature is at or below 12°C, it is likely that the combined electrical inputs are insufficient, and there may be cold shortening. These pH and temperature values are currently those incorporated in the Meat Standards Australia 'window of eating quality', which is currently under review.

Fast chilling of hot, heavy beef sides after slaughter gives more evenly coloured meat, and firmer muscles. It also minimises the subsequent unsightly weep (drip) in display or vacuum packs that might lead to customer complaints. However, where rapid chilling conditions are applied and no electrical stimulation is utilised, the rate of pH decline can be quite slow. As a result, at 24 hours after slaughter, the ultimate pH has not been attained; therefore, it is incorrectly assessed as dark cutting. Effective electrical stimulation will overcome this effect by accelerating the rate of pH decline.

Normal colour of vacuum-packaged and 100% CO_2 flushed chilled meat

The removal of oxygen during vacuum packing leads to changes in the colour of meat. Inside a vacuum package, residual oxygen is consumed and carbon dioxide (CO_2) is produced as a result of metabolism by the muscle tissue. The resultant atmosphere contains less than 0.5 per cent oxygen, some 20-40 per cent CO_2 with nitrogen making up the remainder.

The bright red (oxymyoglobin) colour of fresh meat disappears in the vacuum pack and in the CO_2 flushed pack as the pigment reverts to its purplish-red form. This is the normal and desirable colour of vacuum-packed meat. Within a short time of the pack being opened the surface purple myoglobin changes to bright red oxymyoglobin and the meat blooms to a bright red colour. The relationship between pigments is shown in

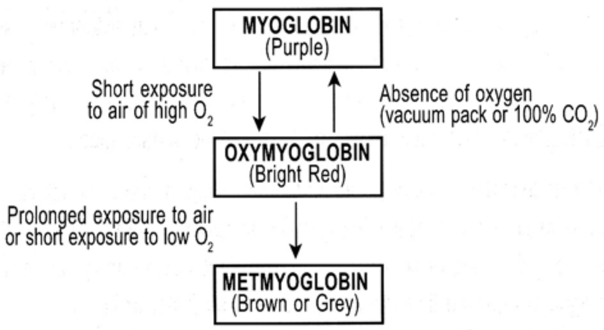

Figure 2.

FIGURE 2 Some colour relationships found in fresh and vacuum-packaged meats

Browning

Browning of meat stored in a vacuum package indicates that there is too much oxygen in the pack. This occurs fastest at moderate (1%) level. If there are poor seals, punctures, or poor air evacuation at the time of packing and sealing, the meat will turn brown during storage.

The oxygen permeability of the films used for vacuum packing is also very important and is a matter to which the packer should pay close attention. To prevent oxygen from gaining access to the meat surface, care is needed to ensure that the appropriate degree of impermeability is chosen. If the permeability is a little too high, or if there are pinholes or poor seals, a small amount of oxygen will gain access to the meat surface and its concentration could very easily reach the critical (low) level at which metmyoglobin formation is most rapid.

It is difficult to evacuate all the air from a vacuum pack but residual oxygen should be used up by respiration of the meat and microbial activity. The speed at which this residual oxygen is used up is dependent on the age of the meat when packed. If the meat is not fresh (i.e. is older than 48 hours post-slaughter) at the time of packing, insufficient meat respiration to consume the residual oxygen can cause a problem.

In addition, if there is residual oxygen in the pack due to any of these factors, the browning problem will be exacerbated by high temperatures.

Colour problems with beef stored in high concentrations of carbon dioxide will not occur *provided oxygen is excluded from the pack.* If only 0.5-1 per cent of oxygen is present, the rate of formation of metmyoglobin is higher than in air, and browning occurs more rapidly. In addition to discolouration of the lean surface, problems with the appearance of fat surfaces may occur (brown-grey discolouration). With lamb, a brownish discolouration of the fell surfaces may develop after several weeks storage at 0°C if there is too much oxygen present and, if this occurs, the appearance is inferior to that of fresh primals.

From a colour point of view the aim of vacuum or gas packing is to prevent the production of undesirable brown metmyoglobin by *reducing the concentration* *of oxygen in the pack to below 0.2%.* To achieve this, the meat should be packed and sealed as quickly as possible after boning or cutting the carcase, provided that the carcase deep muscle temperature is adequately reduced.

This type of browning should not be confused with cooked meat browning (grey-brown), which can be caused by excessive heat during shrinkage of the packaging film.

Retail storage of chilled meat in air or in air-permeable film

Because the bright red colour is enhanced by high concentrations of oxygen, most displayed meat is either open to air or sealed in an oxygen-permeable wrap. The wrap allows passage of oxygen but prevents undesirable drying of the meat surface.

Meat displayed in this fashion usually becomes discoloured owing to the development of brown colour (metmyoglobin) before bacteria have grown sufficiently to cause spoilage. Incorrect storage or handling at any stage of the chain will reduce retail storage life.

The principal factor affecting the shelf life of wrapped meat on display is its temperature. This is mainly because the oxidation of myoglobin to metmyoglobin is extremely temperature dependent. However, it is also partly because higher temperatures increase bacterial growth on the meat, and the result is that bacterial metabolites contribute to the increased oxidation rate.

In order to obtain the longest possible shelf life for meat on display, the storage temperature should be as close to 0°C as possible. This will keep microbial growth to a minimum and prolong the retention of the attractive red meat colour. As it is impossible to maintain a steady 0°C in open meat display cabinets, a realistic optimum temperature range is 0-5°C.

Meat should be cooled to below 5°C before cutting and it should be cut immediately prior to display.

Storage after ageing

After three weeks ageing, aged meat exposed to air discolours in the retail situation faster than fresh meat because of a diminished ability of any brown colour that has formed to revert to the desired red colour. The longer meat is aged, the faster it will discolour after opening to air because the enzyme system becomes less effective with ageing.

Table 1 indicates the relative retail display life of consumer cuts of beef (stored at about 5°C) in conventionally overwrapped and oxygen-enriched modified-atmosphere packs (as a function of the meat storage time in the vacuum pack at 0°C). The longer the period of storage in the vacuum pack the shorter the display life of the consumer portions, because of the more rapid conversion of oxymyoglobin to the brown metmyoglobin.

TABLE 1 The relative retail display life of consumer cuts of beef as a functionof the time the meat was stored vacuum packaged

Storage time in the vacuum pack (weeks at 0°C)	0	2	4	6	8
Retail display life (days) *Overwraped trays	3	3	2	2	1

Beef and lamb stored in high levels of CO_2 appear to retain their retail display life better than vacuum-packed lamb. Retail shelf life of product prepared from lamb primals or carcases stored in a CO_2 atmosphere should be three days after 12 weeks chilled storage.

Summary

The delay of adverse colour changes involves efficient refrigeration during chilling, holding, transportation, storage, preparation and display; and proper hygiene, packaging and selection of meat. Attention to the above is necessary, but in particular, if fresh meat is to be maintained in good condition with minimum colour deterioration for an adequate commercial display period, the temperature of the meat must be kept close to 0°C.

Further Reading

Meat Technology Update Newsletter 99/6 ‘ Pre-slaughter aspects of beef eating quality’

Meat Technology Update Newsletter 99/4 ‘Post-slaughter aspects of beef eating quality’

Meat Technology Update No. 97/3 (AMT) ‘Lighting in Meat Processing Areas’

CSIRO *Meat Research Newsletter* 93/5 ‘Displaying Meat for Maximum Return’

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High rigor temperature and toughening in beef

September 2002

Results for today; Ideas for tomorrow

Much has been written about cold shortening and about electrical stimulation as a way to prevent it. For instance, CSIRO first issued information to industry on electrical stimulation in 1978. Much more recently it has been recognised that inappropriate application of electrical stimulation can actually contribute to toughening and changes in colour and texture similar to that observed in PSE pork.

Cold shortening

It is well known that if an unrestrained muscle is exposed to low temperatures before it is in rigor then it will shorten and the resulting meat may be tough or very tough. This is called cold shortening induced toughness. In practice, its effect is minimised in the abattoir, either by the application of electrical stimulation, by use of the Tenderstretch process, or in a few abattoirs, by use of the rinsing and chilling technique, which involves the intra-arterial infusion of a solution of electrolytes at slaughter.

Shortening only occurs before muscles have gone into rigor, which means, in practice, before it has reached its ultimate pH.

Cold shortening is likely to occur if the muscle temperature falls below 12°C while the muscle pH is still above 6.0. Electrical stimulation reduces the pH rapidly, hastens the onset of rigor and hence minimises the incidence of cold shortening. Electrical stimulation is often only one of the electrical inputs applied on the slaughter floor. Other inputs may occur on application of:

- Electrical immobilisation; or
- Hide puller electrical rigidity probes.

The combined effect of these electrical inputs may lead to a very rapid drop in pH such that a value of 6.0 is reached by the time the beef sides enter the chiller. Therefore, there is no chance of cold shortening. However the possibility of toughening can still occur through high rigor temperature.

High rigor temperature

The combination of rapid glycolysis (i.e. rapid pH fall) and slow cooling leads to high rigor temperatures. This in turn can cause toughening. Previously, this has been referred to as heat shortening. However it is now believed that the degree of shortening that occurs in beef muscles at high rigor temperatures is relatively small. Rather, the toughening effect is due to a loss in proteolytic potential (due to inactivation of the proteolytic enzymes), which subsequently leads to reduced tenderisation during ageing. In practice, this toughening may occur if the muscle pH falls below 6.0 when the temperature is above 35°C (see stippled area in Figure 1 below).

Meat Standards Australia requires that the loin muscle of beef carcases fall within the ph/temperature Abattoir Window (Fig. 1).

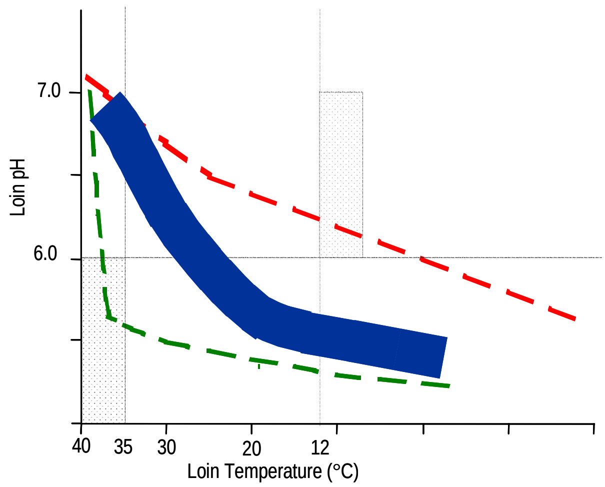

Figure 1. The pH/temperature window showing heat toughening (■), cold shortening (■), and acceptable decline of pH/temperature (■)

Muscles of carcases where the rates of pH and temperature decline are within the window are unlikely to either heat shorten or cold shorten.

A recent study conducted by staff of Murdoch University, W.A. is reported here. A group of heifer carcases destined for the domestic market was divided into 2 groups, one of which received 40 seconds of low electrical voltage stimulation, while the other group was not stimulated. All carcases were placed in the same chiller and because the stimulation caused

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a rapid drop in their pH, the treatment group had markedly different temperatures when the muscles were at pH 6.0 (Table 1).

Table 1. Temperature at pH 6.0 of stimulated and unstimulated muscle.

Muscle	Temperature at pH 6.0 (°C)	
	No stimulation	Stimulation (40 sec)
Rump (gluteus medius)	33	39
Striploin (longissimus)	19	31

After 15 days of ageing in vacuum packs the rump and loin muscles were grilled and submitted to an MSA consumer panel. The MQ4 scores, which represent the overall acceptability of the meat (higher scores represent superior acceptability), are shown in Table 2.

Table 2. MSA MQ4 scores of stimulated and unstimulated muscle.

Muscle	MSA MQ4 scores	
	No stimulation	Stimulation (40 sec)
Rump (gluteus medius)	70	58
Striploin (longissimus)	69	66

The results showed that the rapid pH fall at high temperature due to electrical stimulation decreased the overall acceptability of the product, particularly with the rump. Also, the rump of the stimulated carcasses was in the region of heat toughening in the pH/temperature window (Fig. 1).

Therefore, heat toughening can have an undesirable effect on meat quality.

It is interesting to note that meat scientists have often found that meat from heat-toughened muscles is not particularly tough when measured by the Warner-Bratzler instrument. This is a mechanical device, which measures the shear force of meat, and it usually correlates reasonably well with taste panel or consumer panel scores. Thus, it would appear that consumers downgrade meat from heat-toughened muscles for reasons other than lack of tenderness. It is possible that there is a difference in the fibrous and cohesive qualities of these muscles and people, but not the instrument, can detect the difference.

While electrical stimulation is important in preventing tough meat due to cold shortening, care must be taken that the total electrical inputs (immobilisation + hide puller rigidity probes + electrical stimulation) do not cause a drop in muscle pH so great as to produce heat toughening.

Pale, soft, exudative (PSE)

The description ‘pale, soft, exudative’ (PSE) has been applied to a condition that occurs in pork and, less frequently, in beef. It is associated with a fast rate of post-mortem pH decline. With pork, the combination of high muscle temperatures and low pH values leads to the development of pale soft exudative meat, two characteristics of which are a propensity to exude excessive amounts of drip and a poor water holding capacity – i.e. a poor ability to retain moisture during further processing and cooking.

A similar condition, although usually milder in degree, can occur with beef. It is particularly likely to occur in the larger, slower cooling muscles in the butt.

Electrical stimulation has been associated with PSE in beef carcasses. A Canadian study found that low voltage electrical stimulation, applied to beef for 40 s, exhibited the PSE condition in 10% of carcasses (Aalhus *et al*, 1994).

Acknowledgement and references

Associate Professor David Pethick at Murdoch University, W.A, provided the data.

Aalhus, J. L., Jones, S. D. M., Lutz, S., Best, D. R., Robertson, W. M. (1994) The efficacy of high and low voltage electrical stimulation under difference chilling regimes. Canadian Journal of Animal Science. 74: 433-442.

Further Information

For further information on heat- or cold shortening of meat, please contact Frank Shaw or Dr Heather Bruce from the Muscle Food Quality group of Food Science Australia.

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Meat technology update

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Production factors affecting beef eating quality

Previous *Meat Technology Update* Newsletters (99/4 and 99/6—see Further Reading) have dealt with the influence of pre- and post-slaughter factors on beef eating quality. This final newsletter in a series of four focuses on the on-farm, or production-based, factors that have been shown to affect beef palatability.

There are a lot of misconceptions about what governs beef palatability. Most relate to the relevance of the on-farm factors (e.g. breed, nutrition, growth path, fatness etc.) that, historically, have generally been overstated. That is not to say that factors like breed and growth path do not have a bearing on palatability traits like tenderness. Rather, some of the previous estimates of the magnitude of these effects were often confounded, owing to a lack of control of the post-slaughter environment. Only recently have these effects been more accurately defined through the research of the Cattle and Beef Industry Co-operative Research Centre (CRC) and Meat Standards Australia (MSA).

With the aim to predict eating quality, a logical approach is to identify which factors are relevant to each muscle. The eating quality of each muscle will be determined by a number of factors, including:

- the amount of connective tissue;
- fat content;
- muscle-fibre shortening/stretching during rigor mortis;
- post-rigor ageing/tenderisation.

Given these variables, it follows that there will be fundamental differences in the palatability of different muscles within the carcase and that these relationships will vary, depending on the production, pre-slaughter and post-slaughter conditions. Moreover, it is important to recognise that the influence of any single production factor may not be constant across all muscles.

The production factors covered in this newsletter include:

- within-breed and between-breed variation;
- sex;
- fatness;
- age;
- nutrition and growth path.

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Breed

Within-breed variation

Initial estimates from the CRC indicate that under the slaughter protocol used by the CRC there is limited genetic variation in tenderness (shear force) for *Bos taurus* breeds, although there appears to be much more genetic variation in the tropically adapted breeds (e.g. Belmont Reds, Santa Gertrudus, and Brahman). These results therefore suggest that there is little opportunity for genetic improvement in tenderness within *Bos taurus* breeds. Greater scope for change exists in the case of the tropically adapted breeds.

Between-breed variation

The debate regarding the significance of breed in relation to beef eating quality has attracted considerable controversy. Most has centred on the issue of *Bos indicus* content, with the debate intensifying following the initial decision by MSA to exclude cattle with greater than 25 per cent Brahman content. Whilst the new MSA cuts-based system is far less restrictive in that the full range of *Bos indicus* content is eligible for grading, there is still a negative association between *Bos indicus* content and eating quality within the prediction model.

A number of researchers (both overseas and Australian) have reported that as *Bos indicus* percentage increases, tenderness or palatability of the meat decreases. The magnitude of the breed effect tends to vary considerably between studies and is probably linked to differences in the management or the processing conditions during slaughter. Certainly individual studies by the CRC show that under carefully controlled conditions, *Bos indicus* content up to 75% may have only a small impact on palatability.

Another joint CRC/MSA study has also shown that the *Bos indicus* effect is not constant across all muscles in the carcase. Notably, the effect was more pronounced in the high quality loin cuts (striploin, cube roll and tenderloin), suggesting that the effect is more myofibrillar in origin. These muscles, being predominantly postural, are typically low in connective tissue.

Various suggestions have been made as to why *Bos indicus* cattle have less tender meat. These include the effect of the production environment given that *Bos indicus* cattle are typically raised in harsher environments. This, in turn, results in variable growth rates (possible direct effect on muscle structure and composition), increased age at slaughter (increased collagen-related toughness) and leaner and lighter carcases (increased risk of cold shortening if not controlled). Other theories have arisen from observed breed differences in the intrinsic properties of the muscle. Prominent amongst these is the difference in activities of enzymes responsible for the tenderising effect when meat is aged. More precisely, the inhibitor to these enzymes, calpastatin, is higher in activity in the muscles of *Bos indicus* cattle, thus retarding the ageing process. However, even though differences in the protein-breakdown (proteolytic) activity have been found, they haven’t always coincided with different rates of tenderisation as measured by consumer panels or by shear-force measurements, particularly when the post-slaughter environment has been controlled.

Sex

Small differences in palatability have been observed between the sexes. Beef from bulls can be more variable and this is often associated with the higher variability in ultimate pH. Consequently, male cattle showing secondary sex characteristics—physical characteristics of a bull—have been excluded under the MSA system. Past comparisons between steers and heifers suggest that the beef quality was similar. However, preliminary analyses of the MSA data indicate a small, yet consistent, sex effect, with heifers having lower eating quality scores than steers. Reasons for this effect are not clear at this stage.

Fatness

The fatness of the carcase can exert indirect and direct effects on beef eating quality. The indirect effect is associated with the inverse relationship between the fatness of the carcase and the rate at which the carcase cools (i.e. fatter carcases will cool at slower rates compared to leaner carcases). Any variances in cooling rate relative to the pH decline (refer *Meat Technology Update* Newsletter 99/1) will lead to differences in the degree of muscle shortening and consequently, tenderness/toughness.

The direct effect of marbling on eating quality has attracted considerable debate in the past. Much of this centred on the contention that greater marbling always resulted in more tender meat. Whilst this could be demonstrated, this was largely due to the indirect effect of carcase fatness on tenderness rather than marbling *per se*. In other words, marbled beef was typically derived from heavy, fat carcases in which the likelihood of cold shortening was minimal, in view of the slower cooling rates observed for these carcases. In stimulated carcases (where cold shortening did not occur) marbling had only a small effect on tenderness. Recent results from consumer panels indicate that the direct link between marbling and palatability is through enhanced juiciness and flavour.

Animal age

The chronological age of the animal is important in the context of meat tenderness. Typically, with increasing animal age, the connective tissue contribution to tenderness/ toughness increases as a result of the increased crosslinking within the connective tissue. Dentition scores relating to the eruption of permanent incisor teeth is used to estimate, albeit crudely, animal age.

Ossification

Physiological age can be estimated by the degree of ossification (calcification) that occurs in the chine bones and during fusion of the vertebrae. As the animal ages, the soft cartilage tips of the spinous processes of the vertebrae (chine bones) calcify or harden. However, like dentition, the relationship between the degree of ossification and age can vary considerably. This, to a large degree, is related to the growth history of the animal and ossification is believed to provide a more informative perspective on the physiological maturity of the animal. Animals that endure restricted growth show advanced ossification at the same age compared with animals that have been raised on a good plane of nutrition. Therefore, by knowing the ossification score and the weight of the animal, it is possible to draw some conclusions about the production history of the animal.

Why is this important? The data indicates that at the same carcase weight, there is an inverse relationship between ossification score and eating quality. The nature of this relationship will vary, depending on how the carcase was processed, but it shows that, as the ossification score increases, there is a slight loss in eating quality. There are a number of plausible reasons for this effect; however they have not been validated at this stage.

The MSA scale of ossification goes from 100 to 200 in 10-point increments. With the present system, a maturity score of 200 is the cut-off as a means to exclude older animals. In cattle that have followed a normal growth path, an MSA ossification score of 200 would generally refer to an animal of about 30 months of age.

The vertebrae of the backbone—specifically the cartilage between and on the dorsal edges of the sacral, thoracic (called buttons), and lumbar vertebrae —are assessed (the cervical vertebrae are not considered). All of these cartilage areas are considered in arriving at a level of maturity. The sacral and lumbar cartilages are least ossified in the youngest carcases, as are the buttons, which are also prominent and soft. Ribs can also be used to assess physiological age. They tend to be round and narrow in young animals and flat and wide in older ones. Young animals have red-coloured ribs because they are involved in marrow, red-blood-cell manufacture. As the animals get older, this activity decreases and their ribs become correspondingly whiter.

As an example, a maturity score of 100 indicates a carcase with no ossification of the cartilage and clearly defined spinous processes in all regions, including the sacral chine bones. Figure 1 shows the degree of ossification in a carcase with an ossification score of 100. Note that there was no ossification in the cartilage that was present both between the vertebrae and above the spinous processes. A more detailed view of the sacral region of an MSA ossification score of 100 is shown in Figure 2.

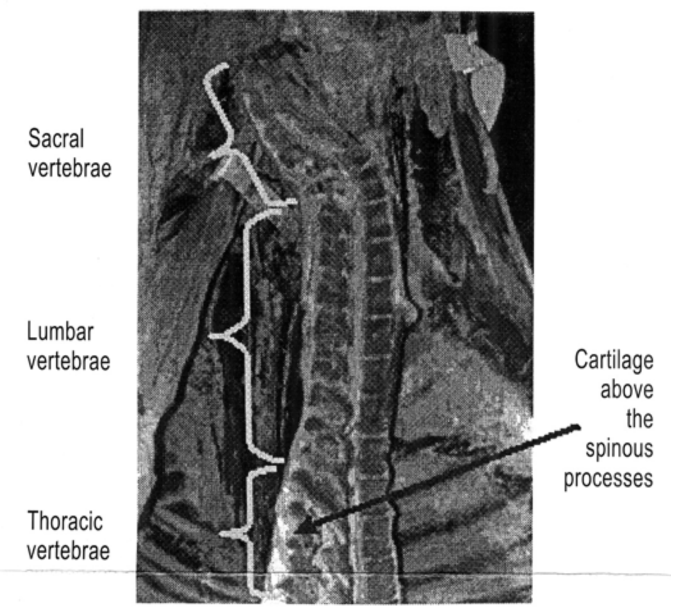

FIGURE 1 MSA ossification score of 100 (vertebral column)

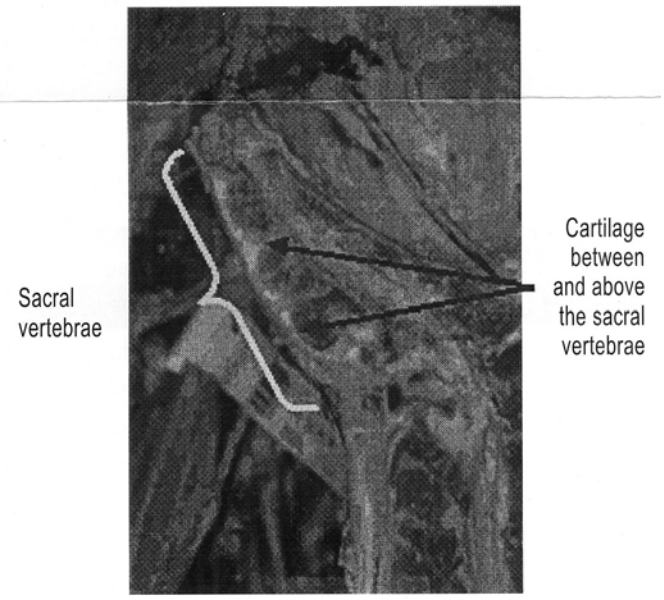

FIGURE 2 MSA ossification score of 100 (sacral vertebrae)

In the absence of other influences, the younger the physiological age of the animal, the more tender the meat will be. As an animal gets older, the connective tissues become more resistant to breakdown during cooking. This manifests as toughness. With increased physiological age, the transition from tender meat to tough meat is gradual and occurs at different rates in different muscles.

Nutrition and growth path

It is often very difficult to estimate the 'true' effects of the type of nutrition an animal receives and its rate of growth, as these are generally confounded. In other words, animals on higher quality feed will generally grow at faster rates and vice versa. Moreover, these factors will also impact on the degree of carcase fatness and animal age at slaughter, which, as stated earlier, will have both indirect and direct effects on palatability.

Results from the CRC and MSA indicate that the rate and pattern of growth impacts on meat tenderness/toughness. However, it must be emphasised that the relationship between growth rate and eating quality could not be classed as strong. Rather, there is considerable variation surrounding this relationship and much of this can be linked to the fact that growth rate does not necessarily describe the growth pattern of animals. Cattle rarely grow at constant rates: there are often periods of no growth, slow growth and rapid growth, depending on the nutritional quantity and quality of feed. The timing and duration of these changes are believed to have a significant impact on the ultra-structural components within muscle, which, in turn, manifests as changes in the meat tenderness/toughness. Changes in the relative rates of both muscle protein synthesis and degradation, and connective tissue structure have been implicated as reasons for this effect. These mechanisms and the overall effect of growth pattern on meat tenderness/toughness will be further characterised following the completion of forthcoming investigations within the Cattle and Beef Quality CRC. However, generally speaking, a high plane of nutrition is desirable.

Conclusion

There have been a lot of misconceptions about what governs beef eating quality. Clearly, the pre- and post-slaughter conditions are still paramount. However, when these have been controlled, we can now quantify the real magnitude of the production or on-farm factors on eating quality. Genetic improvement in tenderness is feasible but predominantly for the tropically adapted breeds. Changes in the rate and pattern of growth will influence not only carcase composition with respect to fatness but also the physiological age at slaughter. However, the issue of growth path is far from being fully understood and is the subject of further research.

Acknowledgements

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- The Cooperative Research Centre for the Cattle and Beef Industry (Meat Quality)
- Meat Standards Australia.

Further Reading

Meat Technology Update Newsletter 99/1, 'A Critical Control Point approach to beef eating quality'

Meat Technology Update Newsletter 99/4, 'Post-slaughter aspects of beef eating quality'

Meat Technology Update Newsletter 99/6, 'Pre-slaughter aspects of beef eating quality'

Meat Technology Update Newsletter 99/7, 'Beef fat quality'

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MEAT TECHNOLOGY UPDATE

Cutting edge technology for the meat processing industry

Meat technology update

99/6 – October 1999
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Pre-slaughter aspects of beef eating quality

Losses of both product quality and quantity during the critical pre-slaughter period are inevitable. These losses are the result of social, physical, environmental and nutritional stresses imposed on the animal between the farm/feedlot and the abattoir knocking box. In the interests of animal welfare and beef quality, it is essential that effective management strategies be implemented to minimise adverse pre-slaughter effects.

Weight Loss

The combination of fasting plus the associated stress during the pre-slaughter phase results in losses in both live and carcase weight. Animals deprived of both feed and water will lose approximately 0.75% per day in initial liveweight. This will vary, depending on the prevailing conditions (e.g. duration of fast, transport conditions etc.) and the condition of the animal. Furthermore, weight loss is not linear with time with the majority of it occurring within the initial 24 hours post-farmgate. The associated losses will be lower when water is made available. In fact, a 48-hour fast with access to water may have only negligible effects on carcase weight loss.

Therefore, it is essential that adequate water be provided to cattle in lairage. However, it is worth noting that not all animals will drink during this period.

Dark Beef

The most serious consequence of severe pre-slaughter stress is the condition known as 'dark cutting'. Dark cutting or *dark firm and dry* (DFD) beef occurs when the pre-slaughter muscle glycogen levels fall below a critical threshold. In well fed, non-stressed cattle and sheep, normal resting glycogen concentrations range between 1% and 2% of muscle weight. In simple terms, glycogen is the reserve energy tank in muscle. It is utilised during stressful events or when the muscle's energy demands cannot be met during normal aerobic metabolism (i.e. presence of oxygen). After exsanguination (bleeding), glycogen is utilised as the primary fuel source and the by-product of its metabolism is lactic acid. Consequently, the muscle pH typically falls from around 7.1 (prior to death) to 5.5–5.6 at rigor. When the pre-slaughter glycogen levels fall below 1%, there is less energy to utilise; therefore less lactic acid is produced and the ultimate pH is higher.

Beef classed as dark cutting has the following characteristics:

- Higher ultimate pH (typically $\geq$5.9)

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- Darker 'bloom' colour, therefore less appealing to consumers
- Higher water-holding capacity
- Reduced shelf life since bacteria grow more readily owing to the higher pH and available moisture
- Reduced tenderness (pH 5.9–6.2). Tenderness can, however, improve above pH 6.2 although it is unlikely it will offset the other disadvantages.

It is also worth noting that dark-coloured meat may not always be related to inadequate pre-slaughter glycogen levels. For example, beef darkens in colour with increasing animal age. Meat from bulls typically has a higher myoglobin (muscle pigment) content than that from steers, heifers or cows at the same age. Another factor is the rate of pH fall and chilling conditions. Where rapid chilling conditions are applied and no electrical stimulation is utilised, the rate of pH decline can be quite slow. As a result, at 24 hours after slaughter, the ultimate pH has not been attained; therefore it is incorrectly assessed as dark cutting. Effective electrical stimulation will overcome this effect by accelerating the rate of pH decline.

Ultimate pH

Under Meat Standards Australia (MSA), there is a requirement that the ultimate pH of the *longissimus dorsi* at the quartering point is $\leq$5.7. This threshold was established based on consumer data and in the interests of minimising the risk of an unsatisfactory eating experience. The relationship between pH and tenderness tends to be curvilinear peaking around 5.9–6.2 (most tough). Whilst the threshold of 5.7 could be challenged for its stringency, it must be kept in mind that the principal goal of MSA is to provide the consumer with a guarantee of eating quality.

It should also be remembered that there are differences in ultimate pH between muscle, which tends to reflect inherent differences in the fibre type and function. A good example here is the *semimembranosus* (topside) which has a slightly lower ultimate pH compared to striploin.

It is also important to note that meat colour gradually darkens with increasing ultimate pH right through the range 5.4 to 7.0. This means that some consumers may regard beef with an ultimate pH of 5.8 as dark, although it would not be classified technically as dark cutting.

How to minimise the incidence of dark beef

Factors such as stress, method of marketing, time off feed, lairage management, extremes in weather conditions, disease and strenuous muscular activity will result in some utilisation of glycogen prior to slaughter. Healthy, well-fed cattle can afford to lose some glycogen (20–30%) without affecting their ultimate pH. However, the primary aim is to reduce these losses because it is not possible at present to practically determine the pre-slaughter glycogen levels in slaughter cattle. Therefore, the approach is based on implementing simple, yet effective management strategies to reduce glycogen losses during the pre-slaughter period. Some examples of these include:

- Utilise skilled and experienced stock handlers and transporters
- Educate cattle to handling and transport
- Select cattle with calm temperaments (i.e. less susceptible to stress)
- Do not mix unfamiliar groups of cattle in lairage
- Utilise direct consignment selling of cattle
- Provide lairage pens with suitable space and water
- Rest cattle on arrival (min. of 4–6 hours)
- Provide nutritional supplements in lairage when required, especially after excessive periods of time off feed.

- Provide supplementation on-farm prior to slaughter during periods when pasture quality is low

- Minimise the use of electric goads during movement of cattle

- Avoid selling if extreme changes in the weather are forecast.

Another factor to be cognisant of is the sex of the animal. Bulls and mature cows have been shown to be quite problematic. Of more relevance is the data, although not conclusive, that suggests that heifers may be more predisposed to dark cutting than steers. This is thought to be associated with the increased physical exertion due to mounting or 'bulling' which occurs when one or more heifers are in oestrus. Generally, within groups of heifers, 5% would be expected to be in oestrus on any given day. Transport stress increases the prevalence of oestrus and the percentage may be as high as 12%. As a practice, it is recommended that those heifers that are clearly showing signs of oestrus should be removed from slaughter mobs.

Time in lairage

It is generally recommended that cattle should be allowed to rest for a short period prior to slaughter. A minimum of 4–6 hours is recommended but once again this will depend on the background of the animals, notably the transport history, time off feed and condition of the stock. A longer period of rest (24–48 hours) is more desirable for cattle that have travelled extensive distances (>1000 km).

Another factor to consider here is that for cattle to be eligible for MSA grading, there is a requirement that they be slaughtered within 24 hours of leaving the property.

Slaughtering cattle directly off the truck is practised in North America. Cattle are typically well conditioned and do not travel large distances. The results to date indicate that this practice may lower weight losses and improve eating quality.

Electrolytes

Water-soluble and feed-based supplements containing a mixture of sugars and electrolytes have also been investigated as a means for reducing the stress experienced during the pre-slaughter phase. They can be provided on-farm prior to trucking or in lairage. In Australia, two commercial products**,** Glucotrans (Pfizer, Animal Health) and Nutricharge (STS Agriventures Ltd)**,** have been tested as part of a joint Western Australian and Victorian study. The results were encouraging but somewhat inconclusive. In contrast, Canadian investigators have shown that the strategic administration of electrolyte preparation not only reduced the incidence of dark cutting but also minimised the carcase shrink during chilling.

Nutritional supplementation in lairage

As ruminants, cattle and sheep rely on bacteria in the rumen to convert carbohydrates into glucose. Consequently, unlike monogastrics (e.g. humans and pigs), it takes considerably longer to replenish lost glycogen reserves in muscle. The glycogen replenishment rates in muscle in cattle that have been exposed to a stressful event followed by nutritional supplementation (typically grain-based ration) is approximately 0.2–0.3% per day. As a comparison, the rates of recovery in man are some 5–10 times faster. It is also important to note that the rate of recovery will depend on factors such as the energy status of the feed, the level of depletion (i.e. the lower the glycogen level, the faster the repletion rate) and the type of muscle.

From these results, some conclusions can be drawn about the effect of feeding in lairage when animals' pre-slaughter glycogen levels fall below that required to achieve a normal ultimate pH. In general, it would take at least 36 hours for lotfed cattle supplemented with grain and at least 72 hours for pasture-fed cattle supplemented with pasture hay to replenish their glycogen reserves sufficiently to avoid dark cutting.

The decision to feed in lairage is not simple. Firstly, there is the obvious difficulty of knowing when slaughter mobs have been unduly stressed on arrival at the abattoir. Secondly, most abattoir lairage facilities were not designed with feeding in mind. Notwithstanding these constraints, there may also be other benefits associated with feeding in lairage in addition to avoiding dark cutting and minimising weight loss (see below).

Can eating quality be enhanced via alternative pre-slaughter management strategies?

Recent research by The Cooperative Research Centre for the Cattle and Beef Industry (CRC) has demonstrated that there may be additional advantages in feeding cattle in lairage other than to avoid dark cutting. In one joint study (CRC, MSA and Stanbroke Pastoral Company), feedlot cattle were trucked to the abattoir 4 days prior to slaughter and allocated to one of three feeding treatments:

Group1	Fed a grain ration for 4 days
Group 2	Fed a grain ration for 3 days and fasted for 1 day
Group 3	Fed a grain ration for 2 days and fasted for 2 days

A fourth group, representing current practice, was trucked the day before slaughter and fasted overnight. The results revealed that consumers rated the steaks from cattle that were fed either 4 days or 3 days in lairage significantly better than the other two groups. Interestingly, the difference was associated more with flavour and juiciness rather than tenderness (see Figure 1).

The research is on-going and the results will be reported in a subsequent newsletter.

Prevention rather than cure

The stresses that apply between farmgate and knocking box result in inevitable losses in weight and beef quality. Effective pre-slaughter management of cattle aims at minimising or better still, preventing the losses. Further improvements in our ability to prevent these losses will arise from the increased research focus on the pre-slaughter domain.

Acknowledgements

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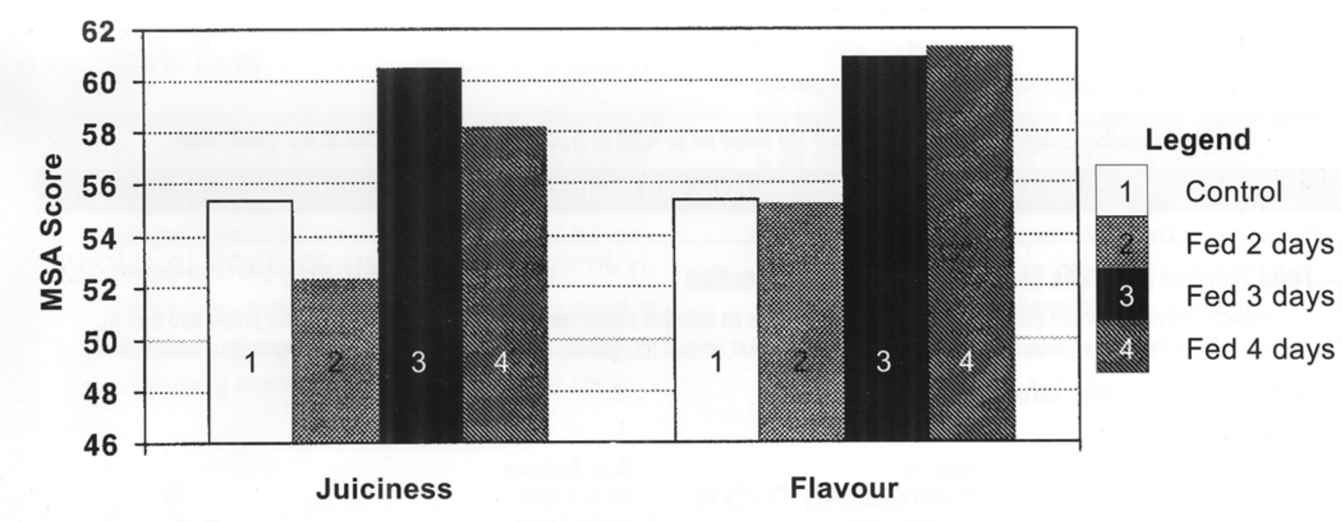
- The Cooperative Research Centre for the Cattle and Beef Industry (Meat Quality)
- Meat Standards Australia

FIGURE 1 Effect of lairage feeding on MSA juiciness and flavour scores



Further Reading

Pethick, D.W., Cummins, L., Gardner, G.E., Knee, B.W., McDowell, M., McIntyre, B.L., Tudor, G., Walker, P.J. and Warner, R.D. (1999), 'The regulation by nutrition of glycogen in the muscle of ruminants', *Recent Advances in Animal Nutrition in Australia*, 12:145.

'Dark-cutting in Cattle and Sheep', *Proceedings of an Australian Workshop* (Australian Meat and Live-Stock Research and Development Corporation), August 1988.

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Meat technology update

1/06 – February 2006

Electrical inputs during beef processing

During slaughter and dressing, beef carcases may be subjected to a range of electrical inputs. These are used to: limit the danger to slaughterers from kicking; assist rapid bleeding; prevent broken backs from hide pulling; and optimise meat quality. Each of these applications may require a specific current, waveform and frequency. Use of incorrect electrical parameters may result in damage to the carcase, poor meat quality and safety risks.

Devices that apply electrical inputs at various points on the slaughter floor are used extensively by Australian processors. Research, funded by Meat & Livestock Australia, has been undertaken over the last few years to develop electrical parameters best suited to each application. A suite of equipment utilising this new generation electronic technology has been developed. This Meat Technology Update provides guidelines on the correct application of electrical currents during beef processing.

The effect of different electrical parameters

For many years, electrical inputs during beef dressing were limited to electrical stimulation (either extra low voltage or high voltage) to limit toughening and downward hide puller back stiffening to prevent broken backs. Back stiffening used the standard 50 Hz mains frequency, and electrical stimulation (ES) used frequencies of about 14 Hz or 40 Hz. The frequency for ES was selected to provide the greatest utilisation of energy from the carcase and hence the most rapid onset of rigor and reduction in muscle pH to prevent cold shortening. While the consequence of inadequate electrical input was long recognised, the consequences of excessive ES were not.

For some heavy, and therefore, fat carcases, the application of any ES leads to too rapid a fall in pH. In some cases the pH was found to be at or below pH 6 by the time the carcase entered the side chiller. This increases the chances of meat quality problems due to toughness from heat shortening and meat colour issues.

The effect of ES on rate of pH fall is related to the pulse frequency (Figure 1). At a frequency of 10–20 Hz the effect on rate of pH reduction is maximal and gradually drops off as the frequency increases. At about 2,000 Hz, the effect on pH decline is minimal; therefore, a high frequency is more suited to applications such as immobilisation, when further stimulus to the rate of pH fall is not required as it would interfere with a later, controlled ES.

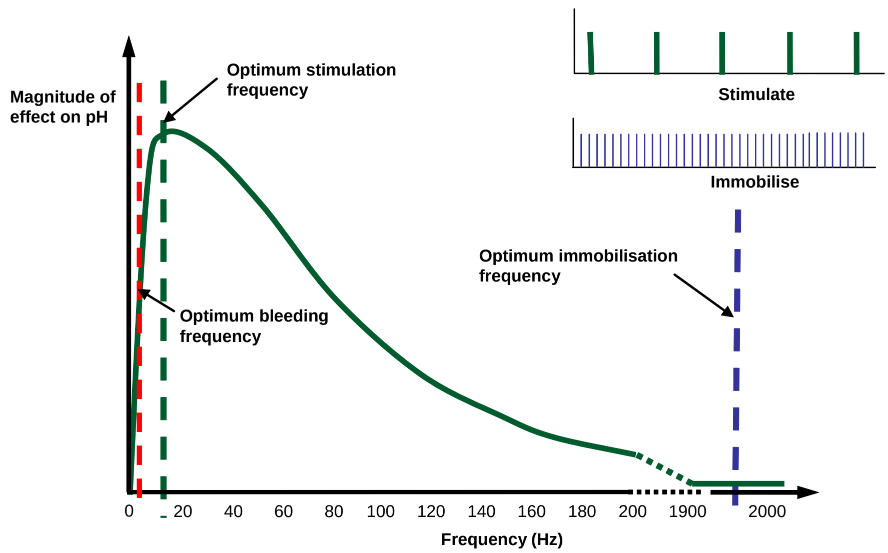

Figure 1: Effect of frequency on rate of pH fall

Principles

Electronic equipment has been developed to generate electrical outputs that are optimal for specific applications and to control electrical stimulation equipment. All the new generation systems consist of several basic modules (Figure 2) to provide a safe, controlled current to the carcase. The heart of the system is a processor and memory, which can store multiple parameters which are switch selectable. Each system can be programmed to suit the individual application.

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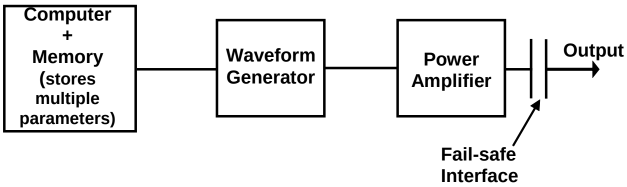

Figure 2: Basic modules of electrical systems for slaughter floors

All systems provide a constant current output. This is achieved by sending a small 'measurement' pulse prior to the main 'stimulation' pulse. Feedback from this pulse, allows the voltage of each main pulse to be adjusted to provide a constant current (Figure 3).

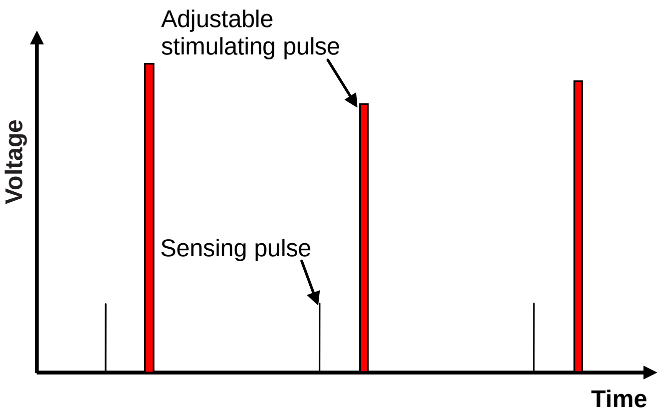

Figure 3: Basic pulse arrangement

Immobilisation

Immobilisation of the carcase in the landing area after stunning is done to limit the risk of injury to slaughterers. It can also streamline production as the stationary leg is easier to shackle for hoisting. Immobilisation currents can be applied on a landing cradle (Figure 4) or a bleeding table.

The recommended immobilisation system utilises a constant current system—at a frequency of 2,000 Hz, current 1–2 A and pulse width of 100 µs—applied for 7 to 15 seconds. This acts through the animal's nervous system and presents the carcase in a motionless state. There is little effect on muscle pH, allowing ES systems to be applied later in the process to produce the optimum rate of pH reduction.

Electronic bleeding

Ever since ES was first introduced, it has been noted that additional blood is released at that location. Experiments to determine the effect of different electrical parameters indicated that at least an extra 1 kg of blood per head could be obtained when the treatment was applied in the blood drain about 2 minutes after sticking (Table 1). Pulse frequencies of 5 Hz and 14 Hz for 35 seconds gave similar results, with a higher yield obtained with 500 mA compared with 300 mA.

A frequency of 5 Hz has less effect on muscle pH and is recommended for situations where heavy carcases are processed. Where ES is required to prevent cold shortening, the higher rate of 14 Hz is recommended. The current can be applied in the bleeding area using fixed rubbing bars. Meat Technology Update 4/03 provides additional details.

Figure 4: Beef landing cradle

Table 1: Effect of ES on blood yield

Group	Frequency (Hz)	Peak current (mA)	Blood weight perhead (kg)
I	14	300	1.5
II	14	500	1.8
III	Control		0.6
IV	5	300	1.5
V	5	500	1.9

Electrical stimulation

Muscles of the live animal have a supply of glycogen from which they derive their energy. After death, glycogen breakdown continues and lactic acid now accumulates, resulting in a reduction of the muscle pH from around 7.0 in the live animal to an ultimate value of about 5.5 in normal muscle after rigor mortis.

If the muscle cools rapidly before it has entered rigor (pH 6), the meat may be tough due to cold shortening. The solution has been to apply electrical stimulation to the carcase, either using extra low voltage systems at bleeding or high voltage (1,100 V peak) after hide removal, or on dressed sides.

The stimulation of the muscles accelerates the breakdown of glycogen which hastens the onset of rigor. Decline in pH can be used as a measure of how much the ageing process has been accelerated. Under the MSA temperature/pH 'window', optimum ageing and meat quality is achieved when the muscle reaches pH 6 between 35°C and 12°C.

Using the earlier ES systems, it was not possible to guarantee that each individual animal received the optimum amount of stimulation to achieve the required rate of pH decline. The latest systems have overcome this by:

- segmenting the system so that each carcase can be monitored individually;
- using feedback from monitoring to adjust the dosage for that carcase;
- utilising waveforms with narrow pulse widths, which allow use of higher currents that still remain safe;
- measuring the carcase resistance using small test pulses and using the feedback to control the dosage.

Carcases can be stimulated either through the nervous system or by direct stimulation of the muscle. The nervous system of a slaughtered animal decays slowly such that by about 40 minutes after death, the nervous system can no longer be utilised.

Pre-dressing stimulation

When ES is applied soon after slaughter, such as in the bleeding area, the nervous system can be stimulated using quite low voltages. Systems were originally extra low voltage (ELVS), but more common now are systems that apply a short pulse width waveform referred to as low voltage electrical stimulation (LVES). This can be combined with electronic bleeding at a frequency in the range 5 to 20 Hz at a current of up to 1 amp. The lower pulse rate will result in good blood recovery without rapid pH decline and is best for heavier carcases where ES may contribute to heat shortening and meat colour problems.

The current can be applied by rubbing bars contacting the butt and shoulder areas of the carcase. Most beef ES systems currently operate pre-dressing because:

- extra blood is released before dressing begins;
- space is generally available in this area; and
- it eliminates nervous responses.

Post-dressing stimulation

The extra low voltage systems were found to be ineffective when applied later in the dressing process and in the 1970s high voltage (to 1100 V peak) systems were developed. When new-generation ES is applied later in the dressing process, wider pulse widths are required than if it is applied pre-dressing because the nerves are no longer as responsive. The r.m.s. voltages are still in the relatively safe zone even with the wider pulses. This is referred to as mid voltage electrical stimulation (MVES).

This is applied to beef sides using rubbing bars similar to the earlier high voltage systems, but without the need for elaborate safety precautions.

Elimination of kicking

When a knife incision is made during the early stages of dressing carcases, a kicking response often results, especially at the first legging station. This can be dangerous for the operator, possibly resulting in bruising and knife wounds. This nervous response can be eliminated by applying an electrical input to the carcase prior to the legging stands. Where acceleration of pH decline is not wanted, high frequency (2,000 Hz) ES applied for 20–30 seconds at a constant current of 1000 to 2000 mA (c.f. immobilisation) will eliminate this response. Alternatively, normal pre-dressing ES can be utilised if an increase in the rate of pH fall is needed.

The current can be applied in the bleeding area using rubbing bars.

Back stiffening

The large forces involved with beef downward hide pullers place severe strain on the vertebrae of the carcase while pulling over the shoulders and head. This can be sufficient to part the vertebrae and sometimes damage the muscle. Breaks in the back have been largely overcome by applying an electric current to the back of the carcase to contract the muscles and support the spine.

In order to get sufficient energy into the back muscles for adequate contraction, large AC voltages (typically 180 V rms, 50 Hz) have been applied over the vulnerable loin area through spikes penetrating the muscles. Currents in the order of 3 A are typically applied to get adequate contraction.

Safety is a major problem with these systems, as potentially lethal voltages are applied to the carcase adjacent to where operators are working. Most installations use an isolated system but should a failure in the wiring occur in which one side of the wiring shorts to ground, the whole carcase will be live with respect to ground, resulting in operators being exposed to a potentially dangerous situation.

The new electronic back stiffener uses a waveform that is more energy efficient than the mains-derived AC voltage, allowing it to be applied with contact plates rather than penetrating spikes. This reduces potential contamination problems.

When subjected to the calculations presented in AS/NZS 60479.2:2002, 'Effects of current on human beings and livestock – Part 2: Special aspects', the electrical output of the electronic back stiffener is regarded as 'unlikely to cause ventricular fibrillation'.

The effectiveness of the current needed to contract the muscle is related to the duration, frequency and magnitude of the pulse. The magnitude of the pulse has a more significant effect than the duration. The very large amplitude, short duration pulses from the electronic system contract the back muscle of the carcase at a considerably lower and, therefore, safer energy level than traditional sine wave systems.

The stiffening effect increases with the pulse rate (or frequency), but has an upper limit. Maximum stiffening occurs at between approximately 40 and 100 Hz. Application of current at these frequencies can also have a significant effect on rate of pH decline, which may not always be desirable. As the frequency increases above 100 Hz, the stiffening effect declines. The electronic back stiffener operates at 40 Hz, which gives sufficient stiffening; the effect on muscle pH is minimised by adjusting the electrical energy to the minimum required and limiting the time of application.

The back stiffener operates at a constant energy by automatically adjusting the applied voltage to compensate for the variable contact resistance. This results in a controlled dose and more uniform level of muscle stimulation than would be achieved with a simple transformer operating at a constant voltage.

Safety

A major feature of this new generation electrical stimulation equipment is its safety. The waveforms are designed to conform to a new draft Australian/New Zealand standard on meat industry electrical safety that is under preparation. Another safety feature built into the electronics is its ability to detect the difference between a beef carcase and a human (beef carcases have a much lower contact resistance than humans; however, sheep carcases do not). If set properly the units will not turn on to full power if a person inadvertently or purposely touches both bars while no carcase is contacting the electrodes.

Summary

Special wave forms, pulse frequencies and currents have been developed and assessed for efficacy and safety for each application. These are summarised in Table 2. The use of certain electrical parameters in a situation for which they have not been tested or approved could potentially lead to both a reduction in meat quality and an electrically unsafe situation.

Table 2: Electrical parameters for each application

Application	Frequency (Hz)	Pulse width (μs)	Peak current (mA)
Immobilisation	2000	100	1000–2000
Bleeding	5	500	300–500
Elimination of kicking	2000	150	1000–2000
LVES	14	500	300–500
MVES	14	1000	400–800
Back stiffening	40	2000	2000–5000

Contact us for additional information

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

98/1 – February 1998
Reprinted November 2006

High-pH/Dark Beef

Colour and pH are important factors in determining consumer acceptability of beef. Since dark beef has a low acid content (i.e. high pH), the meat does not develop the normal bright red colour of oxymyoglobin. The meat appears dark because of the prevalence of the purplish-red colour of the pigment deeper in the meat (reduced myoglobin) over the bright red colour of an unusually thin surface layer of oxymyoglobin, and because less light is reflected from the surface.

Toughness increases as the ultimate pH (i.e. the pH value reached after post-mortem chemical reactions in the meat have ceased) increases from 5.4 to 6.0, then decreases with any further increase in ultimate pH. If meat has a pH of 6.0 or more at 30 hours after slaughter, it is classified as ‘dark-cutting’ or ‘high-pH’ beef. However, it is important to note that meat colour gradually darkens with increasing ultimate pH right through the pH range 5.4 to 7.0. This means that meat with an ultimate pH of 5.8 may be regarded as dark by some consumers, although it would not be classified technically as ‘dark-cutting’ meat.

What is pH?

The pH scale is used to measure the degree of acidity or alkalinity present. The neutral point on this scale is 7, which is the pH of pure water. With increasing alkalinity, the pH number *increases*. Strong alkalis have a pH in the range of 12 to 14; weak alkalis have a pH of around 9. Increasing acidity is indicated by *lower* pH numbers, with weak acids being about 5 and strong acids between 2 and 3.

Importance of pH

The ‘ultimate’ pH of meat, i.e. the final pH achieved by the muscles when the rigor processes have ceased, influences meat tenderness, colour, flavour and shelf-life. Under normal conditions, this pH will be in the range of 5.4 to 5.8. When meat has an ultimate pH above this range:

- meat toughness increases (the present MSA pathways require an ultimate pH of 5.7 or less);
- the ‘bloom’ colour of the meat is darker, and therefore less attractive;
- bacteria can grow more readily on these higher-pH surfaces, shortening the shelf-life of the meat (particularly important for vacuum-packed product);
- the flavour of the meat becomes less attractive; and
- whilst tenderness can improve above pH 6.2, this does *not* offset the above disadvantages.

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What causes dark beef?

At the time of processing, energy stored in the animal's muscles is converted into lactic acid, making those muscles slightly acidic, i.e. lowering the muscle pH. Well-fed and well-rested animals normally have sufficient muscle energy reserves at processing to yield enough lactic aid to reduce the pH of muscles below 5.8. Animals that have been too stressed before slaughter and had insufficient time to re-establish the resultant depleted muscle energy reserves will yield dark meat. Highly stressed animals will yield 'dark-cutting' meat.

Because electrical stimulation speeds up rigor mortis, ultimate pH is reached much sooner when this procedure is used. With unstimulated carcases the pH of the meat falls more slowly after slaughter. For example, the meat pH measured at 40 hours after slaughter may be 0.1 pH units lower than that measured at 20 hours. Colour measurements made before the ultimate pH has been reached will be darker than those made afterwards.

Meat also becomes darker with increasing animal age. Meat from bulls has a higher myoglobin (muscle pigment) content than meat from steers, heifers or cows of the same age, but is not necessarily tougher.

Very rapid chilling of the sides will produce darker meat than that from the same sides slowly chilled. However, this is not a pH effect.

How to minimise the incidence of high-pH dark beef

Anything that uses up muscle glycogen whilst the animal is still alive - for example, stress, cold weather, disease and strenuous muscle contractions - can cause animals to produce dark-cutting meat.

Psychological (emotional) stress appears to be as important as physical stress. Some animals are more susceptible to psychological stress than others (i.e. are more excitable). The intensity and duration of the stress, as well as the susceptibility of individual cattle to stress, will determine the prevalence of dark-cutting carcases.

Temperament is genetically linked. Selecting for cattle with calm temperament may result in benefits in meat quality by indirect selection against stress-susceptible animals.

Handling and transport

There is no doubt that mustering, loading, transporting and unloading of animals all lead to stress. Although there is no single, simple way of overcoming these problems, a better understanding may encourage people to consider ways of dealing with them.

The degree to which animals are stressed during handling and transport depends on their temperament, handling during the journey, condition of the animal, and duration of the journey.

If steps are taken to allow animals to settle down after mustering, and if care is taken during loading, transport and unloading, there is every chance the animals will arrive at the abattoir in an acceptable condition. If animals arrive at the meatworks in a stressed condition they rarely have an opportunity to quieten down prior to slaughter. Animals in good condition and therefore with available glycogen reserves on which to draw, have a much better chance of coping with the rigors of handling and transport, especially during long journeys.

Holding

Holding periods depend on mustering and transport schedules at the property, and on animal condition and slaughtering schedules at the meatworks. It is true that resting and feeding reduce the ultimate pH of the muscle by allowing the glycogen reserves to return to normal. However, a resting period of two to three days would be necessary to restore some exhausted or stressed animals to normal and to reduce the proportion of dark-cutting meat.

Handling prior to slaughter

Preslaughter excitement has an effect. This is because there is no time at all to allow muscle glycogen levels to replenish, and it is therefore of great importance that animals are not unduly excited at this stage. Some degree of stress cannot be avoided because stock has to be moved through yards, races and washes. However, this stress can be minimised. Careful design of facilities to exploit properly the behaviour patterns of cattle ensures a smooth flow of animals, minimises man-animal and animal-animal confrontations, and so reduces stress. Personnel in these areas should be patient, experienced and informed. They should be made aware of the results of improper handling of animals at this stage.

All cattle should be cleared from restraining races and knocking boxes before breaks are taken by personnel.

Disturbing influences such as excessive noise, dogs and electric prodders should be avoided.

Stock which have been subjected to exposure to unfamiliar surroundings or the stress caused when animals are mixed (such as may happen with stock bought from saleyards) are more likely than those sent directly to slaughter to give dark-cutting meat.

In fact, dark-cutting meat is often due to a combination of factors.

Consideration should be given to prompt processing of animals travelling only short distances to avoid the stress of re-establishment of ‘pecking orders’.

Climate

It has been shown that the prevalence of dark-cutting beef increases as ambient temperatures decrease. When animals shiver to maintain their body temperature, muscle glycogen is rapidly used up and soon becomes inadequate to allow normal acid production after slaughter. The effects of cold weather are greatly increased if it is unseasonal (a cold snap in autumn or spring) or accompanied by wet and/or windy conditions, or if there are temperature differentials, e.g cold nights and hot days.

Washing of animals before slaughter should be done strategically and carefully to minimise this cold stress. The longer the animals have been off feed, the greater the effects of cold stress.

Animals should be protected as much as possible from both high and low temperatures - extreme temperatures are distressing to them.

Feed

Adequate feed and water are necessary to minimise stress. Sudden withdrawal of feed after feeding on high-energy rations is stressful.

Social stress

Social stress is caused by the mixing together (and subsequent fighting for social dominance) of animals unfamiliar with each other. For example, in one study when cattle were regrouped several times during a two-day period before slaughter, each regrouping increased the incidence of dark-cutting beef. Fighting can continue to physical exhaustion.

Once the social order has been established, the animals stop fighting. However, recovery from the stressed state may take several days, because muscle glycogen depletion can be more rapid than replenishment. If just one new animal is introduced into a group, fighting to establish a new social order may begin again. Animals that are especially aggressive should be isolated if prolonged fighting occurs.

Avoid mixing mobs of animals just prior to slaughter. If this is unavoidable, mixing is best done in larger paddocks 2-7 days prior to slaughter.

Sex

Bulls tend to be the most aggressive and quite frequently yield dark-cutting meat. Cows - particularly old, pregnant ones in poor condition - give a higher prevalence of dark-cutting meat than that occurring in heifers and steers.

Other factors

Diseased animals, or animals recovering from disease, yield dark-cutting meat to a greater extent than do healthy animals.

Work at Colorado State University concluded that some growth promotant implant practices can contribute to dark-cutting problems.

Preventive Measures

As yet, there is no easy way known to prevent the occurrence of dark-cutting beef. Care should be taken to avoid or minimise all of the above factors.

If possible, records should be kept of source of stock, preslaughter transport, handling, holding and weather. These should be correlated with appraisal records of meat colour (e.g. AUS-MEAT colour scores) and/ or pH. From such records it is possible to detect the occurrence of a higher than average proportion of high-pH carcases, and to take appropriate action.

Solving some dark-cutting meat problems

- Select cattle on temperament as well as performance.
- Look for animal management practices that could be improved.
- Check seasonal conditions. In some areas of Australia, early Autumn is a well-established 'high-risk' period for dark-cutting meat.
- Ascertain whether you are simply breaking the meat before sufficient rigor has occurred - perhaps the meat pH still has some way to fall.

Further Reading

An excellent publication is 'Principles of Abattoir Design to Improve Animal Welfare', by Temple Grandin, Department of Animal Science, Colorado State University, USA.

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

4/11 – June 2011

Very fast chilling

- Cooling meat to below 0°C within 5 hours of slaughter is defined as very fast chilling (VFC).
- VFC can avoid cold shortening.
- VFC can improve yield and the rate of tenderisation.
- VFC is best applied to light-weight carcases or hot-boned meat.

Introduction

The chilling rate after slaughter is a critical part of producing meat that is of high quality and safe to eat. From a shelf-life and food-safety perspective, carcases should be chilled as quickly as possible; however, from an eating-quality perspective, fast chilling can cause cold-toughening. So, with meat processing, the optimal chilling rate represents a balance between the control of microbiological growth and meat tenderness.

With conventional chilling systems, meat becomes tough due to cold shortening when the chilling rate is too fast. Meat is made up of fibres that are bundled together and held intact by sheaths of connective tissue (Figure 1).

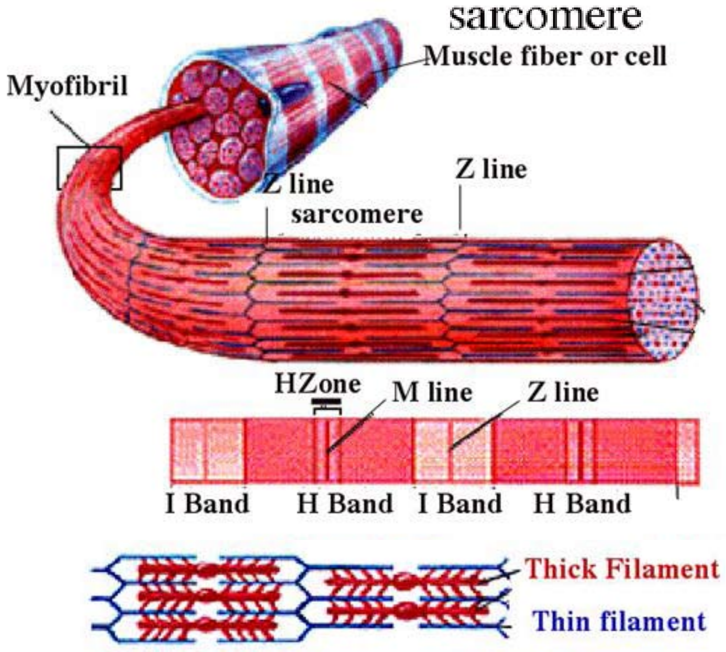

Figure 1 The actin (thin filament) and myosin (thick filament) structure of muscle

These fibres are made up of the proteins actin and myosin that are linked together in an ordered structure. These proteins are responsible for muscle contraction in the live animal whereby the actin and myosin filaments move in relation to each other as shown in Figure 2.

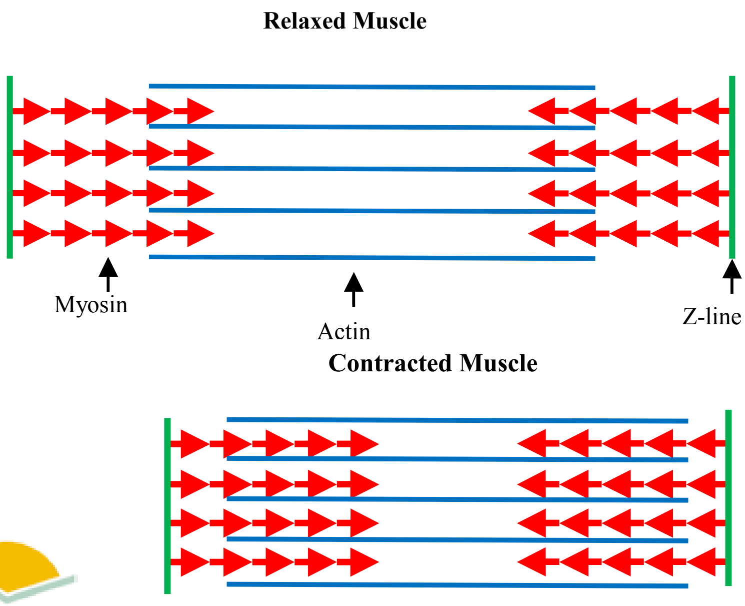

Figure 2: The relationship of actin and myosin in relaxed and contracted muscle

If the muscle temperature drops below 10°C, before rigor onset occurs, calcium floods out of the sarcoplasmic reticulum (an intracellular structure that regulates

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calcium levels in the cell, controlling the degree of contraction) and the muscle contracts. During rigor, the actin (thin filament) and myosin (thick filament) elements become linked by chemical bonds that, once formed, prevent the filaments moving against each other, making the muscle inextensible (rigor). Contracted muscle has more bonds between the actin and myosin filaments, making the meat tough to eat. Cold shortening, as this phenomenon is known, is the most important cause of toughness in meat derived from young animals, in which the effect of connective tissue is small. It occurs when the temperature of the meat drops below 10°C while the pH is above 6. The risk of cold shortening can be assessed by measuring pH and temperature during chilling (Figure 3) as is routinely done during grading for Meat Standards Australia. The paradox with very fast chilling is that cold shortening does not occur despite the temperature being well below 10°C before rigor onset.

How fast is very fast?

Chilling is called 'very fast' when muscle temperature is reduced from 40°C in the live animal to below 0°C within 5 hours of slaughter. By comparison the target for carcase meat cooled conventionally is 10°C about 10 hours after slaughter; although, in practice, this target varies according to other processing factors such as electrical stimulation. The rate of rigor onset can be accelerated by changing the rate of glycolysis and acid formation within the muscle by using electrical stimulation. This means that the pH drops more quickly in electrically stimulated carcases than in non-stimulated carcases, and this allows the cooling rate to be increased while still achieving optimal pH-temperature conditions.

With VFC the temperature is effectively reduced to the point of freezing, and this needs to be done before rigor commences. European researchers first investigated VFC in the 1990s for the

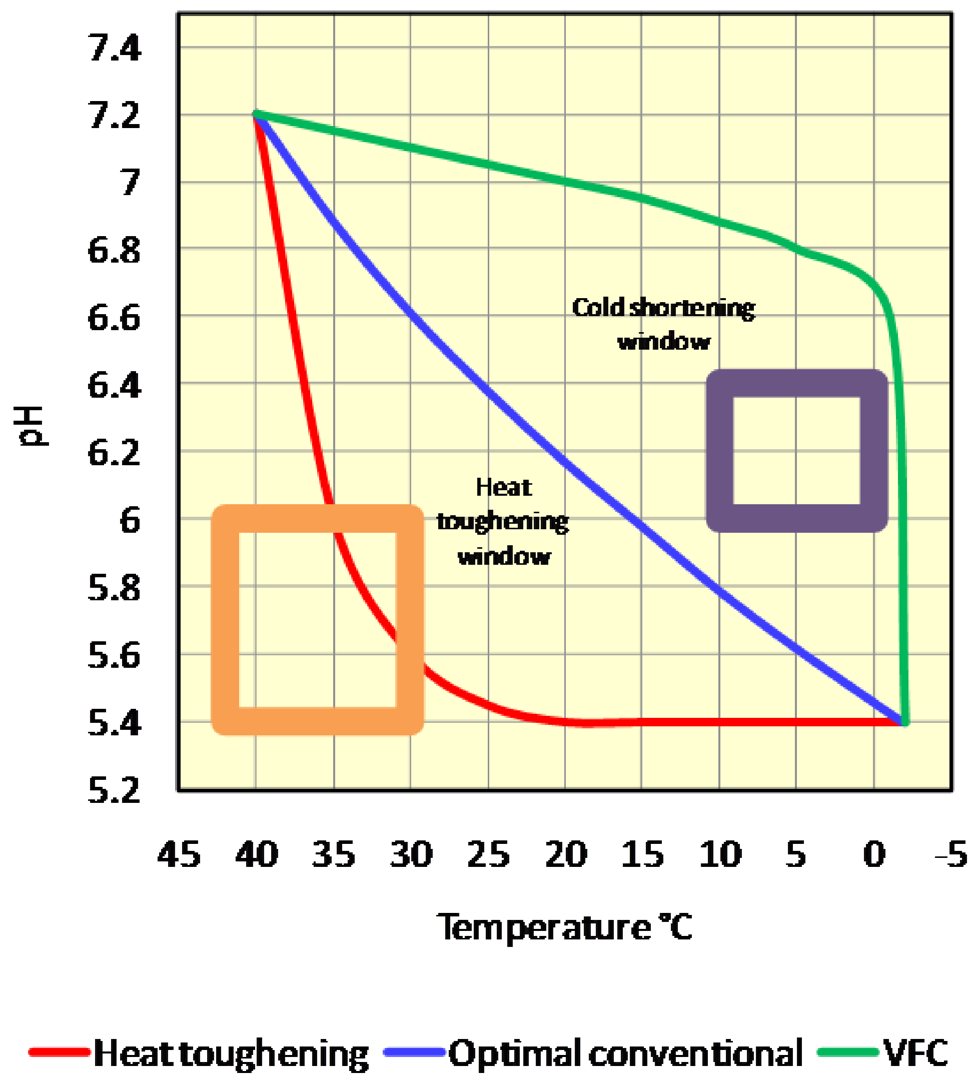

Figure 3 pH temperature profile of meat during chilling for heat toughening, conventional and VFC scenarios purpose of increasing carcase yield. They reported that VFC sometimes resulted in tender meat, but a high proportion of product was not tender and this lack of consistency prevented adoption by the European industry.

How does VFC work?

VFC is a concept still under development, but research done in the last 5 years has provided useful information about the potential to apply this idea to a commercial application. Work has been done with lamb (Figure 4) and beef in laboratory and commercial scenarios using a range of cooling systems. This work has established that VFC is different to conventional chilling in several ways.

1. Cold shortening is prevented even when the meat is hot boned.
2. Tenderisation occurs faster than with normally chilled meat, but the reasons for this are unknown.
3. The rate of pH decline post mortem is faster.
4. Ultimate pH may be higher.
5. Yield is improved.
6. Electrical stimulation is compatible with VFC.
7. There is an increased opportunity to batch chill and avoid mixing hot meat with cold meat.

The importance of meat temperature reaching sub-zero temperatures before rigor onset has been a key finding. If this benchmark is not reached, then severe cold shortening causes meat to be tough and unstable in colour when cut and displayed for retail sale.

How can very fast chill rates be achieved?

VFC can be achieved using a number of different methods including air, plate and immersion chilling systems. Each method has advantages and disadvantages that need to be taken into account for the type of production system applied. The temperature of the cooling medium depends on the chilling method used, but in all cases will be well below 0°C. For immersion and plate systems, specialised packaging may be required to allow rapid heat transfer.

Another key aspect is the thickness of the material being chilled. For VFC, meat should not exceed 80 mm in thickness, otherwise, chilling rate becomes limited by the rate of heat transfer within the meat. This consideration means that hot boning is an essential component of VFC when used to process beef and larger small-stock carcases.

Figure 4 Lamb carcases being loaded into a prototype air chiller for VFC experiments

Why chill very fast?

VFC is likely to be applicable to specialised applications rather than being a mainstream alternative to conventional chilling. VFC has already been used to process meat for sausage making. There are a number of situations where VFC may be considered.

- Hot boning applications
- Renovations to increase throughput, without increasing chilling space
- New plant designs where low capital cost is paramount
- Prevention of the detrimental effects of heat toughening

Acknowledgements

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Meat technology update

5/10 – November 2010

Sources of contamination on beef carcases during dressing

- **The biggest source of contamination during dressing is the hide. Good hygiene practices during hide opening can minimise this risk.**
- **Gut content is another source of contamination. Good practices involving rodding, bunging and prevention of rupture minimise this risk.**
- **Personnel and their equipment can also constitute a significant source of contamination.**
- **Strict attention to hand-washing practices and the wearing of gloves will minimise the risk from personnel.**

During carcase dressing, contamination can arise from the workers, the equipment and from the bodies being processed. The animals are the most significant source of contamination of the resulting carcases. In most cases, the deep tissues of healthy livestock at the time of slaughter are bacteriologically sterile and contamination is introduced onto the meat surfaces during the dressing process.

E. coli O157 or other pathogens in the faeces or on the hide of slaughter animals can be transferred onto the carcase during dressing. Interventions designed to control or reduce bacterial contamination of carcase surfaces, such as steam pasteurisation, or carcase rinsing with organic acids and other substances, are used in many processing plants around the world to assist in minimising the effect of cross-contamination. The interventions can each result in a decrease in microbial numbers on carcases, but the use of multiple decontamination procedures has an additive effect and increases the possible microbial reductions.

Contamination from the environment can also be significant during primary processing. Studies of pig and poultry processing plants have found that up to 25% of samples taken from surfaces in the slaughterhall contain *Salmonella*. The normal cleaning and disinfection procedures in the abattoirs examined did not eliminate the organism. The hands of the workers on the line also become contaminated through handling contaminated animals. In a study where *Salmonella* were deliberately inoculated onto hands, the organisms were detected on fingertips three hours after inoculation. Washing and drying of hands reduced the number of organisms present, but did not eliminate them.

Contamination arising from the gut

The intestines of animals contain large numbers of microorganisms, with *E. coli* levels usually greater than 10^5 cfu/g, and amongst these microorganisms may be found foodborne pathogens such as *E. coli* O157, *Salmonella* and *Campylobacter*. There is a risk that intestinal contents may contaminate carcases during evisceration if practices are poor, or if the gut is ruptured. Normal work practices by trained staff, including rodding and bunging, rarely result in such occurrences and the hygiene risk posed by the gut contents is substantially less than that posed by the microbiological load on the skin of the animal.

It has been recommended that animals are fasted prior to slaughter to reduce the gut volume and reduce the risk of spillage of intestinal content during dressing. Animals are fasted before slaughter, but fasting times are variable depending on marketing and transport conditions. Prolonged fasting, or interrupted fasting, may increase the number of pathogenic bacteria carried by animals and deposited into the lairage and slaughterhouse environment. In cattle, a period of feed withdrawal can cause a rise in rumen pH, which may favour the survival of *Salmonella* and promote a slow rise in faecal *E. coli* content over a 24–48 h period.

In general, carcase contamination by pathogens is related to carriage of the organisms in the live animal. For example, reducing the prevalence of *Salmonella* carriage in the intestines of live pigs can substantially reduce the incidence of the organism on pig carcases.

Contamination arising from the hide

Enormous numbers of organisms are also associated with the hide, hooves and hair of cattle. The surface contamination of hides has been found to range from 3.53 to 12.5 $\log_{10}$ cfu/cm^2. Contamination tends to be higher in winter than in summer and the brisket is the most heavily contaminated area. These

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microbial levels can be greater than that cited for intestinal contents or faeces (e.g. approximately 5 log_{10} cfu/g). This is possibly due to the high proportion of other organic and inorganic material in faeces contributing a dilution effect on the concentration of microorganisms. In addition to microbial counts being greater on hides than in faeces, recent work in Australia has shown that in a number of cases, cattle hides carried a higher prevalence of foodborne pathogens than the faeces. A New Zealand study found that where hides were visibly contaminated with faeces, the *E. coli* count could be around 3.10 ± 1.02 log_{10} cfu/cm^2; and a US study was in broad agreement, finding a range of 2.08 to 7.5 log_{10} cfu/cm^2 *E. coli* count. Australian researchers found *E. coli* O157 on cattle hides at levels of up to 2.24 log_{10} cfu/cm^2. *Salmonella* has also been found in hair samples at 6.6 log_{10} cfu per gram. In comparison, on sheep fleece, the mean microbial level has been found to be 5.38 log_{10} cfu/cm^2, with no real seasonality.

The hide of cattle and the fleece of sheep are a significant source of microbial contamination of the carcase. Good evidence has been found (through comparison of isolates from carcases originating from separate producer groups), that cross-contamination between hides occurs in the abattoir lairage. Immediately after hide removal, carcase counts are reported to be 6.1–7.9 log_{10} cfu/100cm^2 total viable count (TVC), 3–6 log_{10} cfu/100cm^2 total coliform count and 2.6–5.3 log cfu/100cm^2 *E. coli*. Carcase decontamination and chilling significantly reduces this level.

These reported counts, mostly from the northern hemisphere, are substantially higher than the carcase counts found in Australian processors. The latest Australian baseline found 1.33 log_{10} cfu/cm^2 on carcases after chilling, and *E. coli* were detected on only 4.9% of samples.

Visual cleanliness of hides shows no consistent effect on dressed carcase contamination, but is generally considered to result in cleaner carcases. One study found that increasingly greater dag (dried mud and faeces) adhering to the hair (see figure 1) increased the carcase coliform count. This study found that slowing the slaughter line or shaving dag off cattle hides could reduce carcase contamination.

In general, the wetter the hide of the animal, the greater is the carcase coliform count. A study in which the hair surface of hides was deliberately allowed to contact the carcase surface showed that carcase contamination is significantly lower following contact with clean hides than following contact with faecally soiled hide that had been washed prior to slaughter. In fact, contact with wet pre-slaughter washed hide resulted in a carcase microbial load similar to that resulting from contact with fresh faeces. Microbiologically, total counts on beef carcases have been found to be an almost constant fraction of those on hides (0.3% was suggested in the 1970s), but this fraction differs between abattoirs, and is worth exploring as a means of monitoring process hygiene. Faecal and hide prevalence of *E. coli* O157 are significantly correlated with carcase prevalence.

Cleaning livestock prior to dressing

As a result of the association between dirty hides and high carcase microbiological counts, some countries have introduced a 'clean livestock' policy, and use a subjective rating system for assessing the cleanliness of cattle presented for slaughter. Although mobs of cattle that are scored 'cleaner' will tend to give lower carcase microbial counts, there does not seem to be a consistent relationship between cleanliness score for an individual animal and its own carcase microbial load. However, the scores within each sale lot tend to be similar, and this makes the system a useful tool.

Figure 1: Excessive dag adhering to the coat will not only make hide opening difficult, but also lead to carcase contamination (Archive photograph from European research team)

Where animals are rejected on account of dirtiness, there are attempts to clean the hides prior to slaughter or prior to hide opening. Such measures have not been shown to provide a significant reduction in carcase microbial count. Clipping long-haired animals prior to slaughter has been advocated to improve the microbial status of the resultant carcase, and is commonly practised with respect to sheep in a number of countries. Its use with cattle is limited as it can cause stress. Pre-slaughter removal of dags is an immensely hazardous task for the operator. Also, if the hide is damaged it will lose value as a saleable by-product. Furthermore, it is possible that clipping cattle immediately prior to slaughter, or prior to hide opening, will increase contamination of the resulting carcase, as numerous small hair clippings can be observed along the cut-lines on carcases of recently-clipped cattle. Researchers have found that increased microbial counts can be obtained from recently clipped hides when compared to unclipped hides.

Some scientists have recommended that preslaughter washing of cattle—as part of a multiple intervention programme (including strict sanitary dressing procedures and pre-chill decontamination)—could result in reduced mean TVC and improved shelf life when compared to cattle dressed without any interventions, and lesser attention to practices. However, others have demonstrated that preslaughter washing gave no improvements in carcase microbiology. These researchers had applied faeces inoculated with a marker organism to the rumps of cattle, and then washed the faecal matter off after it had dried. Carcase samples from washed animals showed no statistically significant reduction in marker organism count when compared with samples from unwashed animals.

There has also been research into dehairing cattle after slaughter using sodium sulphide solution, but again, there was no effect on carcase microbial counts from dehaired bodies. In addition, the skins were difficult to handle because they were soapy and slippery. In a separate study, a combination of sodium sulphide and hydrogen peroxide was used to dehair cattle hides. This was found to significantly reduce TVC, coliform count, *Salmonella* and *E. coli* O157:H7 levels by 5 $\log_{10}$ on hide pieces; however, the results of this study have not been backed up by commercial trials, although chemical dehairing is in use in some commercial plants in the USA. It is important to note that these plants use electrical stun systems that kill the animal, so they can delay sticking until after the dehairing process is complete.

Contamination arising from handling

Food handlers should wear gloves while handling food, and must wash hands regularly. The effect of contamination via food handlers was demonstrated in the 1990s, when Australian researchers looked for *Staphylococcus* on cattle hides and carcases at three abattoirs. They found the organism on 20–70% of cattle hides, but only on 7–26% of carcases after hide removal; however, after evisceration, 16–50% of carcases carried the organism. Furthermore, the hands of the workers were heavily loaded with *Staphylococcus*, suggesting that manual handling was contributing to carcase contamination. When the researchers compared some of the isolates, the organisms from the carcases after evisceration were mostly genetically similar to the organisms on the workers' hands or those from the skinned carcases prior to evisceration. The organisms from the cattle hides were different. The researchers observed that the workers did not wear gloves and that their hands were severely abraded and continuously wet. This would have contributed to the likelihood of cross-contamination occurring via manual handling during processing.

More recently, wearing rubber gloves has become common practice, and the activities described in published literature as 'strict sanitary procedures' (two-knife system, regular hand washing, regular rinsing and sanitising of knives and other tools) are also normal procedures in Australian abattoirs. In 2008–9 studies were carried out in a Queensland beef abattoir to assess the relative roles of slaughterline activities in contributing to carcase contamination.

Case Study

Two studies were carried out, one year apart. In the first study, the operations of legging, brisket clearing (also known as 'siding in' or 'flanking') and bunging were evaluated. At each station, Whirlpak® sponge samples were taken from:

- carcase surface before operation begins (300 cm^2);
- operators hands before operation (palms and knuckles of both hands—approximately 340 cm^2);
- tool before operation (both sides of skinning knives—90 cm^2 ; or air knives—78.5 cm^2, measured on the equipment used);
- tool immediately after operation (both sides of skinning knives—90 cm^2 ; or air knives—78.5 cm^2, measured on the equipment used);
- exposed carcase surface (300 cm^2).

Table 1: Number of samples out of 30 testing positive for E . coli *or* Staphylococcus aureus *at each operation*

Dressing station	Sample site	*E. coli* *	*Staph. Aureus**
Legging	hide	9	28
	hands before operation	2	8
	knife before operation	0	3
	knife after operation	4	11
	cleared carcase surface	0	2
Brisket clearing	hide	9	23
	hands before operation	4	16
	knife before operation	0	2
	knife after operation	0	5
	cleared carcase surface	0	3
Bunging	carcase before operation	8	7
	hands before operation	3	1
	knife before operation	1	2
	knife after operation	0	2
	cleared carcase surface	2	4
Final	carcase at scales	4	17

** Number of samples positive (total samples = 30)*

The carcases were tagged and tracked to the scale, where a further set of 100 cm^2 samples were taken from the brisket, rump and flank of the hot carcases. These final samples from each carcase were pooled for analysis. All samples were analysed for TVC (see figure 2), *E. coli* count and *Staphylococcus aureus* count (see table 1).

For the hide-opening operations, the hide was the most significant potential source of contamination. The hide carried the greatest microbial load, and the greatest numbers and prevalence of both *E. coli* and *S. aureus*; however, there was no correlation between hide TVC at either legging or brisket clearing and the final carcase TVC. At legging and bunging, the exposed tissue of the carcase after the operation had a mean TVC lower than counts on tools and hands at that station. At the final carcase sampling, the mean TVC was 1 $\log_{10}$ greater than that of the cleared tissue after legging or brisket clearing; and was 0.5 $\log_{10}$ greater than the exposed tissue after bunging. Similarly, the final carcase samples were more often contaminated with *E. coli* or *S. aureus* than the exposed tissue samples taken at each dressing station.

The hands of workers can be a source of contamination of carcases. Improving dressing hygiene through a combination of sanitation of tools, wearing of gloves, and carcase decontamination has been recommended for reducing the microbial load on carcases. The workers involved in the case study were well-trained, all wore gloves, and used a two-knife system for sanitising their implements. As a result, TVC on hands and implements was low, although at brisket clearing, the mean TVC on hands was 2.24 $\log_{10}$ cfu/cm^2, compared with 1.65 $\log_{10}$ cfu/cm^2 on the airknife. At all stations, particularly at legging and brisket clearing, the implements gathered contamination during use; however, the efficacy of the sanitation procedure was variable. In general the sanitation procedure resulted in a reduction in microbial load on the implement of less than 1 $\log_{10}$. At brisket clearing, one instance of sanitation resulted in a reduction of 3.0 $\log_{10}$. Microbial loads were higher after sanitation on nine occasions.

The results suggest that much of the contamination on carcases is picked up later in the process (after bunging), from other workers or from airborne contamination.

The second study, carried out at the same processor, aimed to investigate operations further down the chain, to see if there were any particular 'hotspots' in processing. In this study, samples were taken from:

- hide before skinning;
- skinned carcase before evisceration;
- carcase following high-level trim;
- carcase following low-level trim;
- carcase following weighing, grading and final inspection, prior to chiller loading;
- carcase following pushing into chill;
- carcase after overnight chilling.

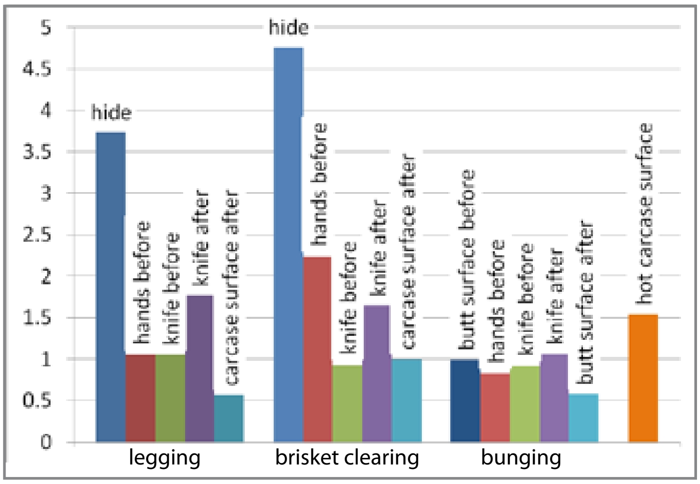

Figure 2: TVC at each dressing station

In addition, at evisceration, a sample was taken from approximately 300 cm^2 of the left and right arm of the worker prior to beginning evisceration, and from each side of the midline cut area of the carcase following completion of the evisceration process.

The results indicated that there is a high standard of hygiene at this plant, and no single dressing activity after skinning stood out as being a significant source of carcase contamination. TVC counts on exposed carcase surface prior to trimming were a maximum of 3.29 $\log_{10}$ cfu/cm^2 immediately post skinning; and at final inspection ranged from <0.52 to 2.09 $\log_{10}$ cfu/cm^2. *S. aureus* counts, when present, were less than 1 $\log_{10}$ cfu/cm^2. The exception could be chiller loading, where an increase in contamination on the flanks was detected, although all staff involved wore rubber gloves and plastic aprons. Chilling decreased the microbial load recovered from rumps and flanks in particular.

Interestingly, the TVC at final inspection was much lower in this study than in the previous one. In the second study, the mean TVC on hot sides was 0.39 ± 0.31 $\log_{10}$ cfu/cm^2 (range <0.52 to 2.09), compared with 1.54 ± 0.69 $\log_{10}$ cfu/cm^2 (range 0.42 to 3.42) in the previous project. The incoming load on hides was similar in both studies. This suggests that the processor had already made significant improvements in slaughter hygiene over the preceding 12-month period. The processor commented that they had been focussing on increasing employee commitment to handwashing during processing. This may have contributed to the reduced microbial load on carcases.

Because the microbial load on cleared tissue immediately after hide opening was very low, it would appear that in this case hide washing or dehairing might not make a significant difference to the microbial load on carcases. Observations at the plant indicated that the cattle were predominantly Brahman type—with short hair—and were visibly clean and dry. This may well have contributed to the low contamination at hide opening. Furthermore, the operators carrying out the hide-opening process were experienced workers, and took steps to ensure that the hide did not roll in and touch the carcase, and that they themselves did not touch the exposed carcase surface. Attention to personnel practices further along the chain reduced the amount of contamination on the carcases.

When considering implementing any intervention procedure, it is worth evaluating the process for potential 'high risk' or 'hot-spot' processes. Using microbiological sampling after each operation, a chart (similar to Figure 2), can be drawn up showing where on the line microbial numbers are reduced, remain static, or increase. Then, each step can be assessed for the potential to improve—either by increasing the reduction in microbial numbers, or by preventing increase in numbers. This will allow strategic placement of interventions to address the higher-risk operations.

Contact us for additional information

Meat Industry Services is supported by the Australian Meat Processor Corporation (AMPC) and Meat & Livestock Australia (MLA).

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

2/11 – March 2011

Heat toughening—Part 1: Effects of heat toughening on quality of beef, and the incidence in Australia

- **Heat toughening occurs when the carcase pH falls rapidly, and reaches pH 6 while the carcase temperature is still greater than 35°C.**
- **Heat toughening has detrimental effects on colour, texture, amount of weep produced, tenderness and eating quality.**
- **Heat toughening is likely to occur in modern processing plants.**

When the consumer buys meat, visual cues for quality include a bright red colour, low fatness levels and the absence of weep in the tray. On consumption, the consumer expects the meat to be tender, juicy and flavourful, with no abnormal flavours or odours. Understanding the factors that contribute to variations in these quality traits assists in determining strategies to optimise the quality traits. The concept of a pH/temperature window was one of the initial specifications for the Meat Standards Australia (MSA) grading scheme in Australia, and was designed to minimise the detrimental effects of extremes in processing i.e. heat toughening and cold shortening. The MSA scheme is aimed at predicting eating quality of individual cuts using a total quality management approach. The pH-temperature window was developed from the meat science literature available from around the world, which generally shows that minimal shortening in muscles occurs when carcases enter rigor at approximately 15°C to 20°C, resulting in optimum tenderness.

Figure 1: MSA personnel measuring the pH-temperature in the loin muscle of a beef carcase

Electrical stimulation of beef carcases was introduced in order to accelerate the rate of post-mortem pH fall to allow more rapid rigor onset and prevent cold-shortening. Most of the standards set down for electrical stimulation in the 1970s were based on the assumption that electrical stimulation was the only electrical input on the slaughter floor. While this assumption was generally true at the time, this no longer applies. Beef processing plants now have a number of possible electrical inputs on the slaughter floor, including the immobiliser, bleed stimulator, electrical stimulator and the hide-puller stiffening probe. There is also evidence that the pH of especially heavy grain-fed cattle, falls more rapidly than that of the lighter cattle processed 30 years ago. Thus the challenge in beef processing now appears to be slowing down the rate of pH fall post-slaughter, rather than speeding it up.

Heat toughening is caused by a fast rate of pH fall while the carcase is still hot. The region to avoid in the pH-temperature window is the red section in Figure 2. If the pH-temperature decline in a carcase goes through this red region, it is defined as a 'heat-toughened' carcase. The loin temperature at pH 6 is calculated from the pH-temperature-decline data measured in the loin muscle pre-rigor.

Definition of heat toughening: A heat-toughened carcase is defined by having a temperature at pH 6 >35°C, during the pre-rigor period.

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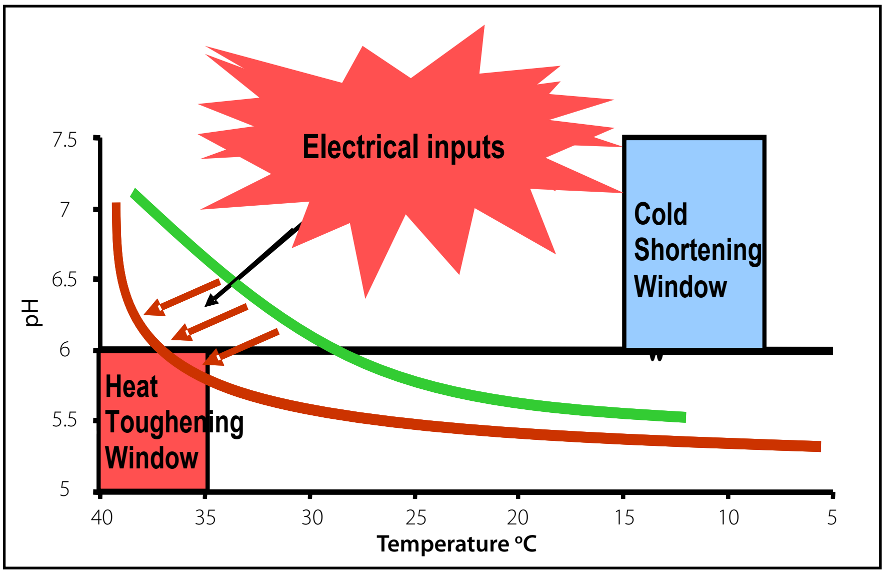

Figure 2: pH temperature window showing the decline in pH and temperature post-mortem in the loin muscle. The regions to avoid, to ensure quality meat, are the cold-shortening region and the heat-toughening region.

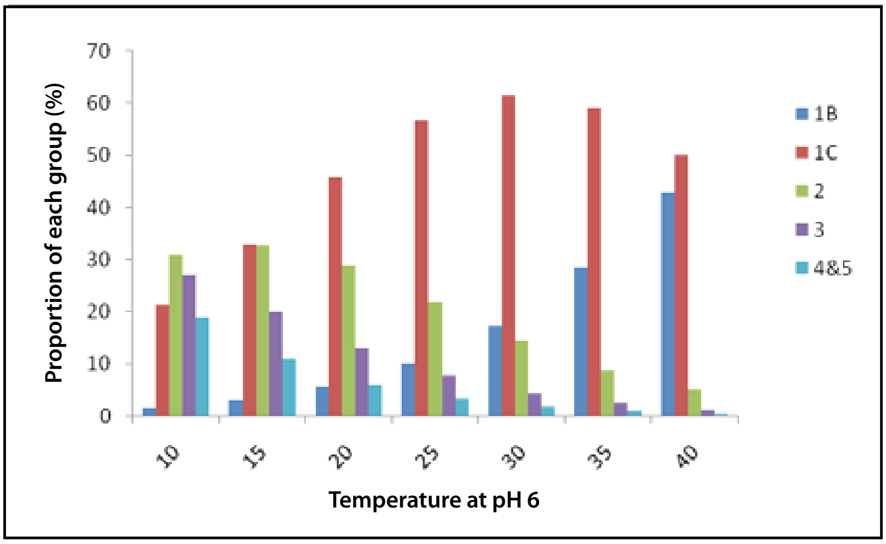

Figure 3: Effect of temperature at pH 6 on the AUS-MEAT colour score . Higher scores are darker; scores 4 & 5 are unacceptably dark.

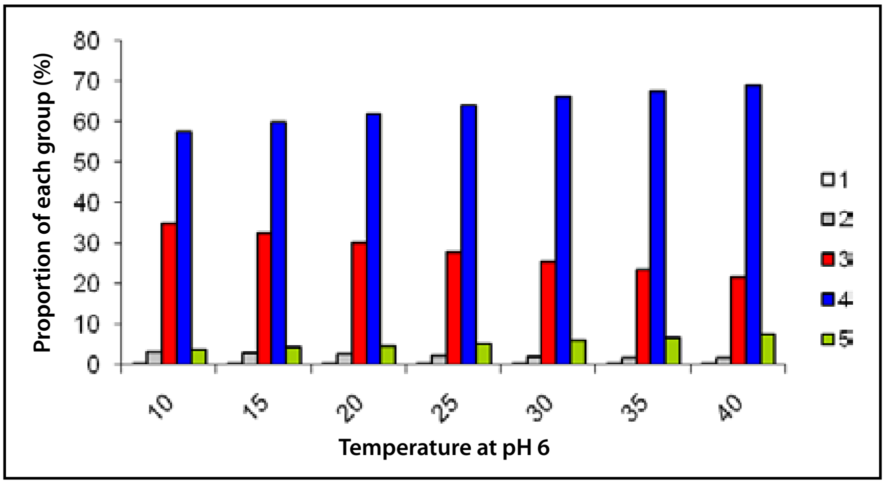

Figure 4: Effect of temperature at pH 6 on the texture score. 1 = firm, fine; 5 = coarse, soft

What are the effects of heat toughening on quality?

Colour: A paler colour occurs in muscles which are heat toughened. In carcases with a loin temperature at pH 6 of 35–40°C, there is an increase in striploins with AUS-MEAT colour score 1B and 1C at grading, and a decrease in striploins with AUS-MEAT colour score 2, 3 and higher (Figure 3). Some markets for beef have a preference for paler meat colour, particularly AUS-MEAT colour scores 1B and 1C. The quality problems associated with the paler colours in heat-toughened beef are the higher weep, or purge, as well as other eating-quality problems described below. Initial research on modifying the frequency and pulse width of the current applied during electrical stimulation indicates there is some potential to increase the number of beef carcases meeting grading specifications for AUS-MEAT colour scores in beef. This can potentially be achieved through applying modulated frequency electrical stimulation, without influencing the occurrence of heat toughening. This warrants further investigation.

Texture: Heat-toughened meat shows a greater prevalence of texture score 'coarse and soft' (high scores), and a lesser prevalence of texture score 'firm and fine' (low scores) (Figure 4).

Wetness: At grading, the loin of a heat-toughened carcase often shows beads of moisture exuding from the meat surface (Figure 5). When MSA graders gave the surface of 1,512 loins at grading a score of 0 for no weep, or 1 for presence of weep, the average weep score increased as the temperature at pH 6 increased (Figure 6).

Tenderness and eating quality: MSA consumer data from 3,864 striploins was analysed for the effect of temperature at pH 6 on eating quality. After accounting for the other factors known to influence eating quality and tenderness (ossification, carcase weight, marbling, cook method, ageing, carcase-hanging method), temperature at pH 6 was found to significantly influence eating quality and tenderness. The striploin from heat-toughened carcases is initially more tender, then shows a failure to age, when compared to striploins going through an ideal temperature at pH 6 of 15°C (Figure 7). MSA eating-quality data from 942 rumps aged for 5 to 28 days showed that rumps from carcases defined as heat-toughened in the striploin, would be about 5 consumer units lower in acceptability than rumps going through the ideal pH-temperature window (Figure 8).

Figure 5: Striploin at grading showing the weep on the surface of the loin of a heat-toughened beef carcase

Table 1: Incidence of heat toughening amongst different categories finished on either grain or grass.

		Number	% heat toughening
Grain finished	Days on grain		
	60-75	211	46.0
	100-200	646	80.8
	214-300	128	92.2
	340-350	97	93.8
Grass finished	Category of cattle		
	Yearling (non-MSA)	70	56.2
	MSA	93	64.5
	Cow	79	45.6
	Ox	78	67.9

Survey of the incidence of heat toughening in beef

From an MLA-funded survey of 1,512 beef carcases in 7 abattoirs during 2007/2008, the overall incidence of heat toughening was 74.6%. Thus the occurrence of heat toughening in beef carcases is prevalent in Australia. The incidence varied from 56 to 94% between the abattoirs. The survey highlighted some factors contributing to the incidence of heat toughening in beef carcases.

Feed type: Of the carcases included in the survey, 72% were finished on grain, 24% on grass and 4% were on milk, with the respective frequencies of heat toughening being 76.5%, 58.4% and 20.1%. Thus it is evident that heat toughening is particularly prevalent in grain-fed cattle, but also has a high frequency in cattle finished off pasture. It is particularly surprising that milk-fed vealers exhibited 20% heat toughening, as this category is usually susceptible to cold-shortening. It was evident that the two plants that were slaughtering milk-fed veal had not optimised their immobiliser settings. This has since been rectified (see Part 2 for recommendations for immobilisers).

Category of cattle: Table 1 shows how the incidence of heat toughening varied amongst the categories of cattle. Grass-fed cattle overall had a lower incidence of heat toughening, and the incidence varied from 46% for cows, to 68% for ox. For grain-fed cattle, the lowest incidence was for cattle fed grain for 60–70 days (46%); and the incidence rose to 81% for cattle fed grain for 100–200 days; and reached 94% for cattle fed grain for 340–350 days.

Hot carcase weight: Hot carcase weight was strongly correlated to days on grain. Thus as the hot carcase weight increased, so did the incidence of heat toughening.

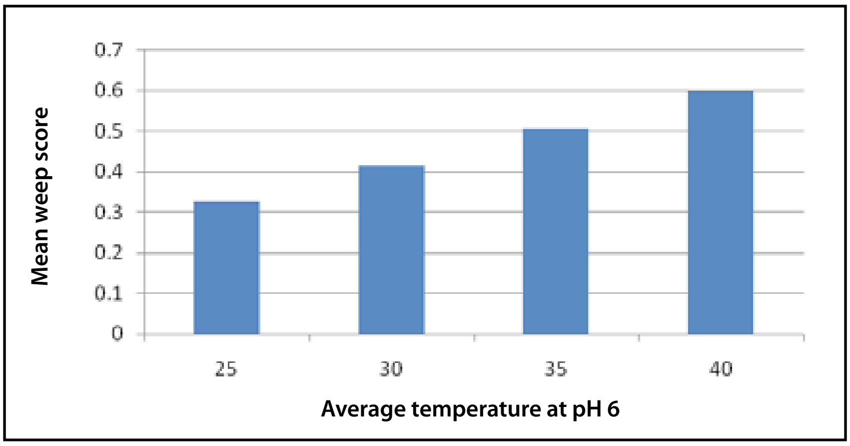

Figure 6: Effect of temperature at pH 6 on the weep score on the surface of the striploin at grading . 0 = no weep; 1 = obvious weep. The chart shows the average score for all the loins in each temperature group.

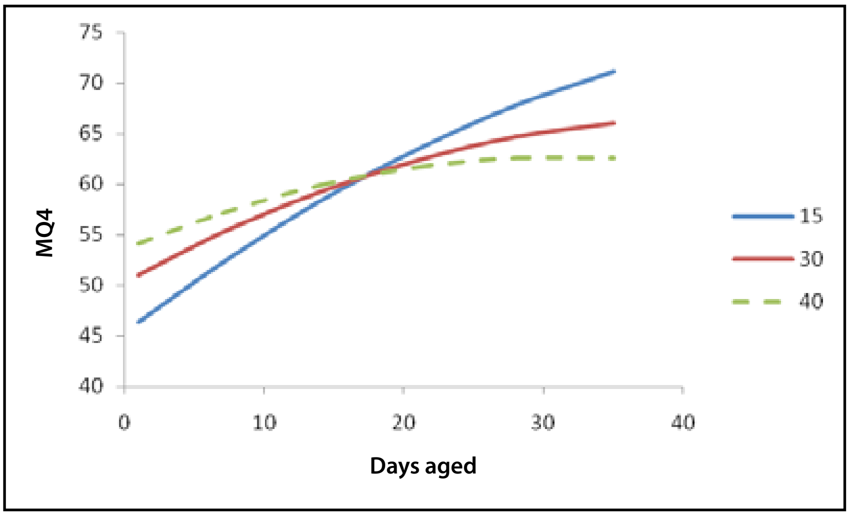

Figure 7: Effect of temperature at pH 6 (TatpH6) and days aged on the predicted MQ4 score for grilled striploin. A low MQ4 score is less acceptable to the consumer and a high MQ4 score is more acceptable.

Electrical inputs on the slaughter floor: The main influence of electrical inputs on the slaughter floor is through the rigidity probe at the hide puller. Recommendations for optimising the rigidity probe and other electrical inputs are given in Part 2. In almost all plants undertaking the heat-toughening study, electrical inputs were in many cases not optimal, and adjustment and optimisation of settings significantly reduced the incidence of heat toughening. Optimising electrical input should be the first response if high incidences of heat toughening are observed.

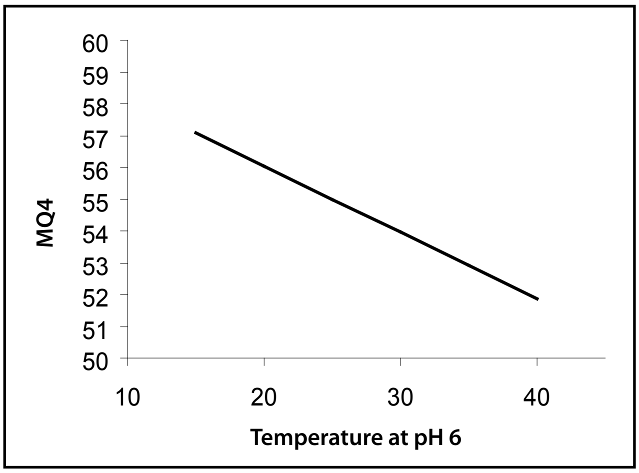

Figure 8: Effect of temperature at pH 6 on predicted MQ4 score for rump. A low MQ4 score is less acceptable to the consumer, and a high MQ4 score is more acceptable.

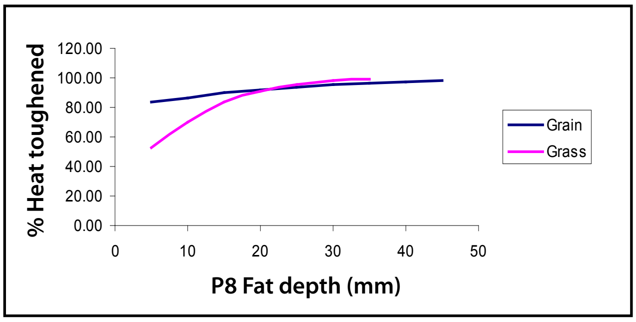

Figure 9: The effect of feed type and P8 fat depth on the predicted % heat toughening

Fat depth: The effects of fat depth were independent of carcase weight, but dependent on feed type. There was little influence of P8 fat depth in grain-fed cattle, on the predicted % heat toughening, but a large influence with grass-fed cattle. Grass-fed lean cattle (P8 = 5 mm) had a relatively low predicted incidence of heat toughening (54%); but in grass-fed fat cattle (P8 = 30 mm), the predicted incidence of heat toughening was high (87%) (Figure 9).

Sex: Females had a lower predicted temperature at pH 6 and a lower predicted % heat toughening than male cattle (71 vs 83% respectively), with the difference being bigger for fat cattle.

A final note on ageing

The effects of heat toughening on quality and eating quality when ageing beyond the normal domestic ageing period (beyond 35 days) is largely unknown and warrants further investigation.

What is the commercial benefit to a beef processor in eliminating heat toughening?

According to one domestic beef processor who originally had excessive stimulation of his beef carcases on the slaughter floor, the big benefit is in improved product performance. The processor stated that although he originally had more beef carcases with AUS-MEAT colour score 1B and 1C, he also had complaints from customers about sloppy meat and water in the bag. He also had comments about two-toning, inconsistent colour and the meat being 'dry' to eat. Now that the processor has optimised the temperature at pH 6 in beef carcases, his customers are much happier with the product performance and consistency.

Summary

Heat toughening can have significant detrimental effects on meat quality, and a number of factors can contribute to heat toughening. There are also a number of ways in which the incidence of heat toughening can be reduced. These are discussed in Part 2.

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Meat technology update

3/11 – May 2011

Heat toughening—Part 2:
Strategies for reducing the incidence of heat toughening in beef carcases

Heat toughening can have detrimental effects on meat quality, and the incidence can be reduced by:

- **rapidly cooling the affected muscles;**
- **minimising electrical inputs during dressing;**
- **not stressing the live animal prior to slaughter.**

Heat toughening in beef carcases is caused by rapid pH fall in the pre-rigor period, while muscle temperatures are still high. This was discussed in the previous Meat Technology Update titled 'Heat toughening—Part 1: Effects of heat toughening on quality of beef, and the incidence in Australia'. This MTU discusses the effects of on-farm, pre-slaughter and post-slaughter factors which contribute to heat toughening in beef carcases. It also presents strategies to reduce the incidence of heat toughening.

Contribution of muscle temperature

Temperature affects the rate of enzyme reactions, with an exponential increase in the rate of enzyme reactions at higher temperatures. Glycolysis is an important enzymic process in post-mortem muscle. It involves the formation of lactic acid from the anaerobic breakdown of glycogen, and results in a pH fall. At higher muscle temperatures, the rate of glycolysis, and thus the rate of pH fall, is exponentially increased. For example, lamb loin muscles held at 35°C had an average pH of 6.0 at 2 hours after slaughter. In contrast, muscles chilled to 2°C, had an average pH of 6.5 at 2 hours after slaughter. The difference in muscle pH was smaller if the carcases had been electrically stimulated, but was still 0.2 pH units lower in the muscles held at 35°C.

If beef carcases are held on the slaughter floor during breaks, or if there is a delay on the slaughter floor, the result will be that the temperature at pH 6 will be higher and the incidence of heat toughening is likely to be higher. Also, if beef carcases are over-stimulated, they will have a higher temperature at pH 6.

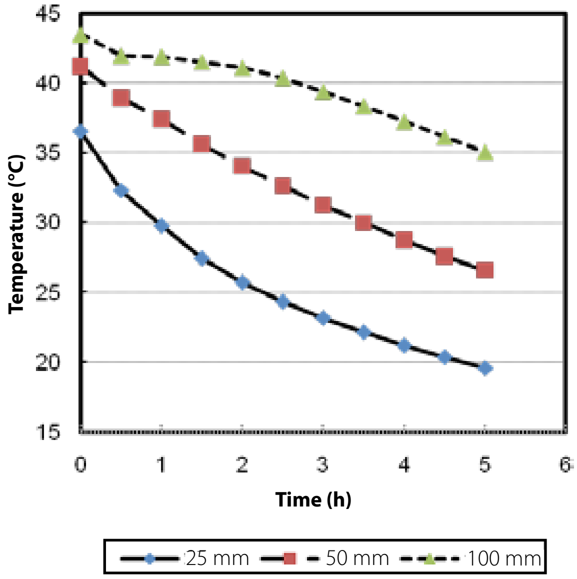

Figure 1: The muscle temperature (°C) at depths of 25, 50 and 100 mm measured every 30 minutes for 5 h post-slaughter (values are means)

Variation between muscles in temperature decline

Muscles in beef carcases vary substantially in their cooling rates. Muscles that are close to the surface of the carcase and have little depth, such as the loin, chill quickly. Deep muscles, such as the muscles in the butt, cool much more slowly, particularly in the centre of the muscle (see Figure 1). The MSA window is based on measuring the rate of pH and temperature fall in the loin muscle (*longissimus lumborum*). Primals (and muscles) such as the rump (especially *gluteus medius*), topside (especially *semimembranosus*) and outside (*biceps femoris*), are deep muscles and are very likely to have a higher temperature at pH 6 than the loin muscle. When measurements in the loin indicate that a beef carcase is heat toughened, the leg muscles are therefore likely to have more extensive quality problems such as pale colour, weep and inconsistent eating quality. In addition, the centre of a deep muscle declines in temperature more slowly and can have a faster pH fall. The outcome of this is that zones of heat toughening can occur in a muscle such as the *semimembranosus*, with darker, less weepy surface towards the outside, and a paler, more weepy surface towards the inside of the muscle/carcase. This can cause inconsistent and variable eating quality across a muscle.

Effect of grain feeding, carcase weight and fat depth on muscle temperature

Heavy carcases cool more slowly. Generally, grain-fed carcases are often heavier, which partially explains why grain-fed carcases are known to have a high incidence of heat toughening. At the same carcase weight, increasing fat depth in grass-fed carcases results in slower chilling rates and an increase in the incidence in heat toughening (see Figure 9 in MTU 2/11). Thus a potential solution for heat toughening in carcases from grass-fed beef is to undertake hot-fat trimming after the scales, in order to increase the rate of muscle cooling.

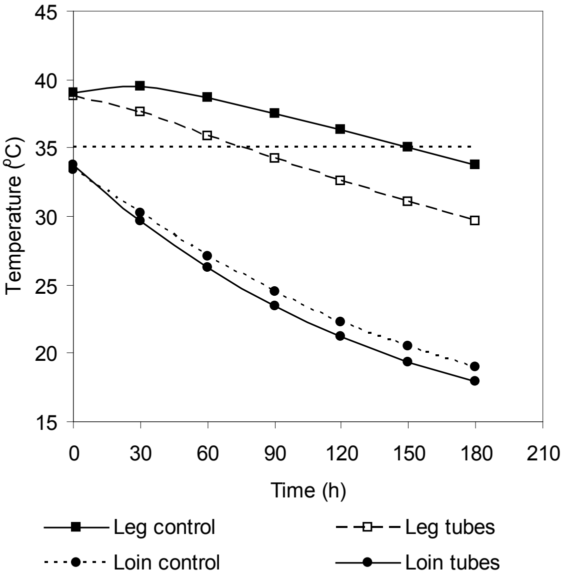

Figure 2: The effect of muscle (leg vs. loin) and heat tubes (control vs. tube) on the temperature time plot (values are means)

In contrast, at the same carcase weight, fat depth has little influence on the incidence of heat toughening in grain-fed carcases (see Figure 9 in MTU 2/11). This appears to be because carcases from grain-fed cattle have an inherently fast metabolism. There is now mounting evidence that grain-fed cattle may be in a state of insulin resistance which can compromise the ability of an individual to thermoregulate and that this can be exacerbated by stressors. The only solution for the high incidence of heat toughening in grain-fed carcases appears to be animal intervention through dietary supplements. The most promising dietary supplements are betaine, chromium, tryptophan and magnesium—either alone, or in combination. Further research on this topic is warranted.

Effects of pre-slaughter stress or exercise on muscle temperature

The muscles in the carcases of animals undergoing stress or exertion pre-slaughter can be 2–3°C higher compared to animals slaughtered with minimal stress or no exertion pre-slaughter. This has been proven across a number of studies which demonstrate that stress and exertion pre-slaughter result in activation of adrenergic pathways and muscle metabolism in the live animal. There is then accelerated metabolism post-slaughter with associated faster rates of pH fall. To reduce the incidence of heat toughening in practice, stress and exertion pre-slaughter should be minimised. This includes consideration of the effect of using electric prodders/goads pre-slaughter on animal stress. Information on minimising stress pre-slaughter and recommendations for handling cattle, are available from the MSA website (www.mla.com.au/msa) or from Temple Grandin's website (www.grandin.com).

Effect of 'heat tubes' on muscle temperature

The rate of chilling of muscle tissue is limited by its poor thermal conductivity. Providing a high thermal conductivity path to the centre of the meat is a potential method of overcoming this problem. 'Heat tubes' are sealed metal tubes containing a refrigerant, which transfers heat to the cooler end of the tube if there is a small temperature difference between its ends. If one end of the tube is placed in contact with a warm medium, such as muscle, heat will be extracted from the medium and transferred to the cooler end of the tube, such as the chiller air. In the trial pictured in Figures 2 and 3, a high surface area was used at the cold medium end in order to increase the rate of heat transfer. Figure 3 shows the insertion of the heat tubes into the leg and rump of a beef carcase, and the sites for insertion of the thermocouples for temperature measurement. The heat tubes had a small effect on the rate of temperature decline in the loin and a much larger effect in the leg (see Figure 2). The importance of the effect of the heat tubes in the leg was to decrease the time taken for the temperature to reach 35°C to within 80 minutes, and to reduce the temperature by 4°C at 3 h after commencement of chilling. A temperature of 35°C is the upper limit of the 'normal' region of the MSA

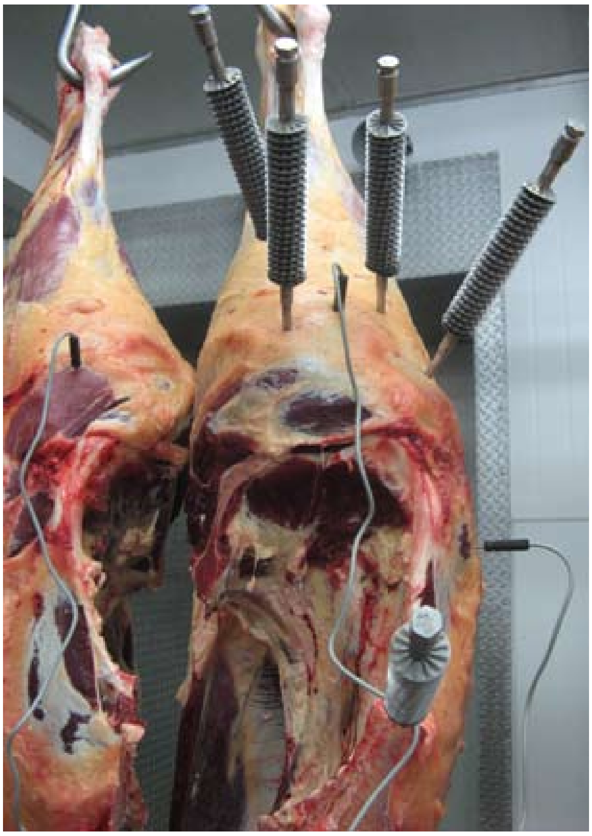

Figure 3: Location of heat pipes and thermocouples for the leg and loin for control and treatment sides.
Note: The heat tubes must be placed at an angle above horizontal, in order to work.

pH-temperature window. Critically, from the point of view of reducing heat toughening, the heat tubes acted to reduce temperature early in the chill period. Heat tubes could be a way of increasing the rate of heat loss from beef legs for the purpose of preventing heat toughening; however, the practicalities of their use need to be considered.

Effect of vascular infusion on muscle temperature and metabolism

Vascular infusion is a process whereby water and, if required, a small quantity of some common substrates is pumped through the cardiovascular system of the intact carcase soon after slaughter. Vascular infusion is now applied commercially (MSPC, Inc., Eden Prairie, MN, USA). The vascular infusion of a cold solution to the beef carcase post-slaughter can reduce the muscle temperature of the loin by as much as 2–4°C.

Vascular infusion offers the potential to effectively administer solutions to carcases and thus manipulate the rate of pH fall. Solutions such as citrate, or sodium bicarbonate could be used in the infusion solution in order to slow down the rate of glycolysis and thus the rate of pH fall. Further, if very cold water could be used then this would reduce carcase temperature which, in itself, may be sufficient to alleviate the problems associated with pH decline in heavy beef carcases, without adding compounds to the water. Infusion of very cold water containing a citrate or bicarbonate compound, provides an avenue worthy of further study.

Electrical stimulation during immobilisation

At most beef slaughter plants, after an animal is stunned it falls out of the knocking box onto a table where an electrical current is applied to immobilise the animal during exsanguination and shackling of the hind leg. The immobilising current is applied for occupational health and safety reasons as it reduces the risk of worker injury due to carcases kicking during these operations. The older immobilisation units, which were set to deliver a higher current and lower frequency, increase the rate of pH fall in the loin muscle.

With the newer immobilisation units, when the settings are optimised, the effect of the electrical current applied during immobilisation on the pH fall, and % heat toughening, should be minimal. In a study of 60 beef carcases, when the immobiliser was set to 1.0 A and a frequency of 2,000 Hz, 100% of the carcases were within the pH-temperature window (see Table 1). When the current was increased to 1.6 A and the frequency reduced to 450 Hz, only 45% are in the pH-temperature window, with 55% heat toughened.

Electrical stimulation for bleeding or to prevent cold shortening

The application of electrical stimulation to a carcase was originally introduced in order to speed up the rate of pH fall, hasten rigor onset, and prevent cold shortening. More recently, it has also been applied to carcases to enhance the 'bleeding out' process, enabling more efficient blood collection. To reduce the incidence of heat toughening, it is recommended that all forms of electrical stimulation applied to the carcase are minimised. Electrical inputs used for immobilisation of the carcase immediately after exsanguination, or the use of a rigidity probe to stiffen the backbone during removal of hides may be unavoidable.

Table 1: Effect of current setting (1.0 vs 1.6 amps) and frequency of current (2,000 vs 450 Hz) applied during immobilisation on the average temperature at pH 6 and % of carcases in the pH-temperature window (i.e. temperature at pH 6 <35°C).

Group	n	Current (A)	Frequency (Hz)	Average temp. @ pH 6 (°C)	% of carcases in the MSA pH-temp. window
1	15	1.6	2000	30.9	87
2	15	1.0	2000	29.8	100
3	15	1.6	450	33.4	47
4	15	1.0	450	34.9	60

Notes: Temp @ pH 6 = group average temperature at pH 6.
% MSA = percentage of bodies grading within the MSA window.

Electrical stimulation during hide removal

In order to remove the hide from a beef carcase using a downward hide puller, a rigidity probe is applied to the back of the carcase, and a current is applied. This is in order to stiffen the backbone and prevent breakage in the spinal column. The application of the rigidity probe increases the rate of pH fall, and causes an increase in the temperature at pH 6. Figure 4 shows this relationship and the corresponding regression equation predicts that if the rigidity probe stimulation is reduced by 10 s, this would reduce the temperature at pH 6 by 2°C, potentially moving a borderline carcase away from being heat toughened. To reduce the influence of the rigidity probe on heat toughening, it is recommended that the rigidity probe stimulation time is as short as possible.

Most stiffening probes operate at 50 Hz at about 180 V through an isolating transformer, but newer equipment is available operating at 40 Hz pulsed DC, 4–5 A peak and reduces the effect on pH while providing effective stiffening.

Potential strategies which require further research

- Compounds such as sodium bicarbonate or citrate show potential to slow the rate of glycolysis if added to the carcase infusion solution.
- Feeding of magnesium, chromium, tryptophan or betaine as dietary supplements pre-slaughter have the potential to either reduce body temperature, or reduce the stress response pre-slaughter.

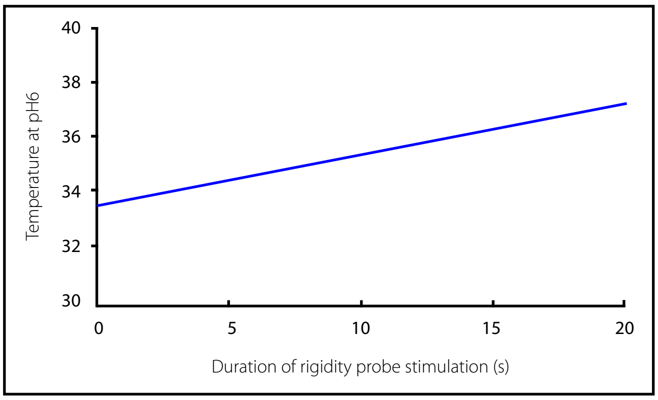

Figure 4: The predicted relationship between the temp. at pH 6 for the loin muscle and the duration of rigidity probe stimulation

Recommendations:

- Ensure the immobiliser is at optimum frequency and current (2,000 Hz and 1.0 A).
- Turn electrical stimulation/bleed units off for any carcases at risk of heat toughening, especially grain-fed or heavy carcases.
- Reduce the time the rigidity probe stimulation is applied at the hide puller to below 10 s.
- Consider hot-fat trimming carcases, particularly carcases from grass-fed cattle, to increase the rate of temperature fall.
- Run carcases off the slaughter floor at breaks.
- Consider strategies to reduce pre-slaughter stress and ensure animals are not being unduly exerted pre-slaughter. For example, walk them quietly from the pen to the knocking box, rather than galloping.
- Consider vascular infusion with cold water.
- Consider using heat tubes for susceptible carcases or susceptible muscles.

The contribution of MSA and DAFWA, particularly Janine Lau and Robin Jacob respectively, to the work reported here is acknowledged.

Strategies and recommendations for reducing the incidence of heat toughening in beef carcases

Site in chain	Strategy	Proposed mechanism	Comment
On-farm	Feeding betaine	Reduces body temperature	Experimental results show promise
	Feeding tryptophan (Trp) or magnesium (Mg) or chromium (Cr)	Reduces stress, therefore body temperature and muscle glycolytic metabolism	Successful in pigs (Mg, Trp) and sheep (Mg)
Pre-slaughter	Minimise electric prodding and improve handling of cattle	Reduces stress and therefore reduces carcase temperature and rate of glycolysis	
	Showering of cattle and providing shade	Reduces heat stress and thus reduces carcase temperature at slaughter	
	Don't excessively exercise or run cattle prior to slaughter	Reduces stress and muscle temperature	
Slaughter floor	Rinse-chill with solution of ice-cold water	Removes heat from carcase	Evidence for reductions in muscle temperatures of 2–3°C
	Rinse-chill with solution containing citrate or bicarbonate	Slows down rate of glycolysis	Proposed
	Expertly applied stunning	Minimal struggling and stress	
	Use high frequency current (2,000 Hz) set at 1 A during immobilisation	Reduces effect on glycolytic metabolism thus little effect on pH	Firm evidence
	Remove electrical stimulation for bleeding or cold shortening	Generally increases rate of pH fall and often increases muscle temperatures	Well proven
	Minimise time rigidity probe is on at hide puller	Rigidity probe current causes fall in muscle pH	Evidence that for every 10 s time reduction, temperature at pH 6 reduces by 2°C
Chillers	Hot-boning and very fast chilling	Reduces muscle temperatures and therefore glycolytic rate	
	Insertion of heat tubes	Reduces muscle temperature	Evidence that temperature in topside muscle is reduced by 6°C at 4 h post-slaughter

Contact us for additional information

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Meat Technology Update

Newsletter 02/6 December 2002

The causes of drip in meat

Lean fresh meat has a water content of approximately 70%. One of the major challenges of meat processing is concerned with preventing loss of liquid from lean meat tissue during storage. When meat is cut, a red solution of proteins that is known as drip (or weep or purge) oozes from the cut surfaces. For primals, the volume of drip produced in the first 48 hours or so after boning is typically quoted to be about 1 to 10 mL per kg of meat (0.1 to 1%), while for steaks or chops; it can be 10 times greater.

In meat that is stored for extended periods (e.g. vacuum-packaged primals), the drip loss gradually increases with time. A 'normal' amount of drip in commercial vacuum packs of chilled primals is usually regarded to be 1 to 2%. Drip of more than 1% is unusual for the main seam-boned primals, but it could be up to 2% for pieces of meat that are subject to cutting and trimming to achieve a specification. The amount will be greater in smaller packs where the surface area is proportionately greater per unit weight. In some of the scientific investigations upon which information for this article is based, the pieces of meat were small (for instance eighths of striploins in one trial) to ensure that different treatment effects were tested with practical quantities of meat. For some of these trials, drip losses of 5 to 10% are quoted.

This article briefly discusses the mechanism of drip formation in meat tissue and its eventual accumulation at the surface. It also considers a number of factors that people have demonstrated or implicated as contributors to drip loss.

Mechanism of drip formation

Muscle consists of bundles of muscle fibres (75-92 % of muscle volume), connective tissues, blood vessels, nerve fibres, and extracellular fluid. The fibres are the structural units (Fig. 1). They may stretch from one end of a muscle to the other. Within each fibre, there are usually at least 1000 sub-units called myofibrils that extend the entire length of the fibre. Each myofibril is made up of sarcomeres. The sarcomere is the repeating structural unit of the myofibril. It is the basic unit in which events of the muscle's contraction-relaxation cycle occur. Sarcomere length is not constant in pre-rigor muscle. The dimensions are dependent upon the state of contraction at the time the muscle is examined. When a muscle is at rest, the typical length of a sarcomere is 2.5 microns. Sarcomeres contract or shorten as muscles enter rigor. They shorten little if the muscle enters rigor at 10-15°C. Increased shortening occurs both at lower temperatures (cold shortening) and at higher temperatures

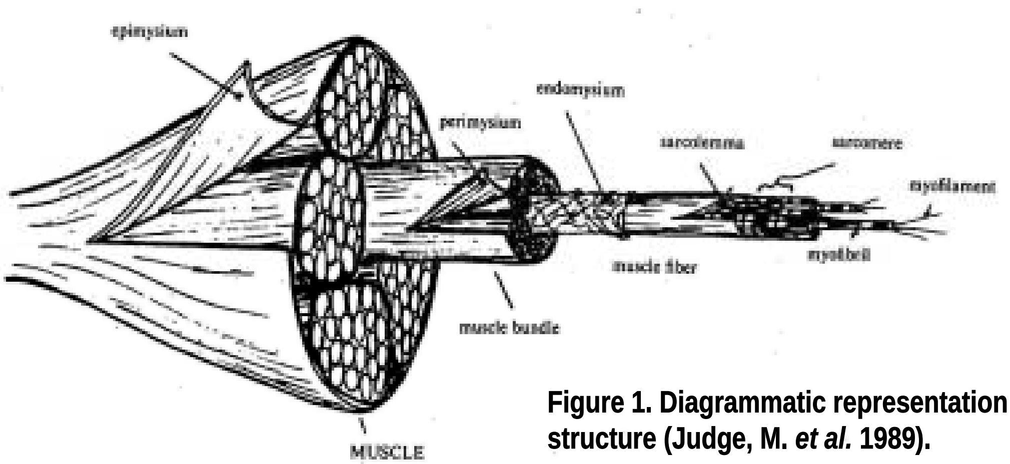

Figure 1. Diagrammatic representation of muscle structure (Judge, M. *et al.* 1989).

(rigor, or heat shortening). Severely cold-shortened sarcomeres can be less than half their normal length.

Once an animal is slaughtered, oxygen supply to the muscles ceases. Thereafter, the main biochemical activity is the conversion of glycogen to lactic acid and other products – a process called glycolysis. Glycolysis will continue until a pH is reached (ultimate pH) where the enzymes that facilitate it become inactivated or the muscle glycogen is used up. As post-mortem glycolysis proceeds, the muscle loses the ability to extend and contract as it becomes set in rigor mortis.

In living muscle most of the volume of a muscle fibre is occupied by myofibrils. There is little space between them. The water and the associated protein are located within the myofibril. About 4 to 6 h post mortem the fibre bundles have shrunk away from one another leaving gaps. After 24 h there are also gaps between individual fibres. Post mortem then, myofibrils shrink laterally, and it is likely that the drip originates by being expelled from the sarcomeres, particularly shortened ones, as they shrink. The exudation of drip from the meat surfaces does not take place abruptly at the onset of rigor; rather it is a gradual process. It appears that the fluid expelled from the myofibrils at onset of rigor initially accumulates within the muscle, from where it gradually migrates to its exterior. Shortening of the myofibrils and fibres hastens this migration.

Pre-slaughter factors that affect drip

From the very few studies where it has been investigated as a factor in drip loss, diet does not seem to affect the eventual loss of drip from vacuum packs or retail packs. Animal age may be a factor, but the evidence is inconclusive however, with drip being higher in vacuum-packaged muscles of older cattle in one study; but lower in another study.

Acute stress prior to slaughter has been shown to increase drip loss and cooking loss in meat that has had no ageing. Moderate stress of cattle before slaughter is also believed to be a cause of drip, although there is no direct evidence of this. There is evidence that when glycogen levels in muscle are low, drip loss is higher - and low glycogen levels are often related to stress. Investigations in this area at the Cooperative Research Centre (CRC) for Cattle and Beef Quality are ongoing.

If animals are stressed to the point they produce high pH meat, drip loss could actually be reduced. The proteins in high pH meat have an increased ability to hold water and, while water may be expelled from sarcomeres, some of it can be bound to proteins. While high pH meat produces less drip, obviously this is not an acceptable option for reducing drip in vacuum packs.

Post slaughter factors

Electrical stimulation does not appear to affect drip loss provided the meat goes into rigor at the same temperature as non-stimulated meat.

If meat – electrically stimulated or not – goes into rigor at too high a temperature, drip loss can be increased. Biochemical changes and physical disruption in muscle that is in rigor is more pronounced if the temperature stays high for too long. A combination of low pH and high temperature can promote re-arrangement or denaturation of proteins. It is known that protein denaturation leads to greater drip loss and pale meat. Rigor shortening, or heat shortening, can occur when meat enters rigor at a high temperature (see below). This also contributes to drip loss. With heavy sides, if the chilling rate is slower than desirable, electrical stimulation can worsen the problem of drip, because the sides do not cool sufficiently before they enter rigor.

It is important to stay within the Meat Standards Australia (MSA) ‘abattoir window’ to optimise tenderness. It may benefit drip as well but an appropriate study has not yet been done.

There is no published evidence that the use of organic acids (e.g. acetic or lactic) as food safety intervention treatments has any detrimental effect on drip. In fact in one study there was less drip loss from striploins that were treated with a mixture of acetic and lactic acids than from those that weren’t treated. However in some commercial trials in Australia with vacuum-packed pork and beef treated with hot (55ºC) acetic acid solution, there were indications of elevated drip loss in the packed product. The extra drip may have been due to denaturation of the surface tissue or it may simply have been due to inadequate drain times after treatment.

Chilling and time to boning

If carcases that aren’t electrically stimulated are cooled too slowly, some muscles can shorten significantly due to rigor shortening. It is known that drip loss increases if rigor shortening has occurred.

If carcases that aren’t electrically stimulated are chilled too quickly, severe cold shortening of some muscles will occur. Drip losses will increase. If they are restrained by, for instance, aitchbone hanging (Tenderstretch), muscles can be prevented from cold shortening.

Little muscle shortening and drip loss occurs if the muscles are cooled to, and retained in, the range 10°C to 15°C. Minimum shortening occurs at around 12°C.

From published data, spray chilling of beef sides does not appear to adversely affect drip loss from primals. However, one Kansas study with sub-primals (insides) found a slight increase in drip (2.0% compared with 1.7%) after 15 days when spray chilling was employed.

Hot or warm boning (accelerated boning) per se doesn’t appear to affect drip loss. In studies where hot boning has been associated with increased drip loss, cold-induced muscle shortening has probably occurred because electrical stimulation wasn’t used.

If the meat temperature at boning is high (some deep muscles will have temperatures near 20°C after normal overnight chilling), it is important that after the cuts have been packaged, a good rate of chilling is continued until the stipulated temperature for shipping is reached.

There is no information on whether there is an influence of the period of chilled holding (one, two, three or more nights) on drip loss.

Rapid fall in pH is an indicator of rapid onset of rigor. As already mentioned, if carcases go into rigor too quickly – before the meat temperature has fallen – subsequent drip loss may be increased. It is important that pH does not fall too rapidly. Researchers at the CRC for Cattle and Beef Quality who have developed (and continue to refine) the desirable abattoir window for rates of pH and temperature decline, have not specifically focused on drip loss. However, there is good reason to believe that if steps are taken in an abattoir to adhere to the MSA guidelines (the window) then drip loss will not be excessive. An example is to optimise electrical stimulation and other electrical inputs on the slaughter floor. Current research funded by MLA is helping to better determine the effects of the inputs on various quality traits including drip.

Cutting style and differences between cuts

The amount of drip is likely to be higher for cuts where much of the meat surface is freshly cut than from those that are seam-boned. Investigators have reported much higher drip losses from retail portions or sub-primals (i.e. portions with relatively large areas of cut tissue) than from whole primals – 5% or higher compared with 1-2%. As many surfaces as possible should be left covered by connective tissue and/or fat. It appears that some cuts tend to lose more drip than others. Published evidence of this is limited but it is documented that drip loss is lower for beef outside flats than insides.

Packaging

It has been suggested on occasions that delays between boning and packaging contribute to excessive drip through the effect of stacking of cuts on tables or in containers. There is no direct evidence for this but it seems likely that inappropriate pressure would encourage movement of any drip from around the meat fibres out to the surface (Fig. 2).

Vacuum packaging results in higher drip loss than other modified-atmosphere techniques. In a New Zealand study, sealed non-vacuumed samples had the lowest drip formation of all samples from a range of treatments that included shrunk (Barrier Bags) and non-shrunk (conventional and aluminium foil) vacuum packs, standard carbon dioxide atmosphere packs and also packs in which the meat samples were supported away from the films within rigid tubes.

The degree of vacuum affects drip loss. In the New Zealand trial referred to above, a full vacuum tended to cause more drip than lesser vacuums. This was explained in part by the physical squeezing of the meat. Although it is not stated in the paper, a snorkel machine was probably used. The rate of vacuum application during packaging doesn't appear to have a significant effect on drip loss. A modified cycle, in which the rate of evacuation was slower and the full vacuum held for a much shorter time, caused slightly more drip than the normal cycle.

Drip formation in heat-shrunk vacuum packs is less than in non-shrunk packs. It has variously been suggested that it is because: a) heat-shrinkable films tend to be softer and more pliable than non-shrinkable ones; or b) there are fewer voids and 'ears' into which drip can emerge from the meat and accumulate.

Figure 2. Drip in vacuum-packed beef rump.

It has been claimed that avoidance of evacuation and exertion of pressure using highly shrinkable film can reduce drip. There is evidence from trials in Germany with cold-boned beef and pork that a packaging technique, Pi-Vac (a system that despite its name, does not involve evacuation), resulted in less drip after 35 days chilled storage than vacuum packaging. With this technique, loins of beef or pork are placed into sleeves that shrink tightly onto the meat, after which the ends are clipped or heat-sealed. A recent investigation of the Pi-Vac system for hot-boned beef also showed it to be an effective method for restricting muscle shortening during rapid chilling. Although it was not mentioned, the avoidance of cold shortening would have also lessened drip loss.

The importance of a good rate of chilling of the vacuum packs has already been mentioned. The primals should reach 5°C within about 20 hours of boning. If necessary, the rate of cooling of vacuum packs in carton chillers can be improved by leaving the lids off for 24 h.

It has been stated that squashing of lower cartons in chilled shipments – due to instability problems – leads to increased drip. There is no published evidence that this is the case. While such excessive uncontrolled pressure may exacerbate drip, the finding from investigation of the Pi-Vac system (above) suggests that reasonable pressure at the appropriate orientation to the meat fibres may in fact reduce drip.

Load-out and storage

It has been stated that meat should not be loaded out until its temperature is uniformly down to the carriage temperature (0°C or below) otherwise drip loss may be increased.

There is no definitive information however, on the effect of storage temperature on drip loss; however the gradual protein denaturation and proteolysis that occur during the ageing process (and which leads to gradual accumulation of drip) occurs more slowly at lower storage temperatures.

Small fluctuations in temperature (say ± 1°C) are unlikely to cause a noticeable increase in drip in vacuum packs. Significant fluctuations in retail display cabinets might be expected to exacerbate drip but there is no published evidence. Drip loss gradually increases with storage time. In some of the investigations, drip loss seems to have reached plateaus after around 4 to 5 weeks. In others it continued to increase for the duration of the trials (15 weeks in one trial). There are no published data on whether the duration of storage in vacuum packs subsequently affects the amount of drip during retail display.

Frozen storage

In meat that has been frozen, there is considerable denaturation of proteins that are associated with the myofibrils. The effects on the muscle microstructure and the proteins are the results of both freezing and thawing processes. Very rapid freezing (4ºC per minute or faster) causes minimal protein denaturation but in practice the rates of freezing of primals is vastly slower than this. When meat is frozen pre-rigor, the detrimental effect of freezing and thawing is aggravated. Extended periods of frozen storage affect meat that is frozen pre-rigor more than when it is frozen post rigor.

In vacuum-packaged meat that is aged, then frozen, then thawed, drip loss will be greatly increased. There are no published data however.

Conclusions

In summary, it appears that the main factors in drip loss in vacuum packs are:

- inappropriate rates of carcase chilling – leading to cold shortening if chilling is too fast or to heat shortening and protein denaturation if too slow;
- which cuts we are talking about and how severely they are trimmed of connective tissue and fat;
- The vacuum packaging process;
- temperature of storage of vacuum packs;
- time of storage; and
- whether they are frozen after ageing.

The existence of drip loss from meat as an ongoing phenomenon is evidenced by the widespread use of soaker pads in vacuum packs and retail packs. Drip loss – particularly from meat that has been frozen or vacuum-packaged, or both – is of considerable commercial significance.

From this brief discussion of some of the factors that contribute to drip, it is clear that too little known about how to vary these factors in order to minimise drip loss. Current research will provide some information, however additional investigations are required.

For more information, contact one of the Meat Industry Services staff listed below.

Food Science Australia Meat Industry Services Section

The Meat Industry Services (MIS) Section of Food Science Australia is an initiative supported by Meat and Livestock Australia (MLA) and the Australian Meat Processor Corporation (AMPC) to facilitate market access for, and support world-class practices in, Australia 's meat industry.

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

6/09 – December 2009

Shelf life of Australian chilled, vacuum-packed, boneless beef

Extensive commercial evidence and recent scientific studies indicate that chilled, vacuum-packaged Australian boneless beef can have a storage life of at least 20 weeks under optimal temperature conditions.

Whether all vacuum-packed product will achieve this shelf life is dependent upon the initial quality of the meat (pH, colour, microbiological quality), adequate vacuum packing and temperature control through the supply chain.

The scientific studies and commercial observations suggest that shelf life may extend beyond 20 weeks, particularly if the primals are used in food service. The primals may also be suitable for retail display beyond 20 weeks, depending upon market expectations for the appearance of product.

Executive overview

Studies undertaken over 25 years ago led to process guidelines for Australian exporters of vacuum-packaged beef to help them achieve storage lives of 10 to 12 weeks at 0°C. Since then, cumulative commercial evidence, supported by recent scientific studies, indicates that a rather longer shelf life—20 weeks or more—is now regularly achieved. This paper provides information on the principle of vacuum-packaging, shelf life and consumer acceptance of meat, and suggests some reasons why the shelf-life extension has occurred. For those readers who seek a more detailed understanding of the science of vacuum packaging, the paper also discusses meat colour, meat spoilage and the role of bacteria, and describes the recent Australian scientific study of vacuum-packaged beef that supports the industry observations.

Long storage life of vacuum packs reflects vigilant attention to detail. In the case of these beef striploins, dividers in cartons minimise the risk of physical damage to vacuum packs during transport and storage

Certain factors that have particular influence on the shelf life of chilled, vacuum-packaged boneless beef are now widely recognized; the most notable are microbiological status of the meat when it is vacuum-packaged, its pH level, the integrity of the package, and the temperature history at which the packs are stored. Careful control of these and other factors by processors and distributors have resulted in consistent superior quality after storage times that were unattainable in the past. A study conducted in 2008 by Food Science Australia on vacuum packs of beef destined for United States markets found that the microbiological count at the time of packaging the primals was generally very low. When the test packs were stored at the recommended temperature for transport and storage (minus 0.5 ± 0.5°C), even after 20 weeks the total viable count on many primals was very low, around 1000 cfu/cm^2. Most of the bacteria were lactic acid bacteria (LAB) that do not contribute to early loss of meat quality. By producing lactic acid and competing with spoilage bacteria, LAB are widely regarded as beneficial. As assessed by a trained meat panel, the confinement odour, the odour noted on first opening the vacuum packs, was highly satisfactory throughout the period of study. At 20 weeks the colour of the beef bloomed to a bright colour and after three days under retail conditions the meat still had a very satisfactory colour. While retail display life would trend shorter beyond 20 weeks, it could be concluded from the study findings that shelf life of the vacuum packs may extend beyond 20 weeks, particularly in food service where storage temperatures are not similar to retail displays.

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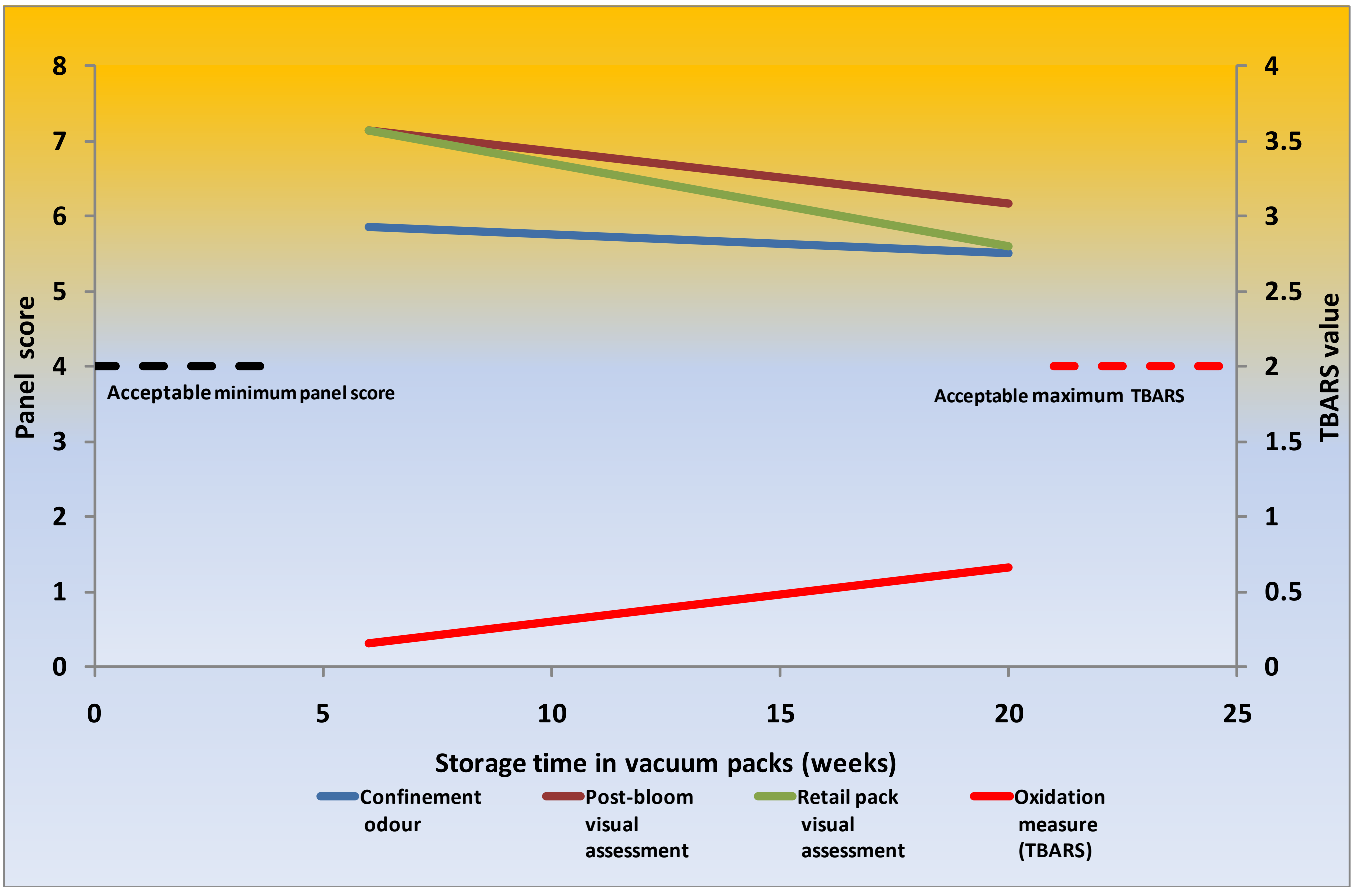

Figure 1: Assessment of vacuum-packaged primals stored for up to 20 weeks. Sensory panel scores plotted for confinement odour (blue line), and visual assessments (brown, green lines), also chemical measure of oxidation (TBARS; red line). The broken horizontal lines indicate the limits of acceptability for the panel scores (black) and TBARS (Red).

Vacuum-packaged primal cuts

It is common to store and distribute chilled beef as primal cuts (2–9 kg) vacuum-packaged in bags made of plastic materials with low permeability to gases. Meat packed in this manner is easy to handle; its colour is preserved and its storage life is greatly increased. Inside a vacuum package the residual oxygen is consumed by tissue and microbial activity, and carbon dioxide is produced. Provided packaging has been performed correctly, there is little head space within a vacuum package. While accurate gas analysis within a vacuum pack is difficult, the atmosphere in the head space most likely contains less than 1% oxygen, some 20–40% carbon dioxide, with the remainder being nitrogen.

Vacuum-packed half striploin and cube roll after 20 weeks of ageing

Vacuum-packaged beef that is stored in low-permeability films is purple in colour since the meat pigment myoglobin is in the reduced form. When vacuum packs of beef are opened, the purple colour should turn to red (return of the 'bloom') within around 30 minutes. Development of a brown colour during storage indicates that an excessive quantity

Tight packs of vacuum-packaged beef. Meat is purple in colour of oxygen has been present during storage. This is caused either by the use of a film which is excessively permeable or because the pack is a 'leaker', with oxygen being able to enter via a faulty bag seam or through a puncture, or because the meat tissue has been unable to consume the oxygen remaining in the pack after vacuum-packaging. One reason for this inability is the packaging of beef too long a period after slaughter. After several days, there is a decline in the activity of certain enzymes in the meat that assist the consumption of oxygen. By avoiding excessive intervals between slaughter and vacuum-packaging (the interval is now frequently less than 24 hours), and by carefully checking vacuum packs for evidence of leakers 24 hours after packaging, Australian processors have successfully prevented premature appearance of brown-coloured beef in vacuum packs.

Maximum commercial storage life of vacuum-packaged primal cuts of red meats is obtained provided that :

1. meat is produced using good manufacturing practice with low initial total counts of micro-organisms that are able to grow at the storage temperature;
2. packaging film is free of leaks and has a low permeability to gases; and
3. there is good control of temperature during the storage period.

When vacuum-packaged beef spoils, it is largely due to aroma and flavour changes. Most usual is the development of an 'off' or atypical flavour in the cooked meat. When first detected this flavour is commonly described as cheesy, sour and acid, but later in storage also as bitter and liver-like. These changes are attributed to the accumulation of acidic end products resulting from the growth of lactic acid bacteria which comprise the main group of bacteria in vacuum-packed product. Sometimes other species of bacteria, including *Brochothrix thermosphacta*, are implicated in spoilage events.

What we mean by shelf life

Generally, food is considered to be past its shelf life when it is no longer acceptable to the consumer. It may either be that the colour, flavour, texture, aroma or nutrient content have deteriorated to the point where the food is no longer acceptable; or it could be when a food-safety issue arises—where the food may make consumers ill. Whilst shelf life is usually equated with spoilage—for fresh meat in particular—the end of retail shelf life might be reached before spoilage, as such, is evident. For example, the loss of bloom of mince (ground beef) or steaks during retail display, or exceeding a microbial count specified as an acceptable maximum by a retailer, may be the determinant of shelf life; whereas spoilage—as defined by off-odour and slime—would be the point at which it is unacceptable for consumption.

The majority of Australian beef sold in vacuum packs is opened, sliced or otherwise prepared for retail sale, and packed for retail display either by overwrapping or in a modified atmosphere. Where shelf life is determined by loss of attractive appearance—as is often the case with retail packs prepared from vacuum packs—that shelf life is set at the time of retail purchase rather than at the time of consumption. The shelf-life guidelines for vacuum-packaged beef given in this paper reflect the widespread retailer requirement for a period of retail display; however, it should be recognized that for food service and similar applications where a period of retail display is not required, the shelf life in vacuum packs will be longer.

While actual spoilage of vacuum-packaged beef is usually microbial in origin, chemical factors also may be important in determining shelf life, particularly when it is defined in terms of appearance.

Consumer acceptance of meat

Appearance is one of the most important attributes by which consumers judge the quality of meat and, therefore, colour deterioration is one of the main factors that limits storage life—at least until the point of purchase. Meat must be packaged in a manner that retains its appearance and presents it in an attractive way.

Many studies have shown that there is no direct relationship between colour and other important properties such as tenderness and juiciness. Once the consumer has purchased the meat, the other properties then become important (odour, flavour, tenderness, juiciness, etc.). The growth of micro-organisms, including aerobic spoilage ones once vacuum packs are opened, may result in changed odour and flavour that is ultimately identified by consumers as spoilage.

Ideally, packaging techniques for retail display and storage should maintain the appearance of meats and delay microbial spoilage.

Meat colour

Myoglobin, a coloured pigment similar to haemoglobin of blood, gives lean meat its colour. The greater the concentration of myoglobin, the darker is the colour of the meat.

Myoglobin is the oxygen-carrying protein of muscle, and can exist in a number of forms which vary in colour. For example, in the absence of oxygen—as in vacuum packs—it is in the reduced form which is purple, but, in the presence of oxygen, it forms oxymyoglobin which is bright red.

The conversion of myoglobin to oxymyoglobin is rapid and reversible. When beef muscle is first cut or has been stored in vacuum packs then exposed to air, it rapidly takes up oxygen and changes from purple to bright red. This is termed blooming and occurs within half an hour in air at 0–5°C. When oxygen is excluded by vacuum packaging, the colour reverts to purple. In the continued presence of oxygen, both myoglobin and oxymyoglobin become oxidized to metmyoglobin which is brown. The reaction proceeds slowly (at least 2–3 days in air at 0–5°C before any metmyoglobin is evident), but it is not readily reversible.

Meat colour is affected by the species, sex and age of the animal. The meat from bulls and older cattle has more myoglobin than does that from young cattle. Within a particular carcase, different muscles contain varying concentrations of myoglobin and so vary in colour. Stress prior to slaughtering also plays a significant role, as it affects the final pH of the meat which, in turn, affects colour. Meat with a high final pH will frequently be dark.

Retail display following vacuum-packaged storage of primals

Vacuum-packaged primal cuts are prepared to smaller consumer cuts prior to sale. The longer the period of prior storage in the vacuum pack, the shorter is the display life of the consumer portions. The end of acceptable display life is normally evidenced by the development of an unacceptable amount of metmyoglobin browning. Longer display life can be achieved by the use of modified atmosphere packaging, but its advantage becomes less as the period of prior vacuum-packaged storage increases.

Meat spoilage

In air, aerobic bacteria predominate on meat. If nitrogen-containing compounds (i.e. amino acids) are used by these bacteria, the end products of microbial growth will include malodorous amines (ammonia, putrescine and cadaverine) and sulphur compounds. Together these cause 'off' odours and flavours that are typically described as putrid. These may become evident when bacterial numbers are as low as one million per cm^2. Because some of these compounds are volatile, spoilage is usually first noted as an off (putrid) odour which causes rejection, i.e. the meat is unacceptable. This can normally only happen in vacuum packs if air has leaked into the packs.

If bacteria use glycogen or other carbohydrates from the meat, rather than the amino acids, the end products are organic acids, especially lactic and acetic acids. Under these circumstances spoilage is due to the accumulation of these acids, and since these compounds do not have a strong odour at the concentrations likely to be produced, spoilage may be noted first as a flavour change (souring). If there is any evidence of spoilage in beef from vacuum packs, it is more likely to be because of flavour—souring—than odour.

Microbial contamination

The muscle tissue of healthy animals contains very few micro-organisms. During processing, the surface of the carcase is commonly contaminated with micro-organisms which come mainly from the hide. These organisms originate from the environment of the animal (soil, etc.) and its gastrointestinal tract (faecal contamination). Other possible sources of contamination include the equipment used in dressing (e.g. knives), and the hands and clothes of the workers. While some micro-organisms of human origin may reach the meat, the bulk of the contamination comes from the animals themselves.

The intention of the meat industry is to produce meat with as low numbers of microbes as reasonably possible, in order to maximise shelf life and minimise the occurrence of organisms associated with food-borne illness. That the industry is successful in doing so is confirmed by scientific studies. National surveys of the microbiological status of Australian beef were undertaken in 1993, 1998, and 2004; the results have been published in peer-reviewed scientific publications. In 2004, chilled beef carcases from 27 abattoirs were found to have an average total viable count of just 21 organisms per cm^2. 96.9% of the carcases had counts of less than 1,000 per cm^2. Although no clear evidence is available, it is likely that the regular attainment of such low numbers of bacteria on carcases from which beef is vacuum-packaged is an important contributing factor in long storage life.

Growth of bacteria on meat

Any contaminating bacteria are largely confined to the surfaces of the meat where oxygen is readily available. Meat is a good source of the nutrients needed by bacteria for growth—proteins, phospholipids, fatty acids and carbohydrate (notably glycogen) and other soluble non-protein substances.

Three environmental factors play a major role in controlling the growth of microorganisms on meats in vacuum packs.

Temperature: Growth rates at 0 to 1°C are only about half those at 5°C and are further reduced as temperature falls. A storage temperature as low as is practical should be used for vacuum-packaged meat. About minus 1°C is optimal provided that temperature control is such that freezing of the packs is avoided.

Gas atmosphere: The growth of many common spoilage organisms, particularly the aerobic ones, is inhibited by the presence of carbon dioxide and/or by the absence of oxygen, i.e. by manipulation of the redox potential. This is the basis of the effectiveness of vacuum packaging in preventing spoilage and prolonging storage life of meat.

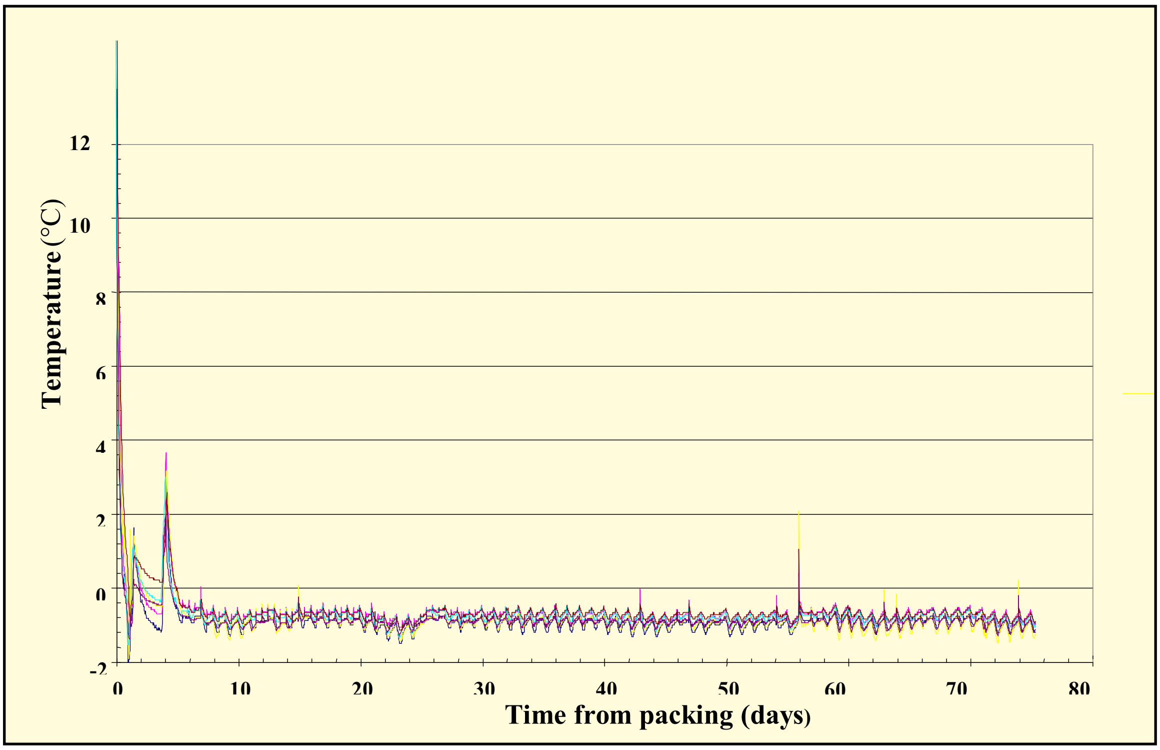

Figure 2: Temperature histories for six test samples stored at Food Science Australia.

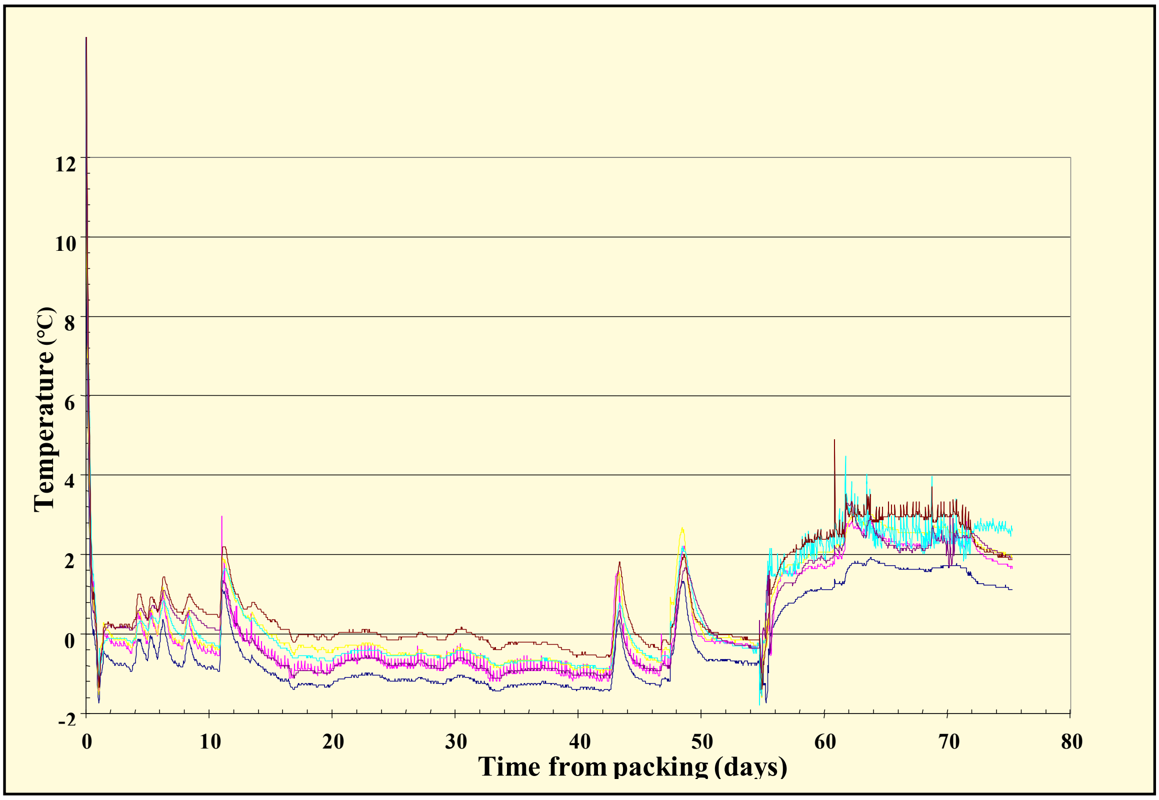

Figure 3: Temperature histories for test samples shipped to, and stored at, US destination.

pH: Whilst most micro-organisms can grow over the range of pH values of muscle (5.4–7.0), this factor becomes important in combination with other factors. For example, if lean red meat is placed in an environment where oxygen is no longer available, the composition of the flora which develops is greatly dependent upon muscle pH. In the context of vacuum packaging, some bacteria that are inhibited in vacuum packs when the pH of the meat is normal (5.4–5.7) can grow to spoilage levels at higher pH. By excluding meat from carcases where the pH of the LD muscle is 6.0 or higher, Australian meat processors of vacuum-packaged meat have eliminated spoilage problems attributed in the past to these bacteria.

Shelf-life study, 2008

A study was conducted in 2008 by Food Science Australia in Brisbane on beef primals destined for United States markets. The study was designed to provide contemporary scientific data on the sensory and microbiological attributes of beef vacuum-packaged commercially by Australian processors. Each of four export-registered slaughter and boning establishments in Australia supplied vacuum-packed striploins and cube rolls for storage and assessment at the Brisbane research laboratory of Food Science Australia. Three of the establishments also shipped vacuum packs of the two primals through normal commercial channels to a destination in the United States.

Samples were stored at Food Science Australia (FSA) under optimal conditions. The temperature of the test primals only rarely (and very briefly) departed from the range minus 1.2°C to minus 0.5°C. Figure 2 shows the history for the first 11 weeks of storage.

The samples sent to the USA were transported under commercial conditions (minus 1.5°C to minus 0.5°C) and then stored at 2°C to 3°C —normal US commercial conditions (Figure 3). The figure displays the short excursions from the target conditions during the loading and unloading of the shipping containers, and up to the time of transfer of the test samples to the US destination at 11 weeks.

The product was examined by a trained meat panel; the panel assessed packs for appearance, odour, and appearance of steaks after retail display. The quality of primals was also assessed by microbiological and chemical testing.

Throughout the storage period, the microbiological count (total viable count) on primals was often very low, less than around 1000 cfu/cm^2. Most of the colonies were lactic acid bacteria. Enterobacteriaceae and *Brochothrix thermosphacta* (bacteria known to contribute in the past to loss of quality of vacuum-packaged meat) were only infrequently detected in samples, even after 20 weeks storage.

The sensory and analytical results for striploins and cube rolls from the four establishments were similar, so results for both primals from all establishments were combined, allowing trends in the data to be calculated.

Throughout the 20-week period of the study, the confinement odour, the odour noticed on first opening the vacuum packs (and an early indication of product spoilage), was assessed as highly satisfactory for all packs (see Figure 1, Page 2). On average, a slight deterioration was noted through the study, but product was still very satisfactory at 20 weeks.

The visual acceptability (colour) of the primals was considered to be highly satisfactory throughout the study period (Figure 1, Page 2). At 20 weeks, the primals were still considered to have very satisfactory post-bloom colour.

Half striploin and cube roll after blooming, 20 weeks of ageing in vacuum packs

The visual appearance after 3 days under retail conditions was considered to be very satisfactory, even in product held for 20 weeks prior to simulated retail packing.

The measured oxidative change (measured as TBARS) is a non-specific test for oxidative products, and at the least, indicates chemical change in the product. The results (Figure 1) are shown for product once it was cut and stored under retail conditions (3°C, under fluorescent light) for three days. Consumer surveys indicate that people may start to detect an off-flavour in cooked meat at TBARS values between 0.6 and 2.0 (Greene and Cumuze 1981). At TBARS values of 2.0, off-flavours are definitely detectable, and the meat is considered to be unacceptable.

Cube roll steaks prepared from primals aged for 20 weeks, after three days of display in overwrap packs

Striploin steaks in retail trays, after 20 weeks storage of primals in vacuum packs

This study demonstrates that Australian vacuum-packed boneless primals (striploin and cube roll) may achieve at least 20 weeks shelf life when held under optimal temperature conditions. Whether all vacuum-packed product will achieve this shelf life is dependent upon the initial quality of the meat (pH, colour), microbiological quality, adequate vacuum packing and temperature control through the supply chain. The results suggest that shelf life may extend beyond 20 weeks, particularly if the primals are used in food service, and they may also be suitable for retail display, depending upon market expectations for the appearance of product. The study supports the commercial observations.

Acknowledgement

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A.F. Egan, I. J Eustace and B. J. Shay (1988) Meat packaging-maintaining the quality and prolonging the storage lie of chilled beef, pork and lamb. *Meat 88: Proceedings of Industry Day*. p.68-75

B. E. Greene and T.H. Cumuze (1981). Relationship between TBA numbers and inexperienced panelists' assessments of oxidized flavor in cooked beef. *Journal of Food Science, 47*, 52-54,58.

The experimental work described in this document is summarized from an MLA report, A.MFS.0132 Investigation of the storage life of vacuum packaged beef (2009)

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Meat technology update

4/09 – August 2009

Hormonal Growth Promotants and Meat Quality

- **Hormonal growth promotants (HGPs) increase cattle growth rates and carcase size. Different compounds are used for heifers and steers, to work in conjunction with natural hormones.**
- **Marbling scores can be reduced.**
- **The use of HGPs can result in detectible reductions in tenderness.**

Hormonal growth promotants (HGPs) are used extensively in northern Australia and the feedlot industry. They are used to a lesser extent in southern Australia and are banned in Tasmania. HGPs are used to improve the rate of liveweight gain and the feed efficiency of cattle by producing a hormone that is very similar in structure to the animal's natural hormone. In excess of 2.5 million doses are sold annually in Australia and, of these, about half are used in pasture-fed steers in northern Australia. The industry currently uses a wide range of HGPs that can be implanted at the different stages of production such as at weaning, at backgrounding on pasture, and at entry to the feedlot. The implants can have a functional life of up to 400 days and contain either oestrogenic or androgenic compounds or combinations of both.

The increase in liveweight due to HGP implants is well documented with an increase in liveweight gain of 10–20 kg over 100 to 150 days; however, the effect on meat quality is less clear. Some studies have found that the use of HGPs leads to tougher meat, but others have found little effect, or that the increased toughness is so slight as to be not commercially significant. A series of trials has been completed by scientists at the Beef Co-operative Research Centre (CRC) and MSA to document the effect of different HGP dosage strategies on weight gain and meat quality.

Growth rate

HGP treatment can result in significant improvement in growth rate of both pasture-fed and lot-fed cattle. In one trial, pasture-fed steers administered an implant every 100 days were on average about 7.5% heavier than non-implanted steers after periods of up to 671 days. There was an advantage to implanted steers during periods of moderate weight gain (~0.75 kg/day), but when pasture was poor and there was static or very slow growth, there was no advantage to the implanted steers. In a commercial situation, however, animals would not be re-implanted every 100 days, so the weight gains reported are unlikely to be achieved.

There is a greater benefit from HGP implantation when cattle are growing quickly, such as during lot feeding. The effect of the implant also increases with time with greater differences in weight between implanted and non-implanted cattle as time on feed increases. In one trial, implanted cattle fed to Korean weight specifications gained 6.7% more, while those fed for the Japanese market gained 7.2% more. Steers responded better than heifers to the implants, gaining almost twice as much as heifers—but, in this trial, steers and heifers were given different HGP formulations and so direct comparisons cannot be made.

Carcase characteristics

Along with the increase in live weight due to HGP treatment, there is a corresponding increase in dressed carcase weight. HGP-implanted carcases also have a higher ossification score, but a 10 to 15% lower marbling score. The reasons for reduced marbling scores are unclear. Some have proposed that implantation early in an animal's life could delay the deposition of marbling, whereas others consider that it is due to the stimulation of increased protein deposition which effectively dilutes the fat content within the muscle. A recent study in the U.S. found that implantation did not have a direct effect on intramuscular lipid deposition, whereas others determined that implanted cattle should be slaughtered at a higher body weight to achieve the same marbling score as non-implanted cattle. The higher ossification scores give the impression of a carcase that is more mature for its age than one that has not been hormone treated.

HGP implantation has no effect on dressing percentage, therefore an overall increase in carcase weight leads to an increase in weight of saleable meat. Subcutaneous fat depth and ultimate pH are not affected by HGP implantation, but intramuscular fat (marbling) was decreased.

The 'aggressive' use of HGPs has been shown to increase the stress susceptibility of cattle resulting in an increase in dark-cutters. Provided the implants are conducted strictly according to directions, there should be minimal effect on meat colour. Allowing a period of at least 100 days between implantation and slaughter should minimise the effects on meat colour.

Meat quality

Most studies have shown that there is a measureable decrease in eating quality of beef from animals that have been implanted with hormonal growth promotants. This has been revealed through both objective measurements (Warner-Bratzler shear force) and by the results of sensory measurements using consumer panels.

Increases in shear force due to HGP treatment were greater the longer the animal had been on the implantation program (Hunter, 2001). Feedlot-finished cattle implanted for 92 days and fed for the domestic market did not have a significantly higher shear force than non-implanted cattle, whereas those implanted for over 300 days and prepared for the Japanese market were significantly tougher (Figure 1). The study indicated that this is not an effect of water-holding capacity: HGP treatment had no effect on quantity of fluid lost during cooking.

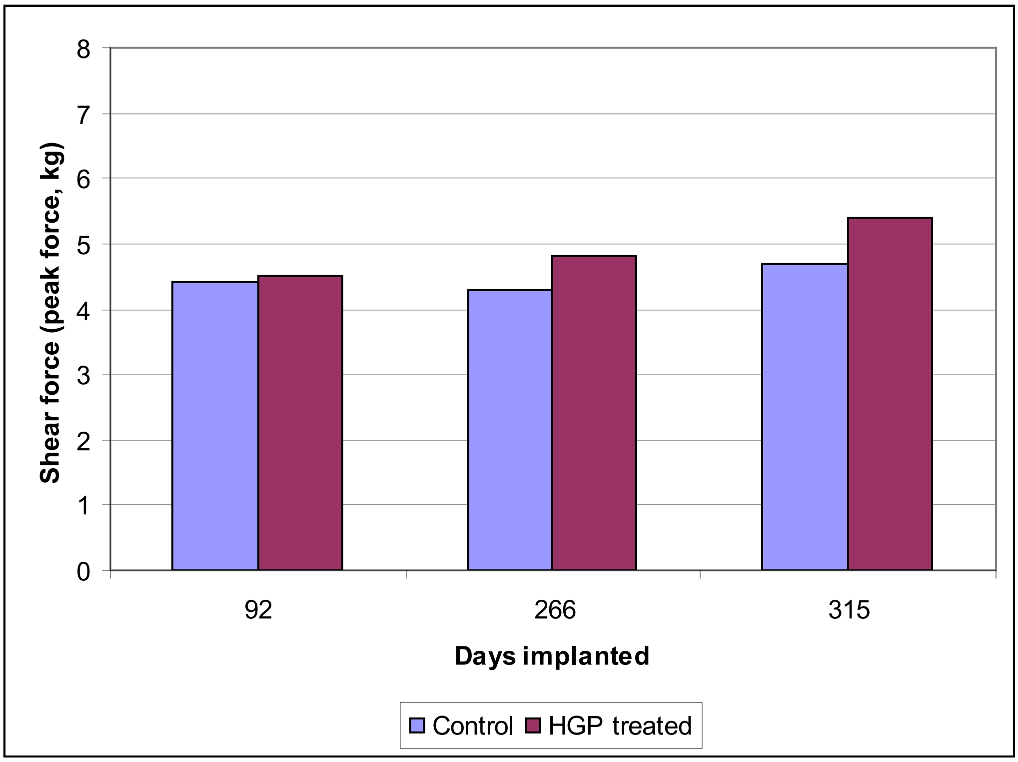

Figure 1: Effect of HGP treatment on shear force of M. longissimus dorsi (Hunter et al. 2001)

Furthermore, consumer panels were able to detect differences between meat from untreated cattle and meat from HGP treated animals. For example, Angus steers that had been HGP implanted and lot fed for 55 days had lower sensory scores (considered to be less acceptable) for the *M. longissimus dorsi* (LD) than similar non-implanted steers that had been on the same feed regime. The differences in tenderness and overall composite score were highly significant, as shown in Figure 2.

A statistical analysis of the combined results from 30 different international HGP treatment-control comparisons on beef also showed that HGP treatment had a negative effect on beef palatability in all but 3 experiments. These studies appeared in refereed journals dating back as far as 1956. This 'meta-analysis' showed that the effect of HGP implantation is to increase the shear force for the LD by 0.27 kg and to reduce tenderness by 5.4 points on a 100-point scale.

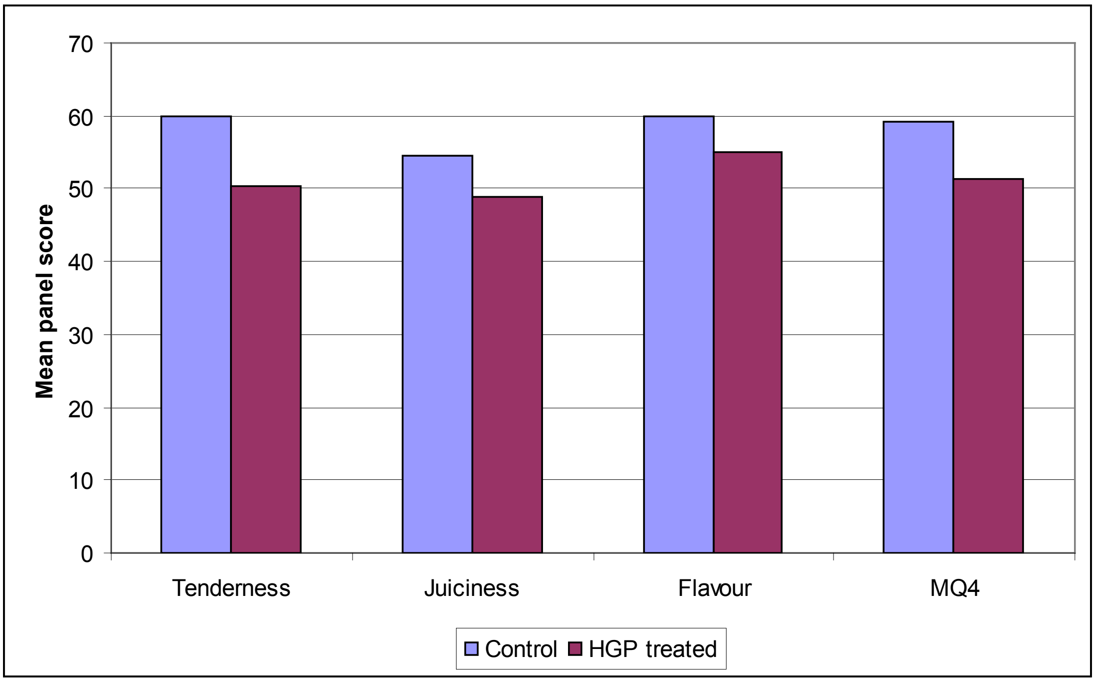

Figure 2: Consumer panel scores for LD muscle (adapted from Thompson et al. 2008a)

Meat scientists disagree on the reasons for this reduced palatability, but a favoured theory is that the results are consistent with reduced protein degradation, possibly as a result of increased calpastatin activity in the live animal resulting in lower ageing rates post slaughter and less tender meat. HGP treatment is known to increase protein synthesis and reduce degradation, resulting in more muscle growth.

Effect on other muscles

The majority of researchers concentrate on the *Longissimus* or loin muscle, when assessing the effects a process may have on meat quality, but this muscle is not always indicative of the effects on other valuable cuts. Trials, which have included six different muscles from beef carcases, have shown that HGP treatment can have significant detrimental effects on the tenderness scores of the *M. longissimus dorsi* (striploin and cube roll) and the *M. biceps femoris* (silverside), but little or no effect on the tenderness of the *M. gluteus medius* (rump), *M. psoas major* (tenderloin), *M. triceps brachii* (blade) or the *M. infraspinatus* (oyster blade).

Generally, it appears that muscles that show the greatest tenderness improvement during ageing are the most affected by HGP implantation and vice versa. The striploin and silverside show significant improvement in tenderness during ageing for 14 days, while the other primals (such as the tenderloin, rump and blade) show little, if any, improvement in eating quality between ageing for 5 days and 21 days. This is consistent with the theory that HGP implantation increases calpastatin and those muscles with the highest calpain to calpastatin ratio (or greatest ageing rate) would have the greatest response to HGP application and therefore, potentially the greatest impact on post-mortem tenderness. The increase in calpastatin slows the ageing rate resulting in less tender meat from those muscles that improve most during ageing.

Effect on Brahman cattle

Cattle with a high proportion of *Bos indicus* appear to respond differently to cross-bred *Bos taurus* cattle to the implantation of HGPs. In a study involving a total of 478 *B. indicus* and *B. indicus* x *B. taurus*-cross steers, carcases from cattle with 100% *B. indicus* were 19 kg lighter, and had lower marbling scores than those with 50% *B. indicus*. Implantation with oestradiol-17β resulted in a 17-kg overall increase in carcase weight relative to the non-implanted controls.

As the percentage *B. indicus* content increases above 50%, the decrease in consumer scores for tenderness due to HGP treatment becomes more pronounced as can be seen in Figure 3. HGP implantation appears to act synergistically to produce even tougher meat from the cattle with high *B. indicus* content. Meat from implanted cattle with high *B. indicus* content can be very tough unless steps are taken to ensure the meat is more palatable. It is known that meat from *B. indicus* cattle has increased calpastatin activity and decreased tenderness compared with meat from *B. taurus* cattle. It is assumed that the combination of *B. indicus* and HGP treatment result in a lower protein turnover rate and consequently tougher meat.

Implantation strategies

A wide range of HGP programs involving different promotants and implantation times can be used to improve the growth rate of cattle. HGPs are generally implanted at the time of other cattle management activities such as weaning, transport to a backgrounding property, during backgrounding, and at entry to a feedlot. Is it more detrimental to meat quality to implant HGPs at all of these stages of production, or only at weaning and feedlot entry?

Implants are normally based on either the female hormone oestrogen or the male hormone androgen or a combination of the two. They can be naturally occurring hormones or synthetic such as the androgenic compound trenbolone acetate (TBA). TBA is often used in combination with an oestradiol compound for finishing steers and heifers.

In a large experiment, several proprietary HGPs containing oestrogenic or androgenic compounds or a combination of the two were implanted at different stages of production. There appeared to be no difference in carcase weight or other carcase quality characteristics between implanting heifers twice and implanting them three times, and also no differences noted between the HGPs tested, although there were only small numbers of animals in each treatment group. Neither were there any differences in sensory scores for meat from the different treatment strategies. There were some small differences in weight gain between treatment strategies for steers, but little apparent difference in meat quality among the different strategies. All implant treatments gave poorer tenderness scores than the non-HGP controls.

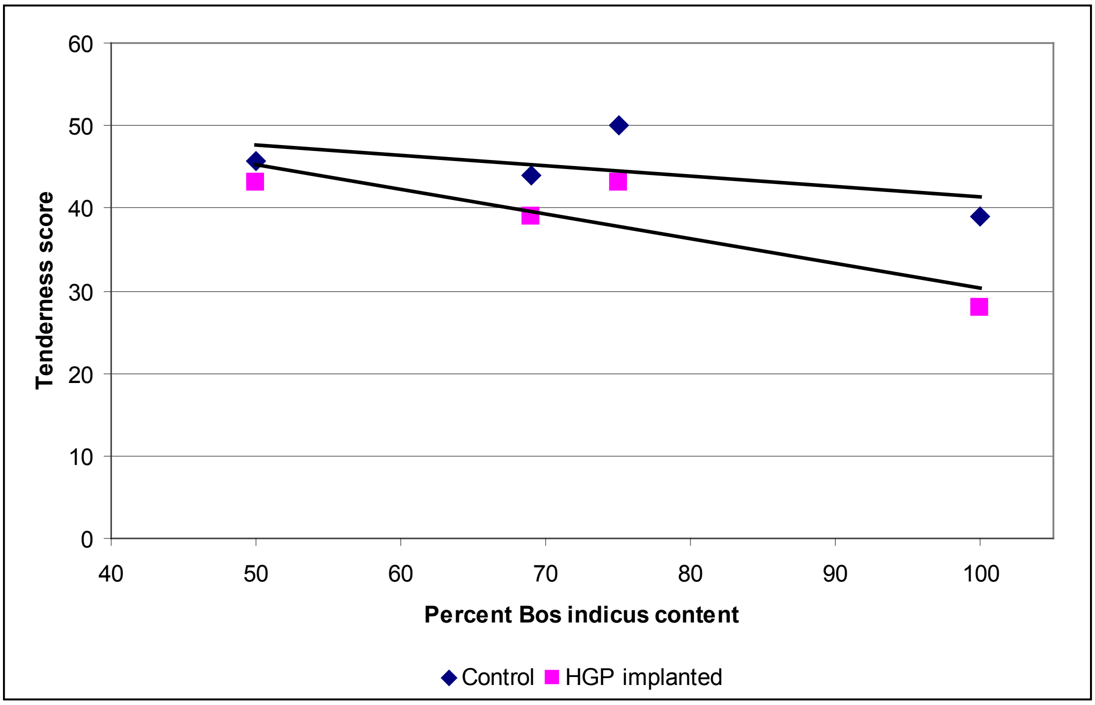

Figure 3: Bos indicus content and HGP treatment on tenderness (adapted from Thompson et al. 2008b)

Safety of HGPs

Although the European Union will not accept meat from animals that have been treated with hormones, it has been acceptable to many other markets for over 50 years. HGPs have been used in Australia since 1979. The main concern to consumers is the level of oestrogen and its possible effect on adolescents and the foetus, which can be sensitive to small increases in hormone levels. Concern has also been expressed regarding the carcinogic effect of oestradiol to humans as it stimulates cell division, thereby increasing the possibility of random errors during DNA duplication.

Residues from hormone implants are higher in internal organs such as livers, than in the muscle of cattle. When heifers had received three or four implants containing the synthetic androgenic hormone TBA, the mean concentration of 17 alpha-trenbolone in the livers was 4.3 ng/g when slaughtered 30 days after implantation. The concentration of 17 beta-trenbolone in the muscle was less than 0.4 ng/g. The Australian Pesticides and Veterinary Medicines Authority has set a maximum residue limit (MRL) of 0.002 mg/kg (2.0 ng/g) for TBA. The natural level of testosterone in meat from steers was determined in Germany to be in the range <0.01–0.14 ng/g. The mean level of the oestrogen-like compound 17β-Estradiol was measured at <0.04 ng/g.

Oestradiol, testosterone and progesterone are naturally present in many foods of animal origin and some of plant origin. It has been estimated that a person would need to consume 77 kg of beef from HGP-treated steers to receive the same amount of oestrogen as eating one hen egg.

Countering the effects of HGPs

It appears that HGP treatment of cattle can result in measureable reductions in palatability of beef, especially in the case of cattle with a significant Brahman content. There are several options that the processor can take to ensure acceptable eating quality of the meat from implanted cattle.

- Meat from HGP-treated animals does not improve as quickly during ageing, so an additional period may be required. For example, cuts such as the striploin and silverside should be aged for at least 3 weeks.
- Tenderstretching (hanging by the aitch bone or sacrosciatic ligament) during chilling has been shown to provide great improvement in the tenderness of certain primal cuts. This will largely offset the effects of HGP treatment.
- Carcase chilling and electrical stimulation should be managed to provide the optimum rate of pH/temperature fall so that the MSA Window is met.

Further reading

http://www.beefcrc.com.au/BeefCRCFactsheets

Australian Journal of Experimental Agriculture Vol. 48, No. 11, Special Issue Meat Standards Australia. http://www.publish.csiro.au/nid/73/issue/4061.htm

Hunter, R.A., Burrow, H.M. & McCrabb, G.J. (2001). Sustained growth promotion, carcass and meat quality of steers slaughtered at three liveweights. *Australian Journal of Experimental Agriculture,* 41, 1033-1040.

Thompson, J.M., McIntyre, B.M., Tudor, G.D. Pethick, D.W., Polkinghorne, R. & Watson, R. (2008a). Effects of hormonal growth promotants (HGP) on growth, carcass characteristics, the palatability of different muscles in the beef carcass and their interaction with ageing. *Australian Journal of Experimental Agriculture*, 48, 1405-1414.

Thompson, J.M., Polkinghorne, R., Porter, M., Burrow, H.M., Hunter, R.A. McCrabb, G.J. & Watson, R. (2008b). Effect of repeated implants of oestradiol-17β on beef palatability in Brahman cross steers to different market end points. *Australian Journal of Experimental Agriculture*, 48, 1434-1441.

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

00/3 – June 2000
Reprinted November 2006

Sheep meat eating quality

Almost all consumers who buy sheep meat expect it to be tender and flavoursome. Toughness is caused by four major factors—advancing age of the animal, 'cold shortening' (the muscle fibre contraction that can occur during chilling), animal stress [unfavourable meat acidity (pH)], and the cut (i.e. connective tissue content/structure). Meat quality can be improved by careful selection of pastures, correct pre-slaughter handling and carcase processing.

Does breed influence quality?

The practical answer is 'no' because any difference is slight. More important are the other factors mentioned above. Meat from suitable animals of all breed can be acceptably tender if processed correctly.

There is some evidence that Merinos may be more susceptible to dark cutting – this will increase the risk of toughness at intermediate elevations of pH.

'Callipyge-like' genes may result in increased toughness.

Animal age

Age-related toughness depends upon the amount and strength of connective tissue in muscles in the various cuts. Within the one carcase, there will be differences in tenderness, with some leg muscles (e.g. the *semimembranosus* and *semitendinosus* muscles) frequently being tougher than the loin muscle (the *longissimus dorsi*). In general, forequarter cuts from a carcase are tougher than hindquarter cuts because they contain more connective tissue.

In the absence of other influences, the younger the animal (even within the category of lamb), the more tender the muscle will be. As an animal gets older, the connective tissues become more resistant to breakdown during cooking. This manifests itself as toughness. Because toughening due to connective tissue increases progressively with age, it is important to recognise the age at which the level of this inherent toughness is likely to be considered undesirable.

However, it is still not clear just when the 'age' effect on toughness becomes significant for consumers, especially when other factors are controlled (particularly cold shortening, pH). The impact on eating quality of lambs cutting their teeth is poorly understood and the subject of current research.

Connective tissue toughness can be minimised by an appropriate cooking method, e.g. slow, moist cooking rather than grilling.

Generally speaking, eating quality declines with age; however, the rate

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varies between muscles. Flavour becomes stronger.

Growth pattern and nutrition

In a 1995 study, meat tenderness was comparable (and acceptable) for all growth paths studied except for that in which lambs were held at slaughter weights for approximately five weeks prior to slaughter.

Recent studies have indicated that, with some sires, there are relationships between growth rate and tenderness. As growth rate increases, there is an increase in tenderness. NZ work suggested slow growth lambs were tougher than high-growth lambs (killed at the same final carcase weight) but this was almost entirely as a result of an elevated pH effect. Feed intake immediately before slaughter may also affect tenderness. Studies with beef suggest that continuous feeding almost until the time of slaughter may improve meat quality.

High growth rate means that animals can be slaughtered at optimum carcase weight(s) at younger ages–the younger the age, the more tender the muscles with a high connective tissue content will be.

There is little objective information on the impact of grain feeding on eating quality.

Flavour

Some people avoid sheep meat because they object to its odour during cooking and to its flavour, particularly the meat from mature animals with its apparently stronger odour and flavour. This effect will vary with country and within country, depending on traditions and prior exposure. Both trained taste panels and consumer panels can detect an increase in flavour with increasing animal age (lambs→hogget→mutton).

Taste panels can also detect flavour differences arising from lambs being fed on different pastures or supplements. Feeds that have been shown, on occasions, to produce less acceptable flavours include lucerne, forage rape and an oat-lupin grain ration. It is not clear whether these less desirable flavours would always be detected by consumer panels.

In a 1993 New Zealand lamb study, the sensory properties of meat of two breeds common in New Zealand—the Coopworth and the Merino (a fine wool breed)—were studied. Although the work showed breed effects, it is argued that pH rather than breed might be the dominant effect on flavour and odour characteristics. The higher-pH meat of the Merino breed (pH 6.2) in this trial gave negative sheep meat flavour and foreign flavour descriptors (bland, fishy, stale, grainy, bloody) and this is consistent with other reports in the literature on high-pH meat.

Other NZ work has shown several compounds associated with flavour and, as we progress our knowledge, the possibility of specific feeding and/or lairage protocols to influence flavour becomes more likely.

A Canadian lamb study revealed that ram and ewe lambs had a superior flavour to wether lambs. There are, however, numerous other reports that indicate ewes and wethers, and rams and wethers, are similar in flavour.

Animal Stress

A significant factor affecting meat tenderness is meat acidity (pH). Toughness increases as the ultimate pH (i.e. the pH value reached after post-mortem chemical reactions in the meat have ceased) increases from 5.4 to 6.0, then decreases with further increase in ultimate pH. In beef, it is generally acknowledged that the cut-off point for optimum acceptability is maximum pH 5.7. The figure for lamb is similar.

Any stimulus which causes use of muscle energy (glycogen) whilst the animal is still alive, e.g. transport and other stress, method of marketing, time off feed, lairage management, extremes in weather conditions, disease and muscular activity, can cause animals to produce high pH (and therefore potentially tough) meat. Also, the size of the glycogen level or ‘tank’ on-farm is important—good nutrition pre-slaughter helps assure the glycogen 'tank' is full on-farm and means the animals can better cope with the stresses of consignment.

Studies on pre-slaughter supplementation to boost glycogen levels are under way

Chilling treatment

A major cause of meat toughness is the contraction of muscles during chilling. If a muscle is chilled rapidly before the onset of rigor mortis ('setting'), the muscle fibres contract (cold shorten).

Rapid chilling of pre-rigor carcases results in cold shortening if unrestrained muscles are cooled below 10°C before the on-set of rigor. More emphasis is now placed on achieving lower meat temperatures at load-out and this can result in loin temperatures being reduced to below 10°C within three hours of slaughter, which can cause tough meat, due to shortening, if corrective measures are not implemented. Muscles already in rigor, however, will not shorten, regardless of the temperature at which they are held.

Ageing

Holding meat in a chilled state for an extended period is known as 'ageing' and is a traditional way of tenderising meat.

Ageing, unlike the Tenderstretch process and electrical stimulation, achieves the tenderising role through the attack of natural enzymes on muscle fibres. Unfortunately, ageing is not effective in overcoming toughness arising from connective tissue, so meat from old animals and cuts containing a high proportion of connective tissue do not respond well to ageing. It is also important to realise that ageing is less effective where severe cold shortening of muscle has occurred. Cold-shortened meat may need a longer ageing period than unshortened meat.

Ageing of 'tenderstretched' or electrically stimulated meat produces a further slight improvement in tenderness (Figure 1).

In a study in Victoria, chilled non-stimulated lamb samples obtained from butchers, wholesalers and boning rooms between 1991 and 1993 were found to be of good, although variable, quality. It was reported that ageing lamb in commercial chillers for three or more days prior to retail sale could significantly improve tenderness. A similar result was obtained in another study for lamb loins purchased from shops in Sydney and Melbourne. It was calculated (based on modelling) that 27 per cent of one-day-old samples would be tough, while only 6 per cent of three-day-old samples would be tough. Thus both surveys indicated that an ageing period of at least three days was necessary to ensure adequate tenderness in unstimulated lamb.

However, there is evidence that a considerable amount of lamb reaches the consumer less than three days after slaughter. This is not surprising, as there are economic incentives for both processors and retailers to minimise storage times. Consumers are therefore quite likely to purchase unstimulated lamb that has been inadequately aged.

In summary, lamb, unless severely cold shortened, ages rapidly. Ageing meat for a period of 3—5 days generally increases tenderness. Longer term ageing (to 14 days) has little further effect on tenderness. However there is a need for further work to redefine ageing profiles.

Electrical Stimulation

It has been accepted for many years that electrical stimulation of beef carcases prevents cold shortening and leads to an improvement in tenderness, and many Australian abattoirs processing beef carcases routinely use electrical stimulation (ES). Similarly, many New Zealand plants routinely use ES on sheep and lamb carcases. There are, however, very few Australian abattoirs that use ES on lamb carcases.

During ES a pulsed electric current is passed through each carcase soon after slaughter. It greatly increases the rate of the natural processes leading to rigor mortis. This, in turn, substantially reduces the ability of the muscle to shorten (and hence toughen) when cooled rapidly.

One of the objectives of a 1997 MRC project was to develop a lower-cost ES unit for treatment of lamb carcases (see Further Reading). Extra low voltage (ELV) ES applied to individual, dressed carcases via rubbing bars in commercial works resulted in a statistically significant improvement in tenderness, even when applied up to 25 minutes after slaughter. MRC trials also indicated that the application of ES to the carcases would reduce the overall quantity of tough product. As seen in Figure 1, high-voltage electrical stimulation of lamb carcases reduced the WB shear force by 50%. Some muscles of lamb that had been electrically stimulated (high voltage) were twice as tender as those that had not been stimulated at all. This single management change transformed lamb that was likely to have been unacceptably tough into an acceptable, tender product.

Tenderstretch has similar effects in hindquarter and loin primals. Neither ES nor Tenderstretch has much effect on the tenderness of muscles restrained from shortening by their carcase attachments.

Electrical stimulation of lamb may improve meat colour (especially in the short term) as well as tenderness.

The tenderness of muscles from non-stimulated lamb carcases may be quite variable. In some cases the muscles may be so tender that ES causes little improvement in tenderness. In other cases, the muscles may be so tough that, even though ES has a marked effect, the muscles from the stimulated carcases are not particularly tender. Therefore the use of ES on its own, without regard to animal variability and other processing factors, cannot be relied upon to produce product of superior tenderness consistently.

Hot-boned lamb, whether subsequently stored chilled or frozen, is likely to be tough unless the carcases receive electrical stimulation.

Frozen lamb

Lamb and mutton frozen soon after slaughter can be very tough as a consequence of cold shortening. As indicated above, toughness in such frozen carcases can be avoided if the carcases are chilled sufficiently and then aged at chiller temperature (before freezing), or by the use of electrical stimulation.

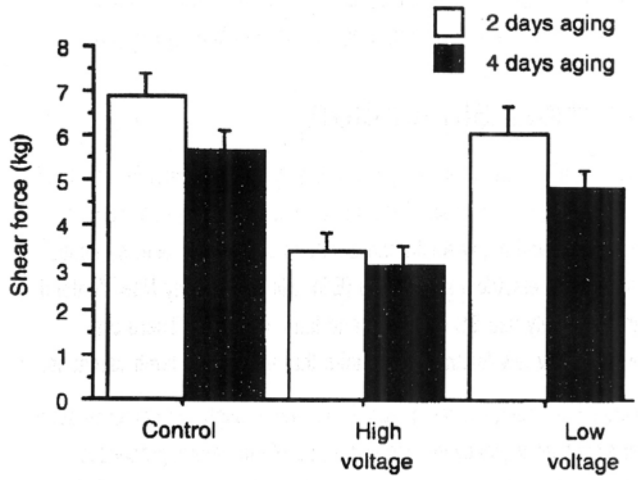

FIGURE 1 Impact of electrical stimulation and days ageing on Warner-Bratzler shear force (tenderness)

Tenderstretch

In this method, many of the valuable muscles of a carcase (i.e. the hindquarter and loin primals) are restrained and prevented from cold shortening during the rigor process by changing the suspension point of the hot carcase from the achilles tendon to the pelvic girdle. This process leads to a tenderness improvement in these cuts.

The carcases must be left hanging, suspended by the pelvic girdle, until rigor mortis is established. After this period the carcase can be hung again by the achilles tendon.

What is the eating quality of Australian lamb?

Recently, Meat & Livestock Australia Ltd (MLA) commissioned a survey to examine variation in the tenderness of lamb. Lamb was purchased randomly from retail butchers and supermarkets in four cities and also from two branded lamb alliances. Lamb mid-loins were objectively measured for tenderness. There was a significant variation between capital cities in the tenderness of lamb available for sale. Lamb purchased in Perth and Melbourne was tougher than that purchased in Canberra and Sydney (Figure 2). Tenderness comparison between two branded lamb alliances also revealed significant variation.

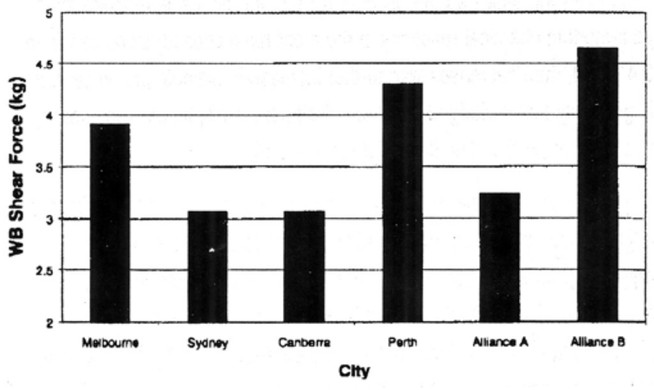

FIGURE 2: Difference between cities in lamb tenderness

Twenty per cent of lamb purchased in the study had WB shear force value of greater than 5 kg—a nominal and somewhat arbitrary estimate of the cut-off level for consumer acceptability. However, four in five samples in the study were likely to have been of acceptable tenderness.

Please note that WB shear force measurements are only an estimate of eating quality and it is now generally agreed that they need to be backed up by actual consumer studies. Warner-Bratzler shear devices measure tenderness, which is only one of the factors that a consumer considers when deciding the overall acceptability of lamb. Flavour and juiciness, neither of which is directly measured by the Warner-Bratzler, are attributes that may be important in the consumer's assessment of lamb.

The major aim of a trial carried out by Meat & Livestock Australia (MLA) in 1999 was to define the basis of consumer perception of lamb and sheep meat quality. MLA is carrying out another consumer attitudinal survey and this will be ready later this year.

The Future

MLA has a lamb and sheep meat eating quality research program underway. Key issues for further research will be determined following extensive consultation with industry.

The possible research scenarios include breed, age, fatness and finishing systems. Processing factors for investigation could include chilling regime, electrical stimulation (including extra-low voltage), hanging method and pre-slaughter stress with emphasis on optimal lairage protocols (in relation to previous on-farm nutrition). The main wholesale/retail factors considered to be of importance are the age of the meat and the cut. The consumer factor considered would be the cooking method.

The aim is to produce a simple consumer-driven model that will allow us to predict the eating quality of sheep meats. The model will be developed with close industry consultation, with final decisions on methods of adoption in the hands of industry.

Further Reading

Pethick, D W et al., 'The regulation by nutrition of glycogen in the muscle of ruminants', *Recent Advances in Animal Nutrition in Australia*, 1999, **12**.

Meat & Livestock Australia Report, Project SMEQ.001, October 1999, *Consumer sensory perception of lamb and sheep meat.*

1999 Lamb Industry Convention & Trade Exhibition-Proceedings.

Jeremiah, L E, Tong, A K W and Gibson, L L, 'The Influence of lamb chronological age, slaughter weight, and gender. Flavor and texture profiles', *Food Research International*, 1998, **31**, No. 3, 227—242.

Meat Technology Update Newsletter No. 98/3, 'Taints in meat'

Meat Technology Update Newsletter No. 98/2, 'Tenderstretch'

Electrical Stimulation Guidelines for Lamb Carcases, 1997, funded by the Meat Research Corporation.

Watanabe, A, Daly, C C and Devine, C E, 'The Effects of the Ultimate pH of Meat on Tenderness Changes During Ageing', *Meat Science*, 1996, **42,** No. 1, 67—78

Ferrier, G R, Thatcher, L P and Cooper, K L 'The effects of lamb growth manipulation on carcass composition', *MEAT '95* Conference Proceedings, September 1995.

Hopkins, D L, Holst, P J and Hall, D G, 'Effect of grain or silage supplementation on meat quality attributes of cryptorchid lambs grazing lucerne or annual grass-clover pastures', *Australian Journal of Experimental Agriculture,* 1995, **35**, 461—5.

Hopkins, D L, Beattie, A. S. and Pirlot, K L, 'Meat quality, carcass fatness, and growth of short scrotum lambs grazing either forage rape or irrigated perennial pasture', *Australian Journal of Experimental Agriculture,* 1995, **35**, 453—9.

Young, O A, Reid, D H, Scales, G H, 'Effect of breed and ultimate pH on the odour and flavour of sheep meat', *New Zealand Journal of Agricultural Research*, 1993, **36**, 363—370.

Devine, C E, Graafhuis, A E, Muir, P D and Chrystall, B B, 'The Effect of Growth Rate and Ultimate pH on Meat Quality in Lambs', *Meat Science,* 1993, **35**, 63—77.

'Benchmarking Lamb Eating Quality', Final Report to Meat & Livestock Australia by Department of Natural Resources and Environment, Victoria.

'An Introduction to the Lamb and Sheepmeat Eating Quality Research Program', Meat & Livestock Australia.

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MEAT TECHNOLOGY UPDATE
Cutting-edge technology for the meat processing industry

Meat technology update

6/05 – December 2005

Processing factors affecting sheep meat quality

Careful selection of processing procedures can do much to optimise the retail acceptability and tenderness of lamb.

A survey of sheep meat from Australian retail outlets in the late 1990s indicated that there was considerable variation in tenderness. A key finding was that 20% of lamb samples purchased during the study were likely to have been unacceptably tough to consumers. Encouragingly, surveys indicated that 75% of consumers would purchase more lamb if they had access to tender and tasty product.

Consequently, Meat & Livestock Australia and the Sheepmeat Council of Australia initiated a series of research projects under the Sheep Meat Eating Quality (SMEQ) program. The projects covered sheep meat production from animal breeding through production, processing, retailing and cooking methods. A feature of the SMEQ program was that the meat acceptability was assessed by consumer taste panels, as the consumer was considered to be the ultimate arbiter of overall product eating quality.

Post-slaughter factors have a significant influence on the eating quality of sheep and lamb meat. This Meat Technology Update provides information for processors on how to optimise sheep meat eating quality and covers factors such as electrical stimulation (ES), hanging and cooling, and meat ageing. Some factors that influence retail display life are also discussed.

The application of best practice based on research results from the sheep meat eating quality program, including application of ES or tenderstretch, has resulted in improved tenderness of lamb purchased by the consumer (Figure 1). Far fewer tough samples are encountered meaning that consumers are less likely to have a poor eating experience.

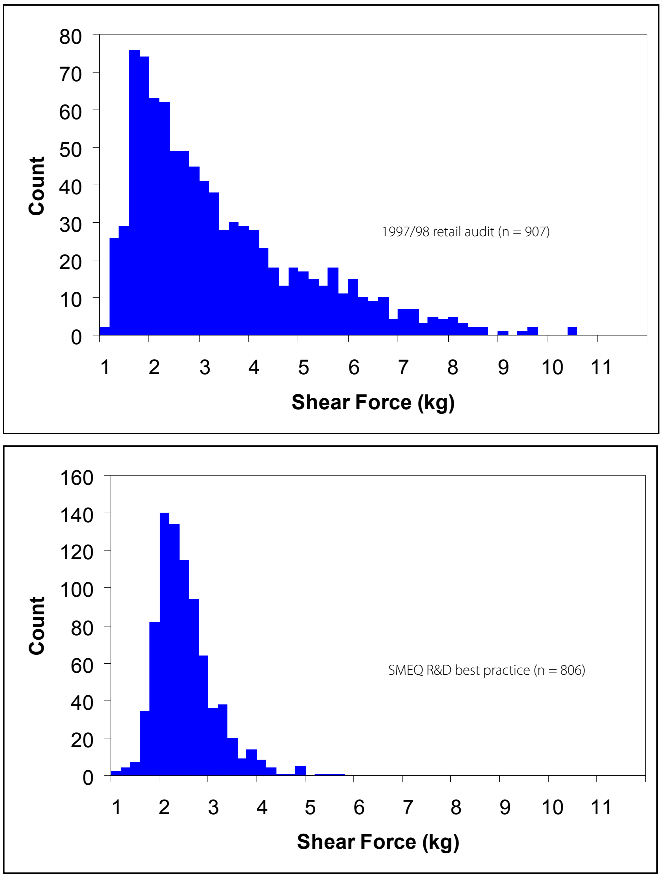

Figure 1: Improved lamb loin tenderness resulting from SMEQ R&D (After Pethick, 2005)

Electrical stimulation

Post-slaughter electrical stimulation (ES) of sheep and lambs has been available for many years, but its use has been limited because the recommended high voltage systems required expensive safety housing and barriers. The high voltage systems used an alternating wave form with peak voltages of 1100 volts at a pulse rate of 14 pulses per second. New waveforms have been developed which use short-duration pulses (at 14 per second) with a peak voltage of about 300 V (Figure 2). The effective voltage (RMS) is considered safe and no special protection is required.

ES results in a rapid fall in muscle pH and allows carcases to be rapidly cooled without inducing toughening due to cold shortening; however, carcases can be over-stimulated and enter rigor too early resulting in toughening due to heat shortening, increased drip loss and pale meat colour. The new technology systems will allow the amount of stimulation to be tailored to the application.

Mid-voltage ES (i.e. approx. 36 V RMS) can be applied to dressed carcases at the end of the slaughter line (Figure 3). The

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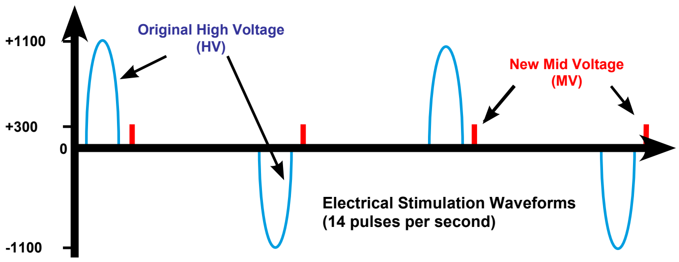

Figure 2: Electrical stimulation waveforms

application electrode can be divided into individual sections to enable control of the stimulation dose to individual carcases and it is relatively safe, so it is easier and cheaper to install. New systems are also available for application to pelt-on carcases at the beginning of the process chain.

Hanging and cooling

Carcases may be hung by either the traditional Achilles tendon method or suspended by a hook placed under the pubic symphysis - tenderstretched. In the tenderstretch method many of the valuable muscles of the loin and hindquarter are restrained and prevented from contracting due to cold shortening during chilling. After rigor mortis, the carcases can be hung again by the Achilles tendons.

The effect of tenderstretching on sensory scores of three different muscles (Table 1) showed that tenderness and overall liking scores were increased for the *longissimus* (loin muscles) and *biceps femoris* (major leg/silverside muscle), but there was little effect on the *serratus ventralis* (brisket).

Table 1: Effect of Tenderstretch on mean sensory scores

Muscle	Tenderness	Overall Liking*
longissimus		
Normally hung	60.0	59.4
Tenderstretch	65.2	62.7
biceps femoris		
Normally hung	52.5	55.8
Tenderstretch	57.0	58.2
serratus ventralis		
Normally hung	59.4	55.8
Tenderstretch	59.1	58.2

* Overall liking included juiciness and flavour as well as tenderness

The relationship between meat temperature at pH 6 (temp@pH6) and overall liking for tenderstretch and normally hung carcases is shown in Figure 4. In normally hung carcases the highest scores occurred at a temp@pH6 of about 21°C. In contrast, scores for the tenderstretched carcases were relatively insensitive to a wide range of cooling conditions.

At low temp@pH6 (<10°C), muscles from the normally hung carcases would presumably have 'cold-shortened' and the meat was therefore tougher. If the temp@pH6 was high (>30°C), then the normally hung carcases would presumably have 'heat-shortened'. High temp@pH6 results in exhaustion of protease activity which reduces the tenderising effect of ageing and in some cases toughens the meat.

If processing conditions are managed such that extremes in temperature at pH 6 are avoided (temp@pH6 between 10°C and 30°C), the benefit of tenderstretching is small. However tenderstretching provides a measure of insurance for eating quality of loin and leg muscles.

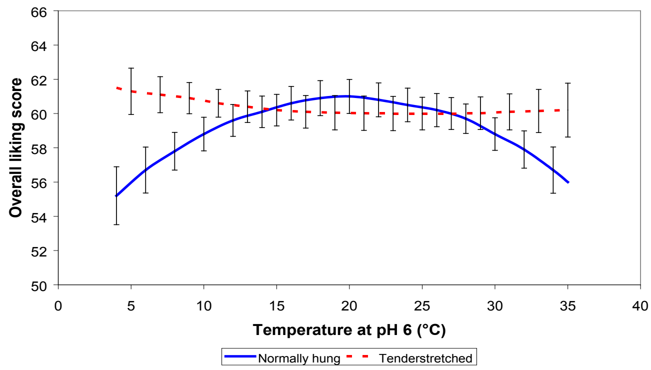

Figure 4: Relationship between overall liking and temperature at pH 6

Figure 3: Mid voltage stimulation of the dressed carcase

Meat ageing

Holding meat for an extended period in a chilled state is known as ageing. Ageing is the sum of a number of biochemical reactions, principally proteolysis, which can continue at chilled temperatures. It is particularly affected by two easily monitored inputs—temperature and time.

In one SMEQ trial, ageing at 1°C for 5 or 14 days (Table 2) resulted in an improvement in tenderness when compared with holding for only 2 days. The major improvement occurred between 2 and 5 days, with little subsequent improvement up to 14 days.

Table 2: Effect of ageing on mean sensory scores

	Tenderness	Overall Liking*
longissimus		
2 days	58.1	58.5
5 days	66.4	62.6
14 days	65.9	62.0
biceps femoris		
2 days	52.8	55.8
5 days	57.3	59.0
14 days	54.2	56.2
serratus ventralis		
2 days	57.1	60.8
5 days	58.9	60.5
14 days	61.7	59.9

* Overall liking included juiciness and flavour as well as tenderness

The temperature at which lamb is aged will depend on the particular market. The time-temperature profile suited to export markets involves rapid carcase chilling, vacuum packaging, and maintenance of a chilled storage temperature as cold as possible (as low as -1.5°C) through to the point of preparation for retail sale. Although ageing may be slowed by the low temperature, good microbiological quality will be maintained and the time—normally several weeks—will be ample for ageing.

In the domestic market, where lamb may be sold within a few days of slaughter, carcase chilling may be slower and the storage temperature can be higher, say 0–2°C. This contributes to faster ageing to achieve optimum meat quality in as little as 3 to 4 days for tenderstretched or ES, Achilles-hung product.

Retail display life

The colour and colour stability of packaged fresh lamb are important qualities contributing to retail acceptability. Fresh meat is perceived to be red, preferably bright red, and certainly not brown due to the surface formation of metmyoglobin. Meat tends to brown more as storage time and storage temperature increase.

Lamb in the Australian market may be distributed to retail outlets as hanging carcases, or as primals or carcase parts that are:

- naked (unwrapped);
- wrapped in stretch film or permeable bags;
- packed in vacuum packs;
- packed in modified atmosphere packs (MAP) in a gas atmosphere that is solely or predominantly CO_2, or
- packed as retail cuts in high-oxygen MAP packs.

For export, primals and carcase parts are vacuum-packaged. Whole carcases or primals may also be packaged in high-CO_2 MAP.

When the product is handled as carcases or carcase parts, it is processed at the retail outlet into retail cuts. In most supermarkets it is then presented on plastic or expanded polystyrene (EPS) trays and over-wrapped with clear PVC film, which has a high oxygen permeability. A shortcoming of this approach is that retail display life may be short—limited to as little as one day if it has been stored for some time in vacuum or MAP packs prior to being prepared for retail sale.

The alternative to preparation of retail cuts in stores is centralised packaging of retail cuts in modified atmospheres that restrict microbiological growth and prolong retail display life by maintaining the attractive red colour. The modified atmosphere gas mixtures most frequently used for retail display of fresh meat contain 70–80% oxygen and 20–30% CO_2. High oxygen levels maintain the bright red oxymyoglobin bloom while the CO_2 slows microbiological growth. For the benefit of this atmosphere to be maximised, the packs have to be big enough. The ratio of gas volume to meat volume has to be at least 1:1; although 1.5:1 is better. The storage life of lamb in high-O_2 MAP is, however, limited to around 10 days at 0–1°C.

In one of the SMEQ experiments, lamb loin chops and leg steaks were prepared from primal cuts that had been aged for 7, 21 or 35 days and then either packed in high-O_2 atmospheres or overwrapped on EPS trays. They were assessed at the mid point (day 3 and 5 for overwrapped and MAP respectively) and end point (day 5 and 9 for overwrapped and MAP respectively) of their expected display life.

At the time of slaughter, the carcases were stimulated with either of two different wave forms, or unstimulated. It was found that electrical stimulation did not influence meat colour of bone-in loin chops or boneless leg steaks when assessed at the initial, mid and end of product display life.

The retail acceptability of lamb cuts displayed in MAP packs was superior to that of cuts packaged on overwrapped trays (Figure 5). It was also clear that after 3 and 5 days display, leg steaks (*quadriceps femoris*) were inferior to the loin chops regardless of the packaging method. The acceptability of both loin chops and leg steaks was limited by browning due to metmyoglobin formation.

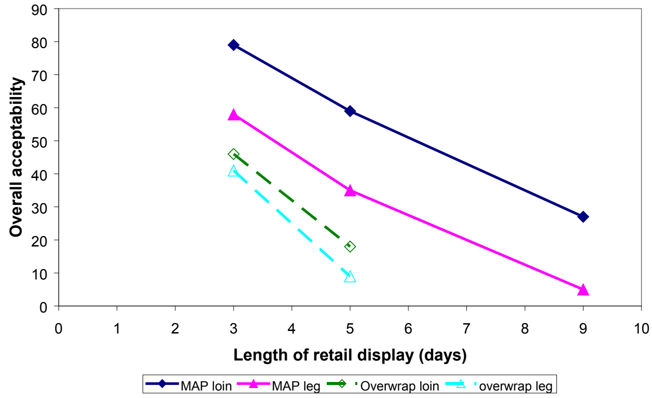

Figure 5: Effect of packaging method on retail display life

The ageing period as primal cuts also affected the acceptability at the nominated mid-point of display life. The acceptability of the over-wrapped retail cuts from lamb primals aged for 21 days was superior to that of cuts from primals aged for 35 days (Figure 6). On this basis it appears that for optimum results, lamb primals can be aged for 21 days in vacuum bags at 0°C before preparation into retail cuts. The trial results support previous findings that when lamb is stored in vacuum packs for six weeks or longer, the subsequent retail display life will be reduced. This has clear implications for lamb that is exported.

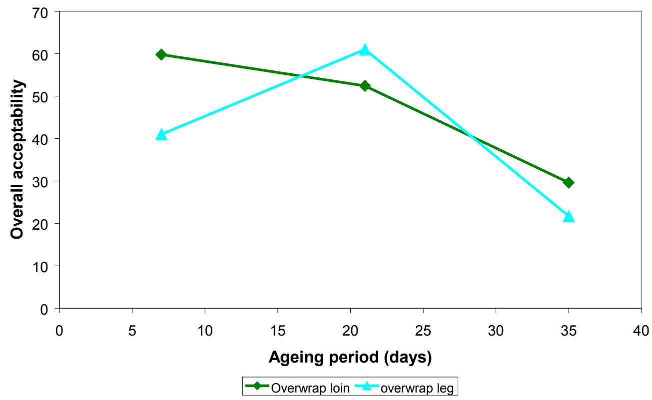

Figure 6: Effect of ageing period on acceptability at the midpoint of display life

To achieve the multiple benefits of centralised packaging of retail cuts—a storage life longer than two weeks and good retail display life—it is necessary to go to systems where the retail packs can be held in a high-CO_2 environment until needed for retail display. The oxygen-impermeable film is then removed, allowing oxygen to reach the meat surface so the meat blooms. Examples are the peelable vacuum skin pack and the 'mother' pack.

Table 3: Key outcomes from SMEQ trials

Processing Factor	Impact on Eating Quality
Electrical stimulation	• Electrical stimulation, applied correctly, will ensure sheep meat enters rigor at the correct temperature. • New generation mid-voltage electrical stimulation applied via a rubbing rail to skin-off carcases is recommended. • When correctly applied, electrical stimulation has no effect on display-life colour. • Where lamb is aged for longer than about 3 days, electrical stimulation may not be required where carcases enter rigor between 8 and 30°C.
Carcase chilling	• Rapid chilling can increase toughness. • For optimal acceptability, conventionally hung carcases should enter rigor (pH 6) at between 13 and 27°C. • The temperature at rigor has little effect on eating quality of tenderstretched carcases.
Hanging method	• Tenderstretch is particularly beneficial to the eating quality of loin and hindquarter cuts. • Tenderstretch is an alternative to electrical stimulation for achieving good eating quality.
Ageing	• Ageing takes place progressively and occurs more rapidly at higher temperatures. • Ageing at low temperatures (-1.5°C) is suited to the chilled export trade. • Ageing at a temperature of 1–2°C for 5 days will achieve optimum eating quality for the domestic market.
Retail packaging	• MAP packs have a longer retail display life than PVC overwrap packs. • Ageing in vacuum packs for periods longer than 21 days can reduce subsequent display life for both MAP and overwrap packs. • The display life of some cuts, such as the leg, may be shorter than cuts from the loin.

Further reading

Channon, H.A., Baud, S.R. and Walker, P.J. (2005) Modified atmosphere packaging improves retail display life of lamb cuts with variation between loin and knuckle. Australian Journal of Experimental Agriculture, 45: 585-692.

Shorthose, W.R., Powell, V.H. and Harris, P.V. (1986) Influence of electrical stimulation, cooling rates and aging on the shear force values of chilled lamb. Journal of Food Science, 51: (4) 889-892, 928.

Thompson, J.M., Hopkins, D.L., D'Souza, D.N., Walker, P.J., Baud, S.R. and Pethick, D.W. (2005) The impact of processing on sensory and objective measurements of sheep meat eating quality. Australian Journal of Experimental Agriculture, 45: 561-673.

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

6/07 – December 2007

Producing quality sheep meat

This Update presents recent findings on some slaughter floor influences on sheep meat quality.

New electrical inputs during slaughter and dressing help to deliver better quality sheepmeat. Medium voltage electrical stimulation enhances meat quality by improving tenderness and meat colour. High frequency immobilisation of bodies at slaughter reduces involuntary movement and permits abattoir workers to begin processing sooner. Medium voltage stimulation at low frequency (10 Hz) hastens blood release.

Also discussed is the 'eating quality window' and its application by sheepmeat processors. Results show that without electrical stimulation, the proportion of carcases that fall within the window is about 5%. With optimal stimulation, the proportion rises to 90% based on a revised window of pH 6.0 between 18–35°C.

Electrical technologies

A range of new electrical technologies is helping Australian processors to consistently deliver better quality sheepmeat. Medium voltage electrical stimulation enhances meat quality by improving tenderness and meat colour. In addition, it can also improve occupational health and safety, increase blood collection and enable faster carcase throughput times. The uptake of this new technology in the Australian sheep meat processing industry has been extensive with 14 abattoirs now having some form of the new technology installed, representing the majority of the slaughter capacity in the country.

The benefit of using electrical stimulation is that it reduces tenderness variability and allows meat to reach tenderness levels acceptable to consumers sooner than unstimulated product. This benefits producers, processors and consumers by boosting the perception of lamb in the market place and therefore increasing overall lamb consumption. A variety of electrical inputs are now available for use by Australian meat processors. Extensive research has been undertaken to ensure the units are optimised to best suit abattoirs requirements.

Figure 1. Six-module medium-voltage post-dressing stimulation system. The number of modules (electrodes) is determined by chain speed. With a faster chain, more modules are required to ensure only one carcase is on an electrode at any one time.

Medium voltage stimulation

A new approach to electrical stimulation has been developed by Meat & Livestock Australia based on medium voltage stimulation (MVS). These systems are favoured over the traditional high voltage systems because (1) they use less electricity and are cheaper to run, (2) are safer for workers as they comply with Australian occupational health and safety regulations, (3) can be located at either the start or the end of the chain depending on the availability of space and (4) they can deliver electricity to each carcase individually dependent on the responsiveness of the carcase. They are more effective than low voltage systems.

How it works

The system is devised of segmented electrodes which ensure that only one carcase contacts the electrodes at any one time. The current remains constant and the voltage is varied (peak 300 V) by controlled electronics which determine the resistance of the carcase and this feedback system alters the voltage accordingly.

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Improved meat quality

Medium voltage systems are an effective way of controlling the rate of pH decline of carcases post slaughter. The rate of pH and temperature decline of a carcase can significantly affect meat eating quality. If the pH decline is too slow (high pH at low temperatures), cold shortening may occur. This is extremely detrimental to the quality of the meat and will result in tough meat and darker meat colour.

The Sheep Meat Eating Quality (SMEQ) program identified that for optimal eating quality, meat intended for the domestic market (short aged) should come from a carcase that has a pH of 6 while the carcase temperature is between 18–25°C . Research has been underway aimed at optimising the MVS units to achieve a rate of pH decline that increases the number of carcases that reach a pH 6 between 18–35°C (the eating quality window); this research is referred to again later.

Immobilisation for improved OHS

The use of high frequency immobilisation (Figure 2) at slaughter reduces animal movement and enables abattoir workers to begin processing the carcases safely within approximately 30 seconds of death. These systems have been shown to have no detrimental effect on meat quality.

Figure 2. High frequency immobilisation reduces animal movement and permits early and safe commencement of processing.

Increased efficiency

If medium voltage electrical stimulation is used at the start of the chain (Figure 3), the amount of collectable blood at slaughter can be increased. This application of electrical stimulation has the potential to reduce abattoir waste, reduce water use and provide additional income for those abattoirs that process blood.

The amount of blood released within 2 minutes of slaughter was 62% greater when a thoracic stick and low voltage stimulation (10 Hz) were used in combination with a Halal slaughter compared to Halal slaughter alone. This process can also improve meat quality and increase consumer acceptance by improving meat colour.

Electrical stimulation also has other efficiency benefits as abattoirs can run their chillers at lower temperatures, thus reducing evaporation losses without compromising eating quality.

Figure 3. Medium voltage stimulation after sticking hastens and increases blood release.

pH and temperature decline and the eating quality window

The rate of pH and temperature decline of a carcase can significantly affect sheepmeat eating quality. The muscle pH of a carcase declines post slaughter from 7.2 to about 5.5 due to the conversion of glycogen (muscle energy source) to lactic acid. If the rate of pH decline is too slow (high pH at low carcase temperature), cold shortening may occur.

The ideal 'window' is a specification used to describe the relationship between pH and temperature fall during chilling and the objective is to manipulate pH fall so it passes through the window.

Hitting the window can shorten the ageing time of meat to reach tenderness acceptable to the consumer, reduce the variation in tenderness, and enhance meat colour. This benefits farmers, processors and consumers by boosting the perception of lamb in the market place and increasing overall lamb consumption.

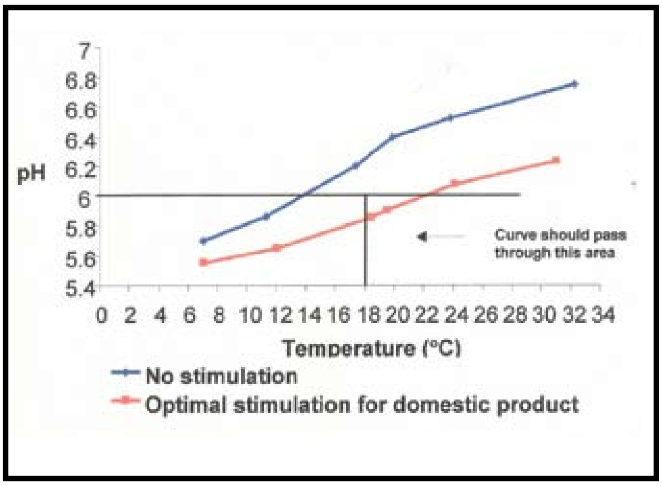

Figure 4. Stimulation results in carcases attaining the pH-temperature window more frequently.

Meat processors participating in the Meat Standards Australia (MSA) Program for Sheep Meat will be required to measure and control systems to 'hit' the pH temperature window. The evidence says that sheep and lamb processors cannot attain the window without methods to either slow temperature decline or speed up pH decline. The former approach can compromise food safety; but the latter option can be achieved with electrical stimulation of the carcase and is the preferred one.

Figure 5. pH and temperature are measured at the lumbar-sacral junction after overlying fat is removed.

Measures of pH-temperature decline

The rate of decline is expressed in terms of the temperature at which the loin muscle of the carcase reaches a pH of 6. To calculate the temperature at pH 6, pH and temperature readings are taken at timed intervals using a combined pH/temperature meter during chilling. Using the standard location for measurement is very important. This is found at the lumbar-sacral junction and overlying fat is cut away so as to prevent fouling of the pH electrode (as shown above). These data are then used to calculate a rate of pH by temperature decline from which it is possible to predict the temperature at pH 6.

Compliance rates

In practice there is considerable variation between carcases and it is difficult to get all carcases within the window under commercial conditions. Results from abattoirs in different locations around Australia show that the number of carcases which can achieve a pH of 6.0 at 18–25°C, without electrical stimulation is about 5% nationally, but this will vary from plant to plant. With the use of an optimal electrical stimulation setting this can be increased to over 60% of carcases depending on the chilling regime of the abattoir (see table below). Recent research has shown that it is possible to expand the temperature range for the window to 18–35°C for lamb that is Achilles-hung and aged for 5 days, without any detrimental effect on eating quality. Expanding the temperature range would mean that for the example in the table below, 90% of carcases would make the window when stimulated, rather than 60%.

Table 1. More carcases fall within the eating quality window if they receive medium voltage stimulation. Test findings at a WA abattoir.

	ph temperature range according to SMEQ 18–25°C guidelines		
	% of carcases @ pH6 between 18–25°C	% pH <6 at 25°C	% pH >6 at 18°C
No stimulation	15	0	85
Optimal setting for domestic market (2.5ms, 1A, 15Hz)	60	30	10

New pH temperature guidelines for sheep meat

Australian research has identified that for optimal eating quality of sheepmeat destined for specific markets, the targets in the table should be met.

Table 2. Temperature range at pH 6 required by MSA

Ageing period	Hanging system	Required temp @ pH6
Short ageing period of 5 days (domestic product)	Achilles hung	18–35°C
Short ageing period of 5 days (domestic product)	Tender stretch/ pelvic hung	8–35°C
Longer ageing period of 10 days	Achilles hung	8–18°C

Auditing performance

Processors should independently audit their plants to determine compliance rates of carcases falling within the pH-temperature window. If a low percentage of carcases hit the window, then a number of alterations can be made including: the use of electrical stimulation, which accelerates the rate of pH decline; varying the stimulation time; and setting or adjusting the chilling regime.

On audit day, processors should randomly select 4 consignments per day that reflect the variation in carcases being processed over the day. Within each consignment 25 carcases should be measured (i.e. 100 sheep per day). The pH and temperature of each carcase should be recorded at 20–30 mins post slaughter (on entry to the chiller) and then again when the temperature at the lumbar-sacral junction is at 18°C. This data should then be used to calculate the temperature at pH 6 using the following equation:

$$\text{Temp at pH6} = \text{Tempi} - \frac{\text{pHi} - 6}{(\text{pHi} - \text{pHs})/(\text{Tempi} - \text{Temps})}$$

Where:
Tempi and pHi represent the first temperature and pH measurement taken 20-30 mins post slaughter (usually above pH 6), and Temps and pHs represent the measurement taken when the meat is at around 18°C (usually below pH 6).

This process should be completed a minimum of 4 times per year, and be done over a variety of seasons. To test whether the stimulator is working, 5 carcases from 4 lots can be measured on entry to the chiller. This should be done monthly.

Contacts

For queries on electrical technologies Dr David Hopkins (NSW DPI), Ph 02 6349 9722.

Further Reading

Hopkins, D.L., Shaw, F.D., Baud, S. and Walker, P.J. (2006) Electrical currents applied to lamb carcases – effects on blood release and meat quality. Australian Journal of Experimental Agriculture 46: 885-889.

Pearce, K.L., Hopkins, D.L., Toohey, E.S., Pethick, D.W. and I. Richards (2006) Quantifying the rate of pH and temperature decline in lamb carcasses using mid voltage electrical stimulation in an Australian abattoir. Australian Journal of Experimental Agriculture 46: 869-874.

Toohey, E.S., Hopkins, D.L., McLeod, B.M. and Nielsen, S.G. (2006) Quantifying the rate of pH and temperature decline in lamb carcases at three NSW abattoirs. Australian Journal of Experimental Agriculture 46: 875-878.

Toohey E.S. and Hopkins, D.L. (2006) Optimisation of a new generation pre-dressing mid-voltage electrical stimulation unit. Proceedings 52nd International Congress of Meat Science and Technology, Dublin, Ireland, p. 627-628.

Toohey, E.S. and Hopkins, D.L. (2007) Does high frequency immobilisation of sheep post-death affect meat quality? Proceedings of the 67th New Zealand Society of Animal Production. p. 420-425.

Key Messages

- **A number of electrical inputs are available to Australian meat processors to improve meat quality and occupational health and safety.**
- **Medium voltage electrical stimulation units at the start or the end of the chain can improve tenderness and meat colour by increasing the rate of pH decline.**
- **High frequency immobilisation at the start of the chain reduces animal movement and improves occupational health and safety.**
- **Medium voltage electrical stimulation at the start of the chain can increase the amount of collectable blood that can be sold, and also reduce waste.**
- **Optimising the rate of pH and temperature decline improves sheepmeat eating quality.**
- **Meat Standards Australia will require sheepmeat processors to measure and control systems to fall within the pH temperature window.**
- **Four times per year, processors should select 4 consignments per day and 25 carcases per consignment to determine the number of carcases hitting the window. pH should be recorded 20–30 mins post slaughter and again when the carcase is close to 18°C.**

The information contained herein is an outline

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

1/12 – July 2012

The effect of diet on sheepmeat flavour

- **The vast majority of pastures and feeding systems produce sheepmeat of highly acceptable quality and flavour.**
- **There are some pastures or feeding systems that can directly, or indirectly, have a positive or negative influence on sheepmeat flavour. These need to be identified and processes put in place to ensure consumers in Australia, and overseas, always have a good eating experience.**
- **In order to minimise any off-flavour associated with sheep fed brassica crops, sheep should be removed from brassica crops for 2 weeks prior to slaughter.**
- **Grazing sheep on pastures high in protein (e.g. clover, lucerne) can increase the occurrence of 'pastoral' flavour in meat. The perception of 'pastoral' flavour as unacceptable may depend on habituation and prior experience.**
- **Consumer acceptance of the flavour of 'mutton', or 'pastoral' flavour could be assisted by masking the flavour with seasoning such as herbs and spices.**

Introduction

Flavour is an important sheepmeat quality trait. Flavour is comprised of aroma (volatile) and taste (non-volatile) compounds. Aroma is perceived during eating by olfactory receptors in the nose, and taste is perceived by receptors in the mouth and throat. Fresh, uncooked meat is quite bland; it is only as a result of cooking that meat flavour develops. The resulting characteristic flavour is regarded as typical for a given species, e.g. lamb, beef, pork etc. During cooking, the non-volatile components of lean and fat tissues undergo a complex series of heat-induced reactions that generate a large number of volatile aroma products. The compounds formed are mainly derived from two distinct reactions that occur during the cooking process: Maillard reactions between amino acids and reducing sugars; and thermal degradation of the lipid components to produce volatiles.

Historically, most attention has been given to undesirable sheepmeat flavour attributes, such as 'mutton' and 'pastoral' flavours. 'Mutton' flavour, associated with the age of the animal, is more common in cooked meat taken from older sheep; while 'pastoral' flavour has generally been related to the pasture diet fed to the animal pre-slaughter. Branched chain fatty acids are recognised as the main compounds which contribute to 'mutton' flavour, while 3-methylindole ('skatole', also a contributor to 'boar' taint in pigs) and 4-methylphenol (*p*-cresol) are the main compounds which have been implicated in 'pastoral' flavour. Diet can also have other effects on the flavour of sheepmeat, aside from pastoral flavour. This MTU discusses the overall effect of different pre-slaughter diets on sheepmeat flavour.

Sensory evaluation

Sensory evaluation of cooked sheepmeat is usually performed with either consumer panels (untrained or naive) or trained sensory panels. Consumer panels rate the cooked meat based on their experience of the product quality. Some of the factors that consumers assess include tenderness, juiciness, liking of the smell and overall flavour. Consumers can give an 'opinion' of the meat, which will be based on their experience. A trained sensory panel is used as an objective measurement tool where the panellists are taught to identify and quantify specific sensory attributes (aroma, flavour, texture and mouthfeel) and rate them in the cooked meat product. It is an objective process that can quantitatively measure complex flavour attributes, which may not be easily measured using conventional instrumental techniques. A trained panel, by the nature of the training involved, cannot be used to give an 'opinion' of the meat. Meat Standards Australia runs consumer panels where the product is linked between tasting sessions, and a standard cooking and presentation approach is used for all tasting sessions, thus providing objectivity.

Chemistry and linkage to sensory

Volatile compounds are measured using gas chromatography-mass spectrometry (GC-MS). Volatile analysis involves extraction and concentration, chromatographic separation,

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detection and quantification. Considerable effort has been made to characterise the volatile compounds associated with cooked sheepmeat. Despite reports of hundreds of volatile compounds in the literature, few studies have demonstrated which of them are important to the aroma. In fresh food products, there are usually only a small number of the total volatile compounds that actually contribute to the aroma. In order to identify the 'odour-active' volatiles, a more specialised technique is required: gas chromatography-olfactometry (GC-O). In GC-O (Figure 1), the volatile extracts are subjected to chromatographic separation and instrumental detection; and also simultaneously 'sniffed' by a human assessor and the odour intensity is rated. Ideally, GC-O is performed by a panel of assessors (similar to using a trained sensory panel) to account for human variability in sensitivity for different aroma compounds. The aim of this type of research is to identify which volatile compounds are the most significant contributors to the cooked meat aroma.

Effect of diet on cooked meat flavour

The use of pasture-based finishing diets, compared to grain-based, can impact on the sensory properties of the cooked sheepmeat (Table 1). Pasture diets, in comparison to grain, may introduce different flavours to the final product which are often perceptible by trained sensory and consumer panels. Depending on the consumer (cultural background, prior lamb consumption, habituation to meat from pasture or grain-fed animals), the flavour of cooked pasture-fed sheep may be described as typical 'sheepmeat' or 'lamb', or unfamiliar and potentially unacceptable.

Some differences have been described for the meat flavour of sheep grazing on different pastures and forages. For example, in comparative trials of different pasture species, unacceptable flavours have been found by trained panels for white clover, lucerne, phalaris, rape (*Brassica* sp.) and related brassica feeds (see Table 1). Other studies have reported no differences in sensory panel assessments between meat from sheep grazing forage species such as tropical legumes vs grass and chicory vs lucerne. The stage of growth for pasture species and also time of year can influence the water-soluble carbohydrate content, crude protein % and digestibility, all of which can potentially impact on the occurrence of off-odours and flavours in ruminant meat. Importantly, the majority of pastures and feeds do not create flavour or odour problems in the meat; however, and of equal importance, the forages that have potential to impact on product quality need to be identified, in order to minimise any risks of the consumer getting a poor eating experience.

In some instances, the impact of pasture species on sheepmeat flavour can be significant. One example is forage rape or canola (Figure 2) and anecdotal evidence suggests that certain Brassica crops in common use may impart negative flavour attributes in lamb. A diverse range of *Brassica* species is available and used in Australia, which naturally vary widely in glucosinolate and protein content. There is speculation that Brassica with high glucosinolate content may impact on flavour, through sulphur-containing breakdown products, although this still needs to be proven. In addition, pasture diets with high protein content have been implicated with the pastoral flavour notes found in lamb. Grain-finishing diets are also increasingly used, although how grain-fed lamb flavour differs from other diets requires clarification.

Effect of diet on aroma (volatile) compounds

Lactones are important aroma and flavour compounds that are found in many natural products. Higher levels of γ-lactones have been found in the meat taken from grain-fed sheep, and are believed to be derived from the free fatty acids that are present in the grain. δ-lactones have been reported to be high in the meat obtained from pasture-finished animals. Different synthetic pathways exist for the formation of the γ- and δ-lactones.

Both 3-methylindole and *p*-cresol have been implicated as the main contributors to 'pastoral' flavour. Pasture has a high protein-to-readily fermentable carbohydrate ratio, and the protein from pasture is more readily digestible in the rumen compared to that available in grain and concentrate diets. Additionally, substantial degradation of feed protein to amino acids occurs in the rumen, which allows a higher availability of peptides and amino acids for absorption, which cannot be fully incorporated into microbial protein since insufficient energy is released from carbohydrate metabolism. Tryptophan and tyrosine, both amino acids, are transformed by rumen bacteria to form 3-methylindole and *p*-cresol, respectively. Usually, these compounds would be metabolised by the liver after release into the blood supply from the intestine; but, when in excess, some will escape liver metabolism and be released into the blood supply resulting in deposition into fat tissue.

Table 1. Impact of feeding regimes on sheepmeat flavour

Feeding system	Impact on flavour
Pasture compared to concentrates	
Pasture vs grain concentrate	'Lamb' flavour higher in concentrate
Pasture vs lucerne or maize concentrate	'Sheepmeat' flavour higher for pasture
Ryegrass vs concentrate	'Off' odours/flavours in ryegrass-fed meat
Mixed pasture vs grain-based or poor quality dry feed	No difference between pasture vs grain
Pasture vs concentrate vs pasture/concentrate	Lower acceptance of pasture-fed animals
Other comparisons	
Rape vs pasture	Stronger, less acceptable flavour for rape
Perennial ryegrass + other grasses vs grain-based	'Sheepmeat' flavour higher for pasture than grain
Saltbush vs barley/lupin/hay	No difference

Diet has also been implicated in the formation of branched chain fatty acids (BCFAs), regarded as the main contributors to 'mutton' flavour. Higher concentrations of these compounds have been observed in animals receiving a grain-based finishing diet prior to slaughter. This has been attributed to carbohydrate availability in the diet since higher amounts are associated with grain and concentrates compared to pasture-based diets. Although it might be logical to assume that grain-dominated diets result in increased 'mutton' flavour in the cooked meat, cereal grains differ in their propensity to generate BCFAs, so some care is required in extrapolating this observation.

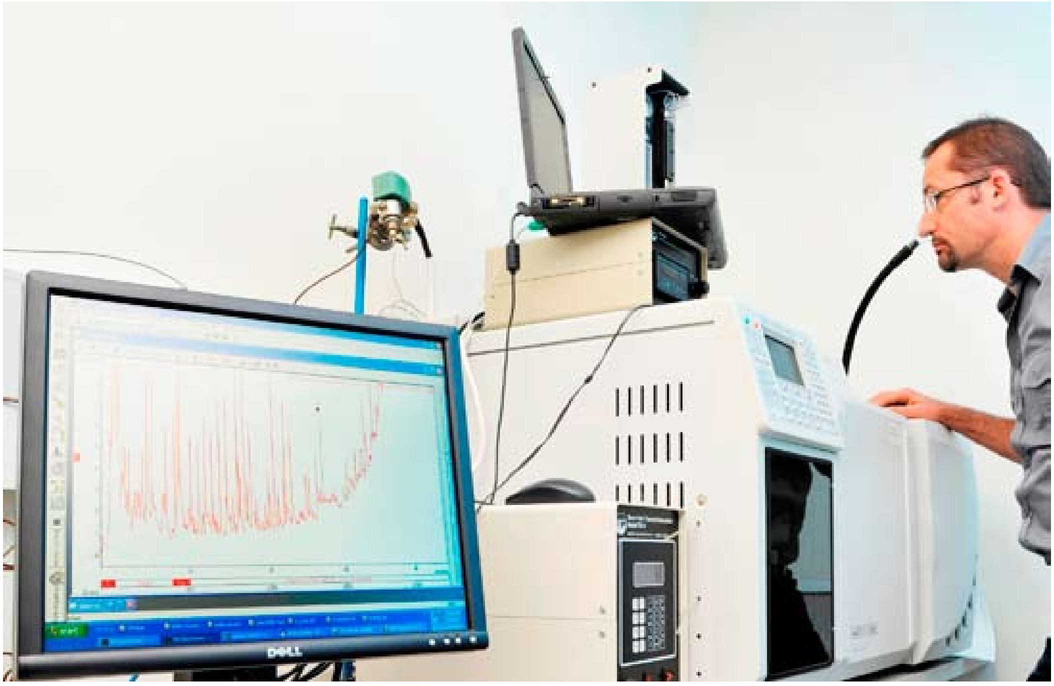

Figure 1: Sniffing aroma on a GC-olfactometer

Taste compounds in meat

To date, research relating to non-volatile taste compounds in lamb meat specifically, and meat in general, has been fairly limited; but, in recent years, interest in this area of research has been increasing. There is a wide range of compound classes that can contribute to the taste of meat and related products. These are, namely: organic acids (e.g. lactic and succinic acids); compounds derived from lipid precursors (short-chain fatty acids); sugars (such as glucose and fructose); peptides and free amino acids (produced from enzymatic hydrolysis of muscle proteins); nucleotides; and Maillard reaction products.

Low molecular weight, water-soluble compounds (namely sugars, amino acids and other nitrogenous components) are important as:

(a) background basic taste attributes (sweet, sour, salty, bitter and umami) as well as complex sensations such as mouth-fullness; and
(b) precursors of the characteristic aroma (meaty flavour) of cooked meat.

Other indirect effects

Components of the diet that change the final pH, intramuscular fat, or antioxidant status of muscle can also affect the final flavour characteristics. For example, carnosine, the most abundant dipeptide in skeletal muscle, and vitamin E, a lipid-soluble vitamin derived from pasture, both decrease lipid oxidation. Lipid oxidation in muscle post-slaughter causes deterioration in meat flavour, including the unacceptable 'warmed-over' flavour. Carnosine also has a positive influence on the thermal generation of pyrazines, a class of compounds that contribute to 'meaty' aromas. Differences in diet can impact on other factors which will influence the final flavour characteristics of the meat product. For example, meat from concentrate-fed animals undergoes lipid oxidation more readily compared to that taken from pasture-fed animals, which impacts on the amount of lipid-derived volatiles during cooking. Pastures and feeding systems which allow the adequate deposition of muscle glycogen and also intramuscular fat, by providing adequate energy and protein, will also result in more acceptable flavour in the meat.

Saltbush-fed lamb has been anecdotally reported to have a superior flavour, although the studies comparing saltbush-fed lambs to pasture-fed lambs have found no difference. As saltbush appears to impart higher levels of antioxidants to the muscle, it is possible that the superior taste is associated with prevention of the off-flavour associated with oxidation.

A consumer perspective

An estimated world total of about 1 billion sheep exist for wool and milk production, and slaughter for meat, skin and wool. The largest number are in China, about 130 million, followed by Australia (70 m), India (65 m), Iran and Sudan (50 m each), Nigeria, New Zealand and the UK (30 m each). Most of the sheepmeat produced in China is intended for local consumption. Australia, by contrast, has a high local consumption and, along with its neighbour New Zealand, is a major sheepmeat exporter. In both Australia and New Zealand it can be assumed that a significant fraction of the native population accept the characteristic flavour of locally produced sheepmeat as 'normal'. These populations can be described as habituated to the local product.

The source of sheepmeat for processed foods is usually older ovines, typically mutton, which is a cheaper source than lamb. In these processed foods the meat is usually comminuted, which eliminates any problem of toughness due to muscle origin and animal age; however, mutton is more strongly flavoured and, due to the negative perception by some consumers, its inclusion into meat products is not routinely promoted, e.g. mainstream sausages prepared with mutton are often labelled 'beef-flavoured sausages' to avoid consumer misapprehension. Conversely, this is why 'mutton-flavoured sausages' are never seen.

The aversion to meat taken from older sheep was highlighted in a consumer survey in New Zealand that tested the association between

Figure 2: Canola (brassica) field in Temora, New South Wales (from en.wikipedia.org)

consumer perception of different types of red meat (lamb, mutton, beef, venison) and their perceived taste, quality and healthiness. Consumers were asked to rate expected quality with no actual meat eaten or on view. The perceptions of hogget and mutton were lower compared to the other meats, which included lamb. Whilst a negative perception for mutton might be reasonably founded on flavour differences due to the presence of higher BCFAs, a lower rating for hogget, where the animal may only be older than a lamb by one day, suggests that the mere name hogget has an unfortunate marketing consequence.

Different consumer populations around the world vary in their liking of sheepmeat. In many cases this relates to lack of exposure, familiarity and traditional use of sheepmeat in the local culture and cuisine. Sheepmeat consumption is greater in Australasia than in Japan, and this is reflected in product habituation. Researchers, in a comparative study between female Japanese and New Zealand consumers, spiked beef samples with zero, low and high concentrations of mixed BCFAs and of skatole to simulate nine flavour combinations of sheepmeat fed on pasture, designed to represent a range of sheepmeat typically available to New Zealand consumers. For the Japanese consumers, there was a strict linear decrease in liking as BCFA concentration increased. In contrast New Zealand consumers on average liked a low level of added BCFAs best, similar to those found in young lamb suggesting an effect of habituation and familiarity. The results for skatole were more complicated, but the highest concentration was clearly most disliked by both populations.

Consumers not familiar with the flavour of sheepmeat are likely to be less accepting of this product and so it will remain a challenge to overcome the negative perceptions, whether due to the inherent presence of a 'natural' lamb flavour, or due to the presence of BCFAs which contribute to the 'mutton' flavour. In order to overcome the barriers in these populations, masking lamb flavour with herbs and spices is an obvious path to take. Each culinary tradition has well-defined 'flavour principles' that could be utilised to produce an acceptable meat product suitable for unhabituated consumers. Development of optimised feeds, which impart desirable flavour attributes or, alternately, mask less desirable qualities, may also be an effective strategy for the sheepmeat industry.

Prepared by Dr Peter Watkins with contributions from Drs Damian Frank and Tanoj Singh, and Assoc. Profs Owen Young (AUT University, Auckland) and Robyn Warner.

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MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

1/11 – January 2011

Effect of slaughter method on animal welfare and meat quality

- **Although all stunning procedures are not totally comfortable from the animal's point of view, penetrative stunning is less noxious and more effective in inducing insensibility when compared to high power non-penetrative stunning and low power non-penetrative stunning.**
- **Subjecting animals to unstunned slaughter followed by penetrative stunning is more stressful than high power non-penetrative stunning and low power non-penetrative stunning.**
- **High power non-penetrative stunning and unstunned slaughter followed by penetrative stunning resulted in inferior meat quality in cattle.**
- **Thoracic sticking can improve meat quality.**

The manner in which livestock are mustered, yarded, handled, transported, restrained, slaughtered, and exsanguinated can affect their welfare and final meat quality. Welfare requirements dictate that animals should be insensible to noxious, potentially painful, stimuli during slaughter. In abattoirs, pre-slaughter stunning is usually applied to induce rapid desensitisation of animals to the pain of slaughtering, and to minimise bodily injury risks to abattoir personnel. This is important as the neck region contains a number of sensory nerve fibres that are capable of triggering powerful reflex reactions upon throat cut; therefore, stunning should be done effectively. This minimises the possibility of animals regaining consciousness, and renders the animal insensible during the throat cut. The insensibility should last until total cessation of vital signs. Stunning procedures in cattle include the use of electrical and mechanical (penetrating and non-penetrating) stunning. Electrical stunning in cattle, however, has been associated with blood speckle and blood splash in the carcase. With mechanical stunning, the intent is to cause concussion with or without penetration. The power of the mechanical stunner can be adjusted to suit the size of the animal handled.

For the application of religious slaughter, where certain modes of stunning are acceptable, it is mandatory that stunning should be reversible. The throat cut, itself, should be the cause of death. Some Muslim authorities accept non-penetrating mechanical stunning of cattle, but not penetrating captive-bolt stunning. The basis for this is that non-penetrating stunning is recognised to be 'reversible' while penetrating stunning is considered to be 'non-reversible'. Nevertheless, head injuries to cattle caused by non-penetrating stunning can be severe.

The impact of the stunner head against the relatively thin frontal bone, which forms the roof of the cranium in cattle, can result in severe, well-circumscribed, depressed fractures of the skull with subarachnoid haemorrhage in the brain below. In some countries, non-penetrative mechanical stunning is not allowed because of a risk that insufficient power could result in an ineffective stun and, therefore, compromise animal welfare. The potential for error in performing the non-penetrative mechanical stunning is a major welfare concern.

Earlier studies suggested that cutting the throat fails to sever the vertebral arteries supplying the brain. This may prolong duration of sensibility following slaughter. Interruption of the blood supply through the vertebral arteries in cattle may be achieved by severance of the brachiocephalic trunk by the use of a 'thoracic stick'—an incision with a knife through the thoracic inlet. Thoracic sticking, which severs the brachiocephalic trunk near the heart, is reported to have resulted in greater rate of blood loss than that following bilateral neck severing. The thoracic sticking intervention is widely practised, and is commonly associated with enhanced bleeding and a hastened death process.

This Update discusses the effects of different mechanical stunning methods—high power non-penetrative mechanical stun (HPP), low power non-penetrative mechanical stun (LPP), penetrative mechanical stun (P), unstunned slaughter followed by penetrative mechanical stun (US)]—and thoracic sticking —low power non-penetrative stunning followed by thoracic sticking (LPPS) and penetrative mechanical stunning followed by thoracic sticking (PS)—on stress-related hormones, meat quality and electroencephalographic reactions in beef cattle.

Stress-related hormones

When discussing stress, the nervous and endocrine (hormone) systems are of primary focus. External and internal stimuli are channelled via the nervous system to the hypothalamus in

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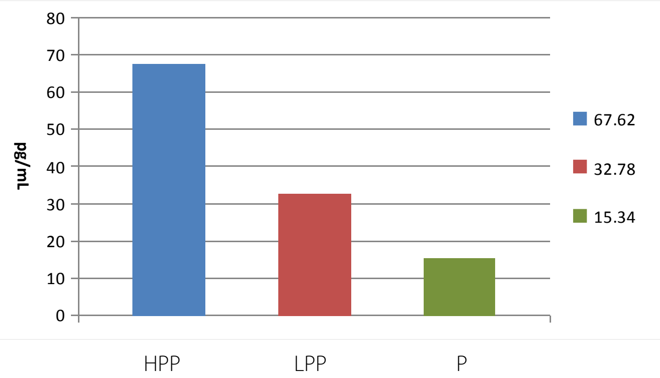

Figure 1. *Plasma adrenalin concentration following stunning.**

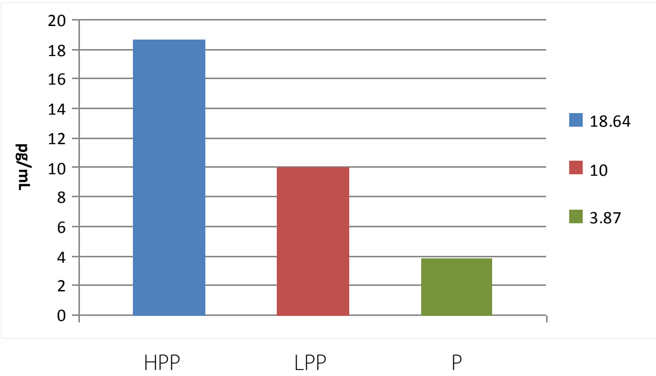

Figure 2. *Plasma ACTH concentration following stunning.**

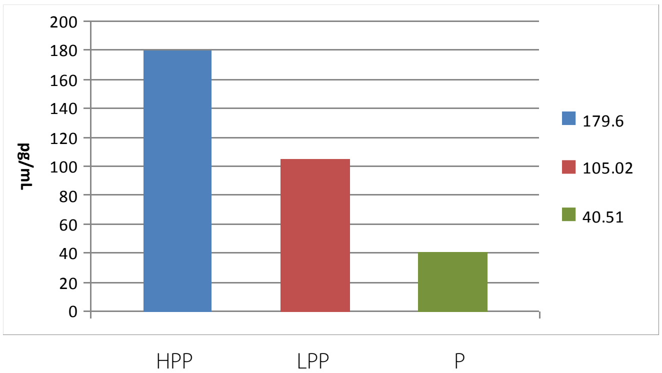

Figure 3. *Plasma noradrenalin concentration following stunning.**

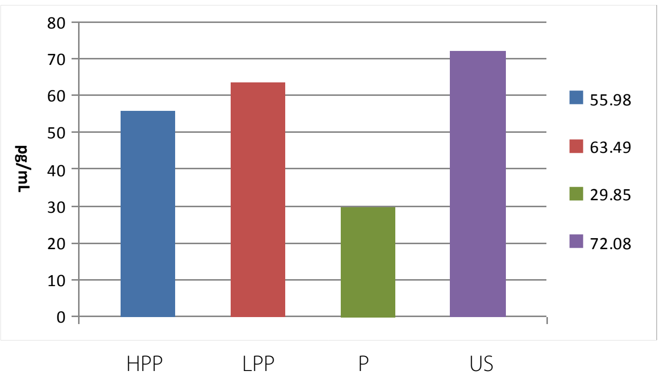

Figure 4. *Plasma adrenalin concentration following slaughter.**

** HPP = high power non-penetrative stunning; LPP = low power non-penetrative stunning; P = penetrative stunning; US = unstunned slaughter followed by penetrative mechanical stun*

the brain. Once a stressor has been perceived, two distinct pathways involving interlocking physiological reactions are evoked. The first pathway encompasses nervous stimulation of the adrenal system which is responsible for elevation in circulating adrenalin and noradrenalin or the 'flight or fight' mechanism. Although this system may have a dramatic physiological impact, it is short term. When it fails to cope with the stressor(s), the second pathway—hormonal system—is induced, and circulating adrenocorticotrophin hormone (ACTH) and corticosteroids will increase. These stress-related hormones may evoke glycogenolysis which is closely associated with muscle changes in stressed cattle.

Penetrative mechanical stunning (P) caused smaller increases in plasma adrenalin concentration (Figure 1) when compared to the HPP and LPP groups, suggesting animals experienced less distress. Although the purpose of stunning is to eliminate animal suffering during the slaughter procedures, as measured by plasma levels of ACTH (Figure 2) and noradrenalin (Figure 3), HPP induced a greater physiological stress reaction when compared to P. Earlier studies suggested that, although both P and HPP resulted in similar structural tissue damage, focal injury was more severe in the former, while the latter caused more widely distributed damage. Penetrative captive bolt stunning was more effective, and the likelihood of error was lower than for non-penetrative stunning.

It has been shown that following a throat cut, blood clots can form in the carotid arteries. This occlusion of the arteries can lead to a delay in the onset of insensibility due to alternative blood supply to the brain via the vertebral arteries. Thoracic sticking improves bleeding and negates the effect of carotid occlusion by rapidly draining the blood from a point in the circulatory system prior to the entry to the vertebral arteries. With effective stunning, thoracic sticking is not a welfare concern. The thoracic-sticking procedure had negligible effect on stress-related hormones.

Throat or neck cut without prior stunning is a major welfare issue in many countries. Whether the animal suffers pain during the neck or throat cut has been the subject of much debate. The adrenalin data indicated that animals subjected to P were least distressed during slaughter when compared to HPP, LPP and US (Figure 4). The results show that the penetrative stunning procedure can be a good method to stun cattle because it is less stressful to cattle and effective in reducing the noxious sensory input caused by the neck cut. Although the circulating adrenalin data suggested that US was more stressful than P, there is little evidence that the former caused more stress to the animals during slaughter than HPP and LPP.

Meat quality

Stress associated with improper pre-slaughter handling of livestock has been associated with undesirable pH, water-holding capacity, cooking loss and colour. Tenderness—as the most variable and important determinant in meat eating quality—along with the degree of lipid oxidation are among the traits of major concern in the meat industry. What happens to the animals prior to slaughter usually influences the physiological state, particularly energy metabolism of the skeletal muscle. This, in turn, affects the post-mortem muscle metabolism whereby most of the meat-quality characteristics are eventually attained. However, differences in metabolic and contractile characteristics between different groups of skeletal muscles also explain most of the differences in post-mortem changes and ultimate meat quality as a response to the physical activity and stress experienced by the animal pre-slaughter.

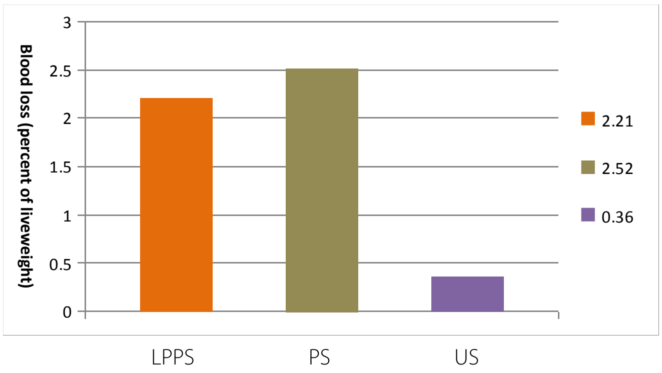

Figure 5. *Percentage of blood loss per live weight following stunning and thoracic sticking.^*

^LPPS = low power non-penetrative stunning followed by thoracic sticking; PS= penetrative percussive stunning followed by thoracic sticking; US= unstunned slaughter followed by penetrative mechanical stun

Generally, meat from HPP and US cattle had higher cooking loss, lower water-holding capacity (WHC), greater degree of lipid oxidation, poorer colour values and high peak force values (tougher). The adverse effects on meat quality resulting from the application of HPP were found to be more apparent and consistent in the *Semitendinosus* (ST) than in the *Longissimus dorsi* (LD) muscle. The resulting lower WHC following HPP stunning could be explained by earlier onset of rigor due to more rapid glycolytic changes caused by the more stressful slaughtering conditions experienced by the animals. The early breakdown of muscle glycogen usually leads to an earlier pH drop which, if occurring at high carcase temperature, can lead to denaturation of muscle proteins—a state where the polarity of proteins and ability to bind water molecules are usually disrupted.

Lipid oxidation in muscle starts immediately after death, following the failure of the circulatory system and the cessation of metabolic activities. It has been associated with deterioration in the quality of meat. It is well accepted that stress and handling of animals during slaughter influence the degree of lipid oxidation in meat. The use of HPP resulted in a higher level of thiobarbituric acid reactive substances (TBARS) which indicates greater lipid oxidation in the muscles.

The application of P improved tenderness of the ST muscle. The reason why only the ST muscle was affected by the stunning could be explained by the differences in metabolic and contractile properties between both muscles. It is well accepted that the ST muscle is mainly involved in locomotion and exercise during pre-slaughter handling. Thus, the response given—by both muscles as a result of different pre-slaughter and slaughter condition—could also be influenced by their activities.

Most of the colour values (L*, a*, b*, hue and chroma) of both muscles remained unaffected by the various stunning methods; however, they appeared redder (greater a* value) when the animals were subjected to thoracic sticking following the application of LPPS and PS stunning. Furthermore, penetrative stunning followed by thoracic sticking (PS) also reduced cooking loss and lipid oxidation while improving water-holding capacity and tenderness. The lowered TBARS level highlights the benefits of PS in reducing lipid oxidation in beef. This could be explained by the higher percentage of blood loss following LPPS and PS, compared to unstunned slaughter followed by penetrative stunning (US) (Figure 5). The findings further support earlier reports that residual blood in the carcase and meat determine their stability and shelf life.

Electroencephalography response

Electroencephalography (EEG) can be used in conjunction with stress hormone measurements in blood and physical observation, to monitor the presence of pain and stressful changes. EEG waveforms could also provide information on the effectiveness of stunning. The presence of low frequency delta waves, which occurred in HPP, LPP and P animals, is frequently associated with anaesthesia and unconsciousness in an animal with intact vital signs, and is suggestive of an effective and survivable stunning procedure. Conversely, the presence of large intervals of higher frequency alpha and beta brain waves, which usually occur in conscious animals, suggest stressful conditions related to post-slaughter pain; however, it should also be noted that delivery of the stunning force could also induce massive cellular and signal disruption, resulting in EEG changes that should be taken into account during interpretation. While animals subjected to P had the lowest alpha and beta wave intensity immediately post-stunning, and at 30 seconds after throat cut compared to both LPP and HPP animals (Figure 6), the converse was noted for US animals. This could possibly be explained by the animals' awareness of pain or other stressful factors attributed to the slaughtering procedure.

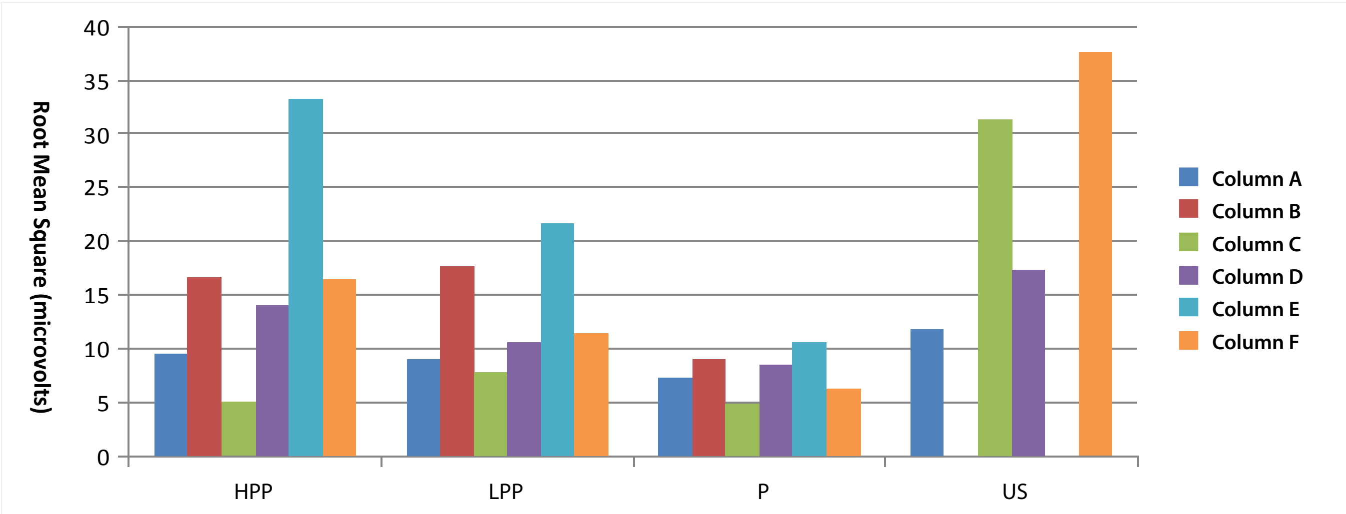

Figure 6. *Alpha & Beta waveform changes (μV) according to stunning method*

A: Pre-stunning alpha; B: Immediate post-stunning alpha; C: 30s post-slaughter alpha; D: Pre-stunning beta; E: Immediate post-stunning beta; F: 30s post-slaughter beta

The delta wave activities typically spiked immediately post-stunning (Figure 7), consistent with the expectation that animals are in a state of unconsciousness following stunning. The alpha and beta waves from the HPP and LPP animals spiked rapidly post-stunning, but declined gradually to their respective terminal values. Coupled with the appearance of low frequency waves within the frequency range of theta and delta waves in all stunned animals, it was concluded that stunning did render the animal unconscious, and less able to perceive noxious stimuli compared to the animals that were subjected to post-slaughter stunning. However, it should be noted that HPP animals probably experienced a significant amount of post-stunning brain excitation, possibly due to tissue damage—as evidenced by the appearance of higher beta wave intensity readings immediately after stunning. On the other hand, the lower beta and alpha activities among LPP and P animals immediately after stunning is suggestive that these animals probably experienced much less post-stunning brain excitation. Penetrative stunning seemed to be the best at maximising the possibility of post-stunning insensibility, while the US animals seemed to demonstrate an increase in EEG activities consistent with the presence of post-slaughter noxious stimuli associated with tissue cut and injury. Because the US animals were also subjected to penetrative stunning immediately after throat cut, the spike in EEG activities at 30 seconds after throat cut could be attributed to the additive effects of both throat cut and stunning. If post-slaughter stunning resulted in more 'suffering' to the animals, one could ask whether the procedure is necessary. However, researchers in New Zealand recently demonstrated that effective post-cut stunning would eliminate any pain responses shown on EEG.

The time post-slaughter to attain terminal or lowest possible EEG values —or 'Terminal Time'—for all waveforms, has been used in conjunction with the absence of vital signs, such as corneal reflex, to determine the point of cessation of brain electrical recordings; however, stunning is not expected to affect the duration from throat cut to the point when the brain stopped producing significant amount of electrical signals. This study clearly showed that stunning method was not a significant contributor to hastening Terminal Time, or cessation of all visible vital signs and reflexes, as well as cerebral functions.

In general, the inclusion of thoracic sticking during slaughter did little to change the EEG waveform intensity across all methods of stunning included in this study. In fact, thoracic sticking did little to shorten the Terminal Time, or time taken for EEG waveform reading to achieve its lowest reading accompanied by the absence of vital signs. This suggested that thoracic sticking was not a significant contributor to hastening the disappearance of vital signs and reflexes, but merely responsible for the rapid suppression of brain activity which probably placed the animal in a state of deep unconsciousness prior to the cessation of vital signs.

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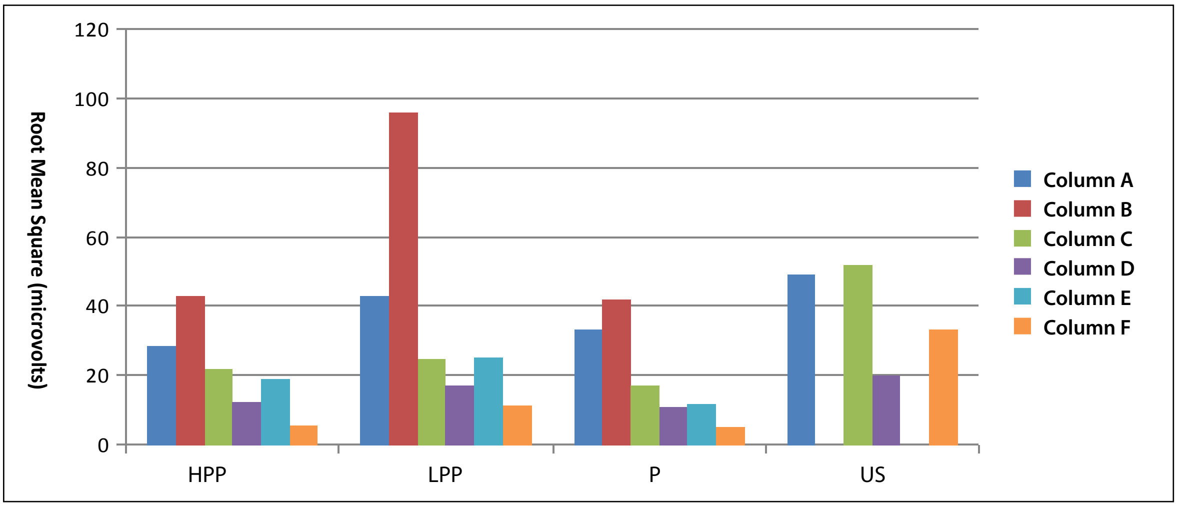

Figure 7. *Delta & Theta waveform changes (µV) according to stunning method*

A: Pre-stunning delta; B: Immediate post-stunning delta; C: 30s post-slaughter delta; D: Pre-stunning theta; E: Immediate post-stunning theta; F: 30s post-slaughter theta

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Meat technology update

3/10 – June 2010

Shelf life of Australian chilled, vacuum-packed lamb

Meat Technology Update 6/09 reported on recent investigations into the reported extension of shelf life of vacuum-packed beef beyond the traditional expected shelf life of 12 weeks. That MTU showed that chilled, vacuum-packaged Australian boneless beef can have a storage life of at least 20 weeks under optimal temperature conditions.

MTU 6/09 also showed that whether all vacuum-packed product will achieve this shelf life is dependent upon the initial quality of the meat (pH, colour and microbiological quality), adequate vacuum packing and temperature control through the supply chain. It then identified those meat-quality attributes and microbiological controls required to achieve this extended shelf life.

This Meat Technology Update investigates the limitations to shelf-life extension of lamb cuts stored chilled under vacuum packaging, and identifies the meat-quality attributes and packing practices, handling practices and storage conditions required to maximise chilled, vacuum-packed shelf life.

Executive overview

The process guidelines for Australian exporters of vacuum-packaged beef—to help them achieve storage lives of 10 to 12 weeks at 0°C, developed from studies undertaken over 25 years ago—have also been successfully applied to lamb cuts by many Australian processors. The application of these guidelines has allowed lamb processors to achieve storage lives of six to eight weeks at 0°C. Recent commercial evidence has indicated that shelf lives in excess of this can be successfully achieved, but are not necessarily understood, or accepted, by key markets.

Australian sheep and lamb processors export vacuum-packed lamb shoulders to a number of countries where they are sliced, packed in overwrap trays and distributed to various supermarket outlets for sale. The shelf-life for the overwrap trays is determined based on the Aerobic Plate Count (APC), using an incubation temperature of 35°C, of small surface pieces from the whole shoulders immediately prior to slicing. However, the microbiological flora of vacuum-packed meat is expected to consist mainly of Lactic Acid Bacteria (LAB) which are unlikely to result in product spoilage, even at high levels. Consequently the determination of shelf life using APC is not likely to reflect the wholesomeness of the product.

A research team at the South Australian Research and Development Institute (SARDI) has recently reported on

Figure 1: Lamb shoulder being prepared during the trial

its finding from two MLA projects investigating the shelf-life evaluation of sliced lamb shoulders. These projects investigated the relationship between microbiological status and sensory attributes of the slices of lamb after extended storage. Both projects demonstrated that there was no relationship between the sensory scores and the microbiological levels of the sliced lamb shoulders.

Despite microbiological levels of sliced product from the short-aged and longer-aged shoulders reaching over 5 and 7.5 log_{10} cfu/g after four days of storage, no relationship between microbiology and sensory attributes could be established. Consequently, there may be opportunities to work further with customers to modify existing shelf-life protocols without negatively affecting consumer acceptance.

Vacuum-packaged primal cuts

It is common to store and distribute chilled lamb as boneless primal cuts (1–5 kg) vacuum-packaged in bags made of plastic materials with low permeability to gases. Meat packed in this manner is easy to handle; its colour is preserved; and its storage life is greatly increased. Inside a vacuum package the residual oxygen is consumed by tissue and microbial activity, and carbon dioxide is produced. Provided packaging has been performed correctly, there is little head space within a vacuum package. While accurate gas analysis within a vacuum pack is difficult, the atmosphere in the head space most likely contains less than 1% oxygen, some 20–40% carbon dioxide, with the remainder being nitrogen.

Vacuum-packaged meat that is stored in low-permeability films is purple in colour since the meat pigment, myoglobin, is in the reduced form. When vacuum packs are opened, the purple colour should turn to red (return of the 'bloom') within around 30 minutes. Development of a brown colour during storage indicates that an excessive quantity of oxygen has been present during storage. This is caused either by the use of a film which is excessively permeable; or because the pack is a 'leaker', with oxygen being able to enter via a faulty bag seam or through a puncture; or because the meat tissue has been unable to consume the oxygen remaining in the pack after vacuum-packaging. One reason for this inability is the packaging of meat too long after slaughter. After several days, there is a decline in the activity of certain enzymes in the meat that assist the consumption of oxygen. By avoiding excessive intervals between slaughter and vacuum-packaging (the interval is now frequently less than 24 hours), and by carefully checking vacuum packs for evidence of leakers 24 hours after packaging, Australian processors have successfully prevented premature appearance of brown lamb in vacuum packs.

Maximum commercial storage life of vacuum-packaged primal cuts of red meats is obtained provided that:

1. meat is produced using good manufacturing practice, with low initial total counts of microorganisms that are able to grow at the storage temperature;
2. best practice is applied in handling, packing and storage of bagged and cartoned cuts;
3. packaging film is free of leaks and has a low permeability to gases; and
4. there is good control of temperature during the storage period.

When vacuum-packaged lamb spoils, it is largely due to aroma and flavour changes. Most usual is the development of an 'off' or atypical flavour in the cooked meat. When first detected this flavour is commonly described as cheesy, sour and acid, but later in storage also as bitter and liver-like. These changes are attributed to the accumulation of acidic end products resulting from the growth of lactic acid bacteria which comprise the main group of bacteria in vacuum-packed product. Sometimes other species of bacteria, including *Brochothrix thermosphacta*, are implicated in spoilage events.

Figure 2: Trial pack prepared for retail display under overwrap conditions

What we mean by shelf-life

Generally, food is considered to have reached the end of its shelf-life when it is no longer acceptable to the consumer. It may either be that the colour, flavour, texture, aroma or nutrient content have deteriorated to the point where the food is no longer acceptable; or it could be when a food-safety issue arises—where the food may make consumers ill. Whilst shelf-life is usually equated with spoilage—for fresh meat in particular—the end of retail shelf-life might be reached before spoilage, as such, is evident. For example, the loss of bloom of mince or slices during retail display, or exceeding a microbial count specified as an acceptable maximum by a retailer, may be the determinant of shelf-life; whereas spoilage—as defined by off-odour and slime—would be the point at which it is unacceptable for consumption.

The majority of Australian lamb sold in vacuum packs is opened, sliced or otherwise prepared for retail sale, and packed for retail display either by overwrapping or in a modified atmosphere. Where shelf life is determined by loss of attractive appearance—as is often the case with retail packs prepared from vacuum packs—that shelf life is set at the time of retail purchase rather than at the time of consumption. The shelf life guidelines for vacuum-packaged lamb given in this paper reflect the widespread retailer requirement for a period of retail display; however, it should be recognized that for food service and similar applications where a period of retail display is not required, the shelf life in vacuum packs will be longer.

While actual spoilage of vacuum-packaged lamb is usually microbial in origin, chemical factors also may be important in determining shelf life, particularly when it is defined in terms of appearance.

Consumer acceptance of meat

Appearance is one of the most important attributes by which consumers judge the quality of meat, therefore colour deterioration is one of the main factors that limits storage life—at least until the point of purchase. Meat must be packaged in a manner that retains its appearance, and presents it in an attractive way.

Many studies have shown that there is no direct relationship between colour and other important properties such as tenderness and juiciness. Once the consumer has purchased the meat, the other properties then become important (odour, flavour, tenderness, juiciness, etc.). The growth of micro-organisms, including aerobic spoilage bacteria once vacuum packs are opened, may result in changed odour and flavour that is ultimately identified by consumers as spoilage.

Ideally, packaging techniques for retail display and storage should maintain the appearance of meats, and delay microbial spoilage.

Meat colour

Myoglobin, a coloured pigment similar to haemoglobin of blood, gives lean meat its colour. The greater the concentration of myoglobin, the darker is the colour of the meat.

Figure 3: Trial packs under retail display

Myoglobin is the oxygen-carrying protein of muscle, and can exist in a number of forms which vary in colour. For example, in the absence of oxygen—as in vacuum packs—it is in the reduced form which is purple, but in the presence of oxygen it forms oxymyoglobin, which is bright red.

The conversion of myoglobin to oxymyoglobin is rapid and reversible. When the muscle is first cut, or has been stored in vacuum packs then exposed to air, it rapidly takes up oxygen and changes from purple to bright red. This is termed blooming and occurs within half an hour in air at 0–5°C. When oxygen is excluded by vacuum packaging, the colour reverts to purple. In the continued presence of oxygen, both myoglobin and oxymyoglobin become oxidized to metmyoglobin which is brown. The reaction proceeds slowly (at least 2–3 days in air at 0–5°C before any metmyoglobin is evident), but it is not readily reversible.

Meat colour is affected by the species, sex and age of the animal. The meat from older animals has more myoglobin than does that from young animals. Within a particular carcase, different muscles contain varying concentrations of myoglobin, and so vary in colour. Stress prior to slaughtering also plays a significant role, as it affects the final pH of the meat which, in turn, affects colour. Meat with a high final pH will frequently be darker and drier than normal.

Retail display following vacuum-packaged storage of primals

Figure 4: A retail pack of sliced lamb

Vacuum-packaged primal cuts are broken down to consumer cuts prior to sale. The longer the period of prior storage in the vacuum pack, the shorter is the display life of the consumer portions. The end of acceptable display life is normally evidenced by the development of an unacceptable amount of metmyoglobin browning. Longer display life can be achieved by the use of modified-atmosphere packaging, but its advantage becomes less as the period of prior vacuum-packaged storage increases.

Meat spoilage

In air, aerobic bacteria predominate on meat. If nitrogen-containing compounds (i.e. amino acids) are used by these bacteria, the end products of microbial growth will include malodorous amines (ammonia, putrescine and cadaverine) and sulphur compounds. Together these cause 'off' odours and flavours that are typically described as putrid. These may become evident when bacterial numbers are as low as one million per cm^2. Because some of these compounds are volatile, spoilage is usually first noted as an off (putrid) odour which causes rejection, i.e. the meat is unacceptable. This can normally only happen in vacuum packs if air has leaked into the packs.

If bacteria use glycogen or other carbohydrates from the meat, rather than the amino acids, the end products are organic acids, especially lactic and acetic acids. Under these circumstances spoilage is due to the accumulation of these acids, and since these compounds do not have a strong odour at the concentrations likely to be produced, spoilage may be noted first as a flavour change (souring). If there is any evidence of spoilage in meat from vacuum packs, it is more likely to be because of flavour—souring—than odour.

Microbial contamination

The muscle tissue of healthy animals contains very few micro-organisms. During processing, the surface of the carcase is commonly contaminated with micro-organisms which come mainly from the skin or fleece. These organisms originate from the environment of the animal (soil, etc.) and its gastrointestinal tract (faecal contamination). Other possible sources of contamination include the equipment used in dressing (e.g. knives), and the hands and clothes of the workers. While some micro-organisms of human origin may reach the meat, the bulk of the contamination comes from the animals themselves.

The intention of the meat industry is to produce meat with as low numbers of microbes as reasonably possible, in order to maximise shelf-life and minimise the occurrence of organisms associated

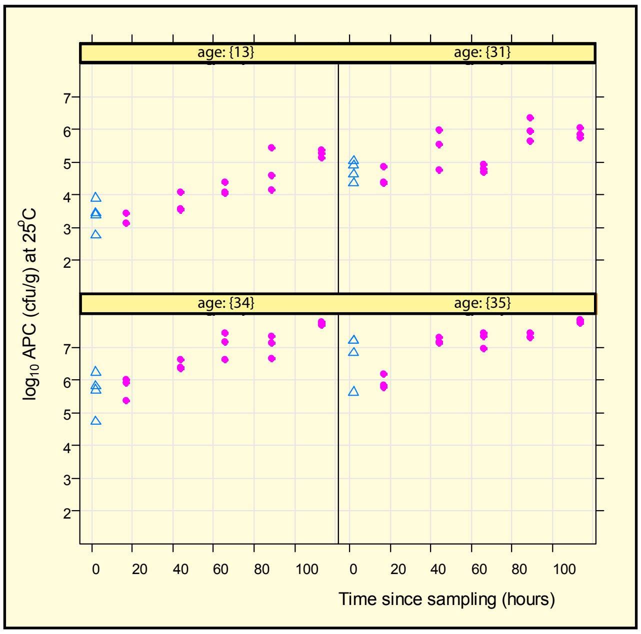

Figure 5: Aerobic Plate Counts, incubated at 25°C over time (in hours between sample collection/slicing and microbiological testing) for the four different ages of lamb shoulders—dots indicate slices; triangles indicate pieces.

with food-borne illness. That the industry is successful in doing so, is confirmed by scientific studies. National surveys of the microbiological status of Australian lamb were undertaken in 1993, 1998, and 2004; the results have been published in peer-reviewed scientific publications. In 2004, chilled sheep carcases from 20 abattoirs were found to have an average total viable count of just 190 organisms per cm^2.

Growth of bacteria on meat

Any contaminating bacteria are largely confined to the surfaces of the meat where oxygen is readily available. Meat is a good source of the nutrients needed by bacteria for growth—proteins, phospholipids, fatty acids and carbohydrate (notably glycogen) and other soluble non-protein substances.

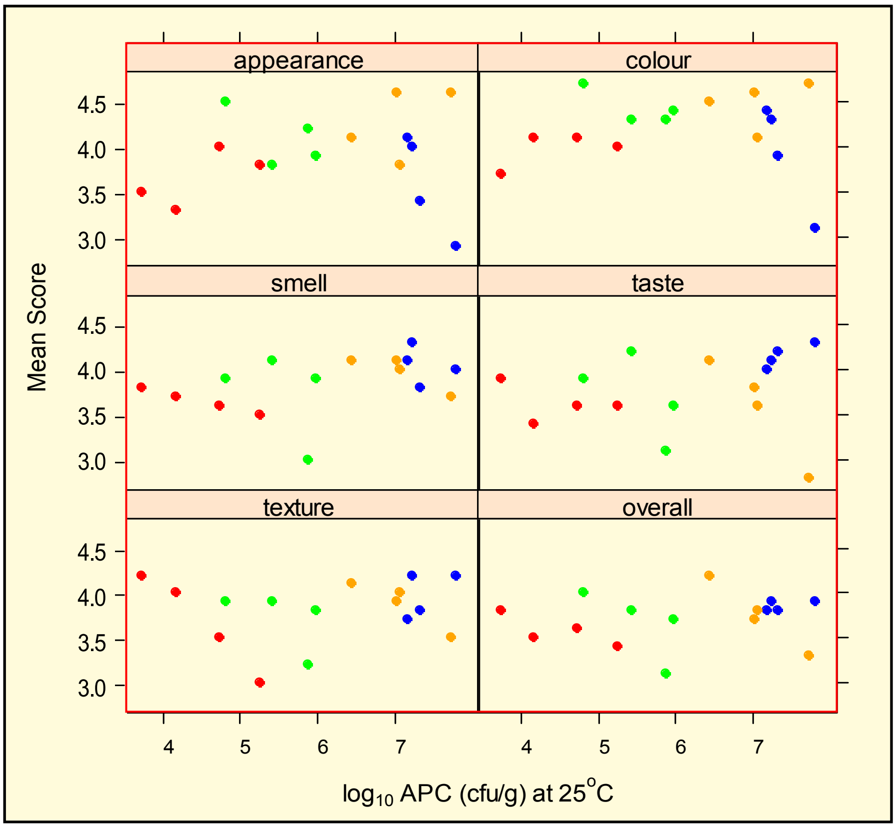

Figure 6: Scatter plot of the sensory scores versus $\log_{10}$ APC (at 25°C)—the different coloured points indicate different product ages. (red = 13 days aged; green = 31 days aged; yellow = 34 days aged; blue = 35 days aged)

Figure 7: A retail display of lamb portions

Environmental factors play a major role in controlling the growth of micro-organisms on meats.

Temperature—Growth rates at 0–1°C are only about half those at 5°C, and are further reduced as temperature falls. A storage temperature as low as is practical should be used for vacuum-packaged meat. About –1°C is optimal, provided that temperature control is such that freezing of the packs is avoided.

Gas atmosphere—The growth of many common spoilage organisms, particularly the aerobic bacteria, is inhibited by the presence of carbon dioxide and/or by the absence of oxygen, i.e. by manipulation of the redox potential. This is the basis of the effectiveness of vacuum packaging in preventing spoilage and prolonging storage life of meat.

pH—Whilst most micro-organisms can grow over the range of pH values of muscle (5.4–7.0), this factor becomes important in combination with other factors. For example, if lean red meat is placed in an environment where oxygen is no longer available, the composition of the flora which develops is greatly dependent upon muscle pH. In the context of vacuum packaging, some bacteria—that are inhibited in vacuum packs when the pH of the meat is normal for lamb (5.5–5.7)—can grow to spoilage levels at higher pH. By excluding meat from carcases where the pH of the LD muscle is excessively high, Australian meat processors of vacuum-packaged meat have eliminated spoilage problems attributed in the past to these bacteria.

Investigating microbiological growth during retail display of sliced, vacuum-packaged lamb

The objective of the first SARDI project was to investigate the changes that occur during the storage of vacuum-packed boneless lamb shoulders prior to slicing and holding in retail-style overwrapped trays. The microbiological and organoleptic properties of sliced lamb shoulders—that had been vacuum packed for between 13 and 35 days before being sliced and stored at 3.5 +/- 1°C for up to four days—were assessed. The relationship between microbiology and sensory attributes were determined.

On each assessment day during the trial, the sliced product was sampled for microbiological analysis. Microbiological tests consisted of Aerobic Plate Count (APC) and LAB incubated at 25°C for 96 hours.

Raw and cooked slices were subjected to an untrained Japanese sensory panel. The panel assessed the cooked product for taste and texture; and the raw product for appearance, colour and smell—rating them on a 1–5 point scale, where 5 = good; 1 = not good.

As expected, LAB were the predominant bacterial group on the sliced product over the storage trial, irrespective of time. The microbial growth over the four days was 0.4–0.5 $\log_{10}$ cfu/g per day (figure 5), which was consistent for APC and LAB. Also, as expected, the length of time that whole lamb shoulders were vacuum packed had a significant effect on the starting levels of the sliced product—13-day-aged lamb shoulders started with approximately 3 $\log_{10}$ cfu/g; while 35-day-aged lamb shoulders started with approximately 6 $\log_{10}$ cfu/g.

For appearance, colour, smell and taste, the sensory panel indicated that there were significant differences between the four different product ages; however, these differences were not consistent—which indicated that factors other than ageing may have impacted on the sensory profile.

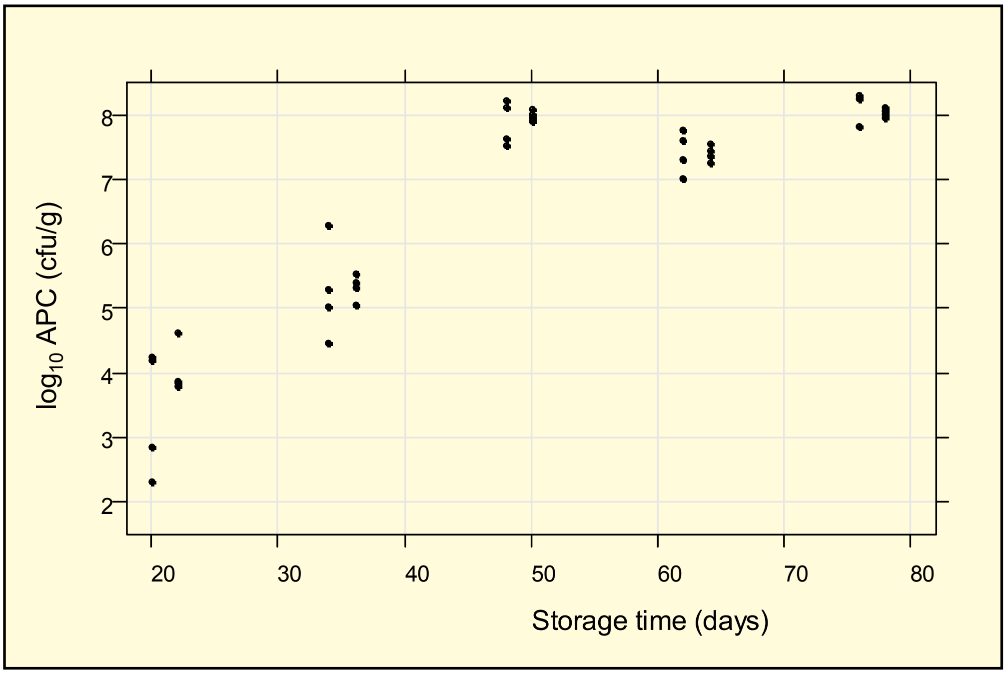

Figure 8: Aerobic Plate Counts for surface pieces collected directly after opening vacuum-packed lamb shoulders

While appearance and colour scores were affected by the order of evaluation (on the 5-point scale, the last product assessed scored on average 0.4 units lower than the first), they were unaffected by how long sliced product had been stored (figure 6). In contrast, smell, taste and overall impression of the four different product ages were unaffected by the order in which they were evaluated, but their score did reduce by an average 0.5 over the storage trial.

Investigating extended vacuum-packaged storage of lamb

The objective of the second SARDI project was to assess the microbiological and organoleptic properties of vacuum-packed lamb shoulders that had been stored for periods of up to 78 days. In particular, the relationships between microbiology and sensory attributes were investigated.

Vacuum-packed lamb shoulders were stored at –1 to 0°C for up to 78 days. Microbiological and sensory evaluations were made at days 22, 36, 50, 64, and 78 days, post vacuum packing. For each evaluation, lamb shoulders were removed from cold storage two days prior to the sensory session and on the day of the sensory session. These shoulders were sliced and packed in overwrap trays. Packs sliced two days prior to sensory evaluation were stored in the chiller during the day and under lights in a commercial display cabinet at night.

Meat surfaces were sampled from whole shoulders directly after opening the vacuum packs at each slicing occasion; and slices of retail product were sampled immediately prior to sensory evaluation from product exposed to zero and two days retail storage. All samples were microbiologically evaluated for APC and LAB. Levels of APC and LAB increased steadily up until 50 days of storage, by which time the stationary phase of 7–8 $\log_{10}$ cfu per g were reached (figure 8). Levels of APC and LAB on sliced product reflected those of vacuum-packed meat. Product freshly sliced exhibited an average of 0.8 to 1.9 $\log_{10}$ cfu/g less APC and LAB than product that had been displayed for two days.

At each sensory session an untrained panel of Japanese consumers evaluated the product for appearance, colour, smell, taste, texture and overall impression, scoring them on a 1–5 scale (5 = good; 1 = not good). No differences in sensory attributes were detected by the panel across the storage period— 22-day-aged product scored on average the same as 78-day-aged product. The only factor which had a significant effect on the sensory scores was the retail display time of sliced product, with product displayed for 2 days scoring lower on average—approximately ¼ score lower for appearance and colour, and approximately ½ score lower for the smell, taste and overall impression.

When sensory attributes were compared to microbiological levels no relationship could be found. That is, the consumer panel could not perceive difference in appearance, colour, smell, taste or texture in lamb with different levels of APC or LAB; however, consumers could perceive differences between freshly cut product and product that had been sliced and displayed for two days, though the observed differences were not related to the storage time of the product and hence the levels of APC and LAB.

Conclusions

From the data collected in these studies, it is clear that there is no relationship between the sensory scores and the microbiological levels of sliced lamb shoulders. Determination of shelf life is unlikely to be achieved through Aerobic Plate Counts, so the establishment of an APC limit is not useful. Organoleptic assessment is a more useful determinant of shelf life, particularly when supported by microbiological assessment of specific bacteria including *Brochothrix*. Consequently, there may be opportunities to work further with customers to modify existing shelf-life protocols, without negatively affecting consumer acceptance.

References

A.F. Egan, I. J Eustace and B. J. Shay (1988) Meat packaging-maintaining the quality and prolonging the storage lie of chilled beef, pork and lamb. *Meat 88: Proceedings of Industry Day.* p.68-75

P.M.Husband (1991) Options for chilled meat trade. *The production of chilled meat for export, Chapter 1.*

Vacuum Packing Primal Cuts 2000, *MLA Advisory Package – Packaging.*

The experimental work described in this document is summarized from MLA reports:

• A.MFS.0185 Shelf-life evaluation of sliced lamb shoulders (August 2009); and

• A.MFS.0196 Extended shelf-life evaluation of sliced lamb shoulders (January 2010)

Contact us for additional information

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DARK CUTTING BEEF AND ANIMAL TEMPERAMENT

INTRODUCTION

Dark cutting syndrome more - commonly referred to as DFD - is an important issue for both producers and processors. DFD results in meat which is dark in colour (figure 1), is less tender, less juicy and spoils rapidly due to the high pH making the environment more favourable for bacterial growth. The economic impact in 2009 as a result of DFD alone resulted in over $35million in lost revenue due to reduced quality of saleable product. In the 2011/12 FY, DFD affected approximately 75,000 MSA graded carcases.

Figure 1-Example of Dark Cutting meat as evaluated by AUSMEAT meat colour assessment dark (5) and light (1C)

The DFD condition is a result of muscle tissue being low or deficient in energy (glycogen) as a result of poor nutrition, exercise or stress prior to slaughter or a combination of the above. The depletion of muscle glycogen during the pre-slaughter period is controlled by numerous factors with one of the causative factors being animal temperament. The temperament of an animal affects how easy it is agitated thus influences the release of the hormone adrenaline during handling. As a result, it can be estimated how much muscle energy is depleted between leaving the farm or feedlot, and being processed.

Figure 2- Steers penned in the forcing pen ready for harvest

Murdoch University researchers Stephanie Coombes and Dr Peter McGilchrist in conjunction with The Department of Agriculture and Fisheries W.A, and Kylagh Cattle Company conducted an AMPC funded study investigating the long held belief that flighty cattle are at higher risk of dark cutting.

Materials and Methods

Approximately 650 British, European and *bos indicus* breed commercial lot-fed cattle (subset shown in figure 2), were assessed for temperament by using flight speed

Figure 3- Laser beam apparatus setup for measuring flight speed when animals exit the wighing chute

measurement (figure 3) through lasers and automatic time measurement devices as the animal exited the weighing chute.

Following slaughter, muscle pH, colour and glycogen were measured (Figure 4) and used to evaluate the relationship between flight speed, muscle glycogen levels at slaughter and dark cutting.

Figure 4-Example of dark cutting meat assessed by pH and colour measures in the loin muscle (m. *longissimus dorsi*

RESULTS & DISCUSSION

Flight speed was measured as the time taken for the animal to travel a distance of 1.8m from the chute. Flightier animals will exit at a faster speed while quiet animals move more slowly.

The effect of flight speed on muscle glycogen concentration is shown in figure 5. From this graph, it can be seen that as the flight speed of an animal increases, there is a positive relationship with muscle glycogen concentration in the loin (LD) muscle at time of slaughter. This indicates that the cattle which had higher flight speeds were in fact at a lower risk of producing dark cutting carcases (due to higher muscle glycogen concentration) in this study.

Grading assessment indicated that only 2% of cattle in this study were dark cutters (pH > 5.7 and/or meat colour score ≥ 4), and these carcases were evenly distributed across the range of flights speeds measured.

CASE STUDY 22 DARK CUTTING & ANIMAL TEMPERAMENT

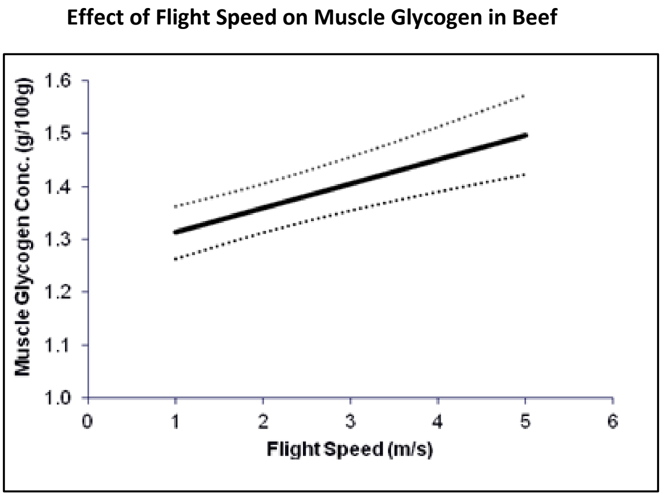

Figure 5-Effect of flight speed on muscle glycogen concentration (g/100g) in the loin (m. *longissimus dorsi*). Dashed lines denote standard errors.

Further analysis (data not shown) showed variables including kill day had the largest impact on muscle glycogen concentration.

Day to day variations between kills included weather, lairage pen number, and handlers during lairage. Time in lairage, distance travelled and nutrition were all maintained in a similar fashion for each kill.

The pen which they were raised in at the feedlot also had a significant effect. Some pens performed worse than other pens and this effect outweighed the impact of the location (property) of origin and breed, both which had no impact.

SUMMARY

- Calm cattle are not exempt from dark cutting
- Producers should minimise variation in temperament across their herd and habituate quieter cattle to change by using techniques like yard weaning
- Management of quiet cattle is important and they need to be handled with great care to minimise agitation in order to eliminate dark cutting beef from these animals
- Processors need to ensure calm cattle are treated with as much care during the pre-slaughter period as their flightier counterparts
- Further research is required to better understand the relationship between temperament, surrounding environments, stock persons and animal handling techniques and energy metabolism of animals during pre-slaughter periods

Figure 6- An example of a calm steer with researcher Stephanie Coombes at the feedlot

For further information, please contact lead investigator Dr Peter McGilchrist at p.mcgilchrist@murdoch.edu.au or visit the AMPC website at www.ampc.com.au

BEEF FACTS
Product Enhancement

Dark, Firm and Dry Beef

Author: Dr. Mark Miller, Texas Tech University

Introduction

Beef characterized as dark cutting will have an abnormally dark purplish red to black colored lean as shown in Figures 1a and 1b. Darkcutting beef is most often known as dark, firm, and dry (DFD). DFD beef can also be called "high pH" beef as a result of an animal's depleted muscle glycogen reserves prior to slaughter. The carbohydrate (sugar) glycogen is used as an energy source for muscle contraction and relaxation. Lactic acid is a by-product of glycogen utilization by the muscle when energy is produced in a stress event. After death, lactic acid accumulation in the meat is responsible for the pH decline from 7.0 to about 5.7 (Figure 2) during normal rigor mortis development.

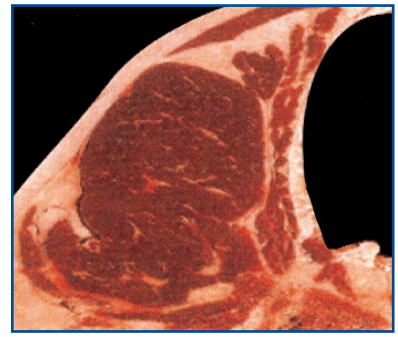

Figure 1a
Dark, Firm and Dry Beef Lean Color

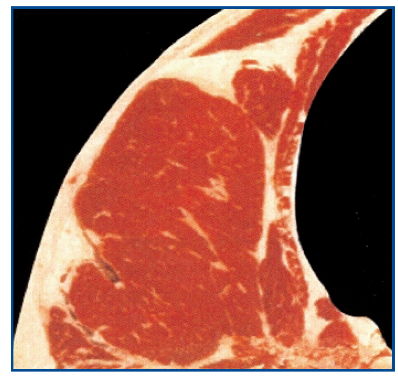

Figure 1b
Normal Beef Lean Color

Consequentially, the normal pH decline of meat during rigor mortis is altered due to a lower level of glycogen at death resulting from stress on the animal prior to harvest, which results in meat retaining a high pH.

DFD beef exhibits a dark, purplish red to almost black lean color and a dry, often-sticky lean surface. Due to high pH, lean surfaces act similarly to a dry sponge resulting in increased water binding capacity within the muscle.

The muscle appears dark because of higher intracellular water, which reflects less light. The higher pH results in less denaturation of myoglobin and would facilitate a higher level of aerobic metabolism at the surface. In addition, the high pH actively holds iron in the reduced (ferrous) state. The muscle is firm due to the high water holding capacity, and the surface feels dry as the water is tightly held within the muscle.

What events lead to Dark, Firm and Dry Beef

In cattle that are rested and not exposed to stress, muscle glycogen levels will be 0.8% to 1.0% prior to death.

However, an animal exposed to various forms of long-term pre-slaughter stress significantly depletes its glycogen reserves. A depleted state of glycogen less than approximately 0.6% will hinder normal postmortem pH decline. Muscle with a post-rigor pH of greater than 5.9 generally develops some form of darkcutting characteristic. The pH range of normal meat of an unstressed animal is 5.4-5.7. DFD meat will have a much higher pH of 5.9-6.5, with some meat being as high as a pH of 6.8.

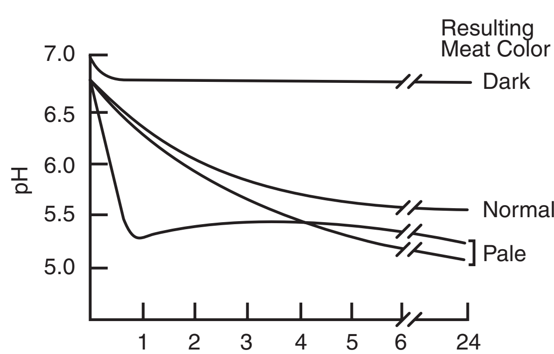

Figure 2
Postmortem pH decline and the resulting meat color
Source: Principles of Meat Science, 4th Edition

The depletion of muscle glycogen may be caused by a variety of severe pre-slaughter stresses including transport exhaustion, fear, climatic stress, aggressive behavior with young bulls, hunger, prolonged withholding of feed prior to slaughter, mixing of unfamilar animals and

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extreme adrenaline excitement. Cattle susceptible to stress whose carcasses exhibit the DFD condition are slaughtered before they have sufficient time to replenish their muscle glycogen stores. Replenishment of muscle glycogen stores can be slow and vary in duration. Replacement of muscle glycogen stores may take a few days or as long as two weeks post stress.

What Problems Surround Dark, Firm and Dry Beef?

Normal muscle blooms to a bright red color when exposed to air (Figure 1 b). Muscle with the dark cutting condition will not bloom to a bright red color and remains a dark purple red to black in color (Figure 1 a). The dark red state of DFD meat in a retail display case has proven to be one of the leading causes of consumer rejection of dark cutting beef. Consumers relate the dark colored lean to meat from an old animal, spoilage, undesirable flavor, toughness and poor shelf life. The extreme undesirable nature of dark cutting beef has resulted in the U.S. Department of Agriculture enforcing strict grade standards that impose stringent discounts on dark cutting carcasses. The discounts given to dark cutting carcasses have become a major issue to packers and producers alike. The discount is realized to the packer when cattle are purchased on a live basis, and realized by the producer when animals are sold on a carcass basis. According to the 2000 National Beef Quality Audit an estimated 2.3% (Figure 3) or 697,130 head of cattle slaughtered in 2000 produced DFD carcasses. USDA Agricultural Marketing Service reported the discount for dark cutters to be $30 per CWT (100 lbs). Therefore, a $164,592,393 loss to the beef industry or $5.43 per fed steer and heifer harvested in 2000 was realized.

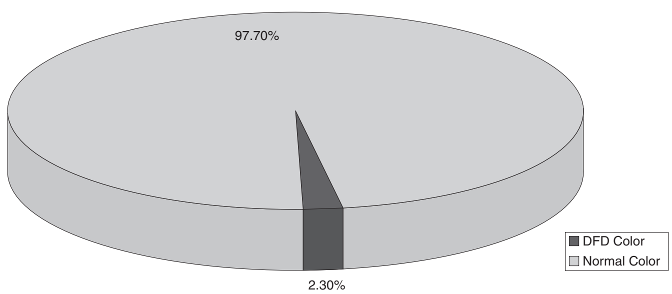

Figure 3
Percent of Cattle exhibiting DFD Color
According to the 2000 National Beef Quality Audit

Dark, firm and dry beef is of significantly lower quality as it has a reduced shelf life and a greater ability to support microbial growth. Increased microbial growth leads to increased spoiloge and an undesirable flavor. Reduced shelf life is largely due to a higher than normal pH and an increased water-holding ability, which are both conducive to microbial growth. Decreased levels of muscle glycogen lead to overall limited amounts of glycogen in the meat that can be converted to lactic acid. Lactic acid bacteria normally grow on meat and "compete" with spoilage causing bacteria. The reduction in glycogen, utilized by lactic acid bacteria, leads to a substantial decrease in lactic acid bacteria. Therefore, bacteria that produce hydrogen sulfide, which causes an off odor and green discoloration, proliferate and become numerous. It has been noted that dark-cutting beef consumed prior to spoilage has been regarded as having a slightly soapy off-flavor. However, the consumption of DFD beef is as safe and nutritious as normal beef.

What Are the Incidences and Causes of Dark, Firm and Dry Beef?

There are a variety of factors that result in animal stress. When stress factors are coupled with extreme or changing weather conditions, the animal's stress levels are severely increased and its chances of producing DFD beef also increase. The occurrence of DFD in grain-finished cattle normally ranges from 1.5% to 5%. However, in extreme circumstances, it is possible for a particular group of cattle to exhibit 65% to 75% DFD carcasses. It has been established that young bulls most often display DFD characteristics because of aggressive behavior. Cattle stress factors include, but are not limited to; biological type, implant strategies, geographical origin, mounting behavior (bullers), environmental conditions, temperature, relative humidity, wind, mixing of unfamiliar animals and carrying of cattle overnight at the slaughter plant. One or a variety of the above factors can contribute to the development of DFD meat.

Perhaps the most common stresses are mounting behavior and the mixing of unfamiliar animals. The mixing of unfamiliar animals, especially bulls, leads to increased mounting and aggression. This behavior increases physical activity, hence, depleting muscle glycogen. Secondly, young bulls are generally more aggressive and tend to have a higher incidence d DFD carcasses. Heifers in estrus generally tend to exhibit a higher percentage of dark, firm and dry lean due to the expression of breeding behavior.

Furthermore, adverse or fluctuating weather conditions, such as extreme temperatures, increase the stress level of an animal. The addition of precipitation or high winds can also raise the level of stress an animal can incur. It has been found that an average temperature above 35°C (95°F) over a period of 24-48 hours can drastically increase animal heat stress (panting) and therefore cause DFD carcasses. Temperatures of a freezing nature (<0°C) for 24 to 48 hours before slaughter can also contribute to an animal's cold stress (shivering). Heat stress may be lessened with shade. The highest incidence of DFD carcasses has been shown to occur in the fall months when temperatures fluctuate frequently. Weather patterns in September and October fluctuate between warm, mild days to cold, windy and/or wet conditions. This dramatic fluctuation tends to occur in a short time period leaving the animal little time to acclimate.

Today's beef cattle breeding utilizes numerous breed types to take advantage of the heterosis and complementarity of crossbreeding. It has become apparent that some stress factors may relate to biological type or breed.

Research has shown that Bos indicus or Brahman influenced cattle tend to acclimate to high heat stress levels more so than Bos taurns cattle (Cook 1998). This may be reversed if Bos indicus cattle are placed in a cold environment. Mixing of cattle from different locations also increases the chance for DFD carcasses. Animals from different origins tend to "fight and ride" to establish a new "pecking" order. Therefore, it can be stated that mixing of cattle prior to slaughter significantly increases the chances of DFD meat (Cook 1998).

Utilization of growth promotants or implants has become a vital part of the overall management decisions of producers. Particular implant strategies have been shown to increase DFD carcasses. The type of implant utilized and when it is administered is extremely important as the implant may alter the animal's hormonal balance and increase stress levels. Certain analogs of testosterone have been implicated in an increase in DFD carcasses. It is important to evaluate an implant strategy for possible secondary outcomes such as DFD, due to hormonal balance changes. The flowchart below (Figure 4), (Cook, 1998) denotes a system of DFD incidence according to type of implant strategy utilized. The study was performed using 272,936 head of cattle. In each category, the number of animals producing a DFD incidence is stated per 1000 head.

Summary

Dark, firm, and dry carcasses contain lean with dark, purplish red to black color with a high pH and water holding capacity. Consumer rejection of dark meat is the leading problem facing DFD carcasses. Furthermore, an increased incidence of spoilage and reduced shelf life poses yet another problem. It has become apparent that reducing stress levels through appropriate management decisions can drastically reduce DFD carcasses. Therefore, cattle must be monitored throughout feeding, implanting, penning, processing, transporting and holding prior to slaughter. If proper steps are taken to minimize stress and allow for acclimation and rest after a stress event, then the incidence of DFD carcasses will drastically decrease. Nonetheless, identification of animals that have a greater risk of incurring stress and preventing its occurrence remains to be a challenge for the industry.

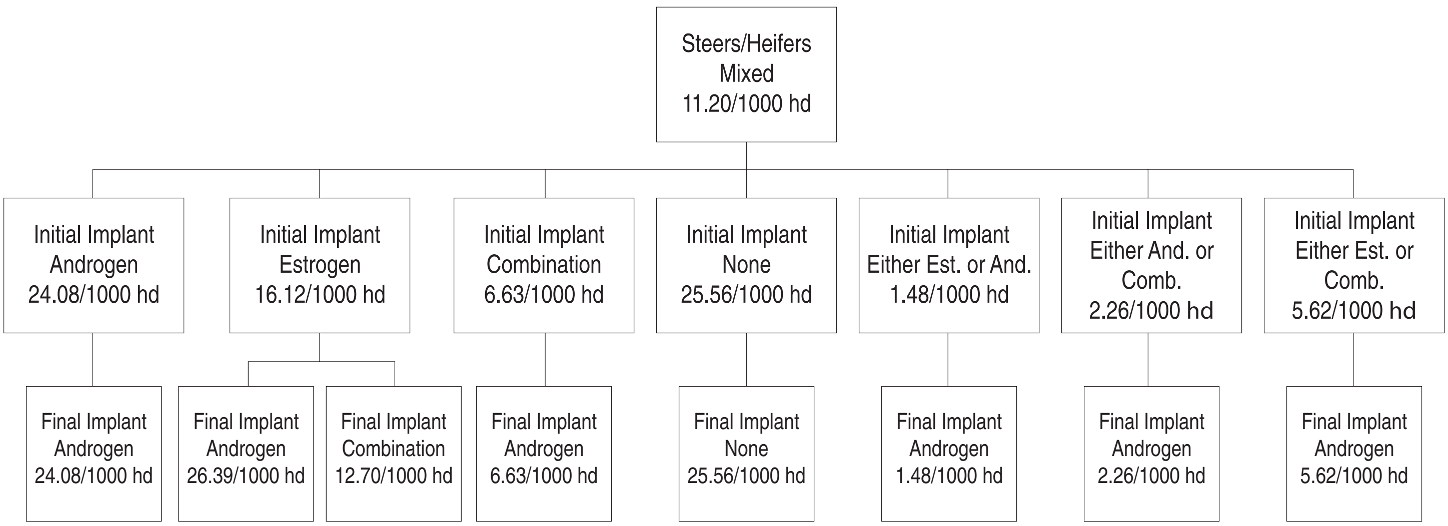

Figure 4: DFD incidence per 1000 head in mixed steer and heifers, sorted by implant strategy.
Source: Cook, 1998

References

Aberle, E.D., J.C. Forrest, D.E. Gerrard, H.B. Hedrick, M.D. Judge, R.A. Merkel, and E.W. Mills. 2001. *Principles of Meat Science, Fourth Edition.* Kendal/Hunt Publishing Company.

Cook, T. W. 1998. *Factors Contributing to the Incidence of "Dark-Cutting" Condition in Beef Carcasses and Management Strategies to Prevent Reductions in Value as a Result of their Occurrence.* Master's Thesis, Texas Tech University, Lubbock, Texas.

Eagan, A.F., and B.J. Shay. 1998. The effect of pH on the microbiology and storage life of vacuum-packaged meat. Proc. Australian Workshop on Dark-Cutting in Cattle and Sheep. AMLRDC, Sydney South. NSW.

Kenney, F.J., and P.V. Tarrant. 1987. The behavior of young Friesian bulls during social grouping at an abattoir. Influence of an overhead electrified wire grid. Appl. Anim. Behav. Sci. 18:233.

D.R. McKenna, P.K. Bates, D.L. Roeber, T.B. Schmidt, J.B. Morgan, J.W. Savell, T.H. Montgomery, and G.C. Smith. 2001. National Beef Quality Audit-2000: Results of carcass assessments. Final Report to the National Cattlemen's Beef Association, Texas A&M University, College Station.

Page, J.K., D.M. Wulf, and T.R. Schwotzer. 2001. A survey of beef muscle color and pH. J. Anim. Sci. 79:678-687.

Tarrant, P.V. 1988. Animal behavior and environment in the dark-cutting condition. Proc. Australian Workshop on Dark-Cutting in Cattle and Sheep. AMLRDC, Sydney South, NSW.

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National Cattlemen's Beef Association
on behalf of The Beef Checkoff

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Scientific Literature

JOURNALS:

Meat Science: http://www.sciencedirect.com/science/journal/03091740

International Journal of Meat Science: http://scialert.net/current.php?issn=2071-7113

Animal: http://www.animal-journal.eu/

Animal Production Science: http://www.publish.csiro.au/nid/72.htm

The Journal of Nutrition: http://jn.nutrition.org/

British Journal of Nutrition: http://www.nutritionsociety.org/publications/nutrition-society-journals/british-journal-of-nutrition

Meat Technology Updates (MTU): http://www.meatupdate.csiro.au/MeatQualityIndexPage.htm

DIGITAL DATABASES:

Pubmed: PubMed comprises more than 22 million citations for biomedical literature from MEDLINE, life science journals, and online books. Citations may include links to full-text content from PubMed Central and publisher web sites. http://www.ncbi.nlm.nih.gov/pubmed/

Science Direct: Science Direct is a leading full-text scientific database offering journal articles and book chapters from more than 2,500 peer-reviewed journals and more than 11,000 books. There are currently more than 11 million articles/chapters, a content base that is growing at a rate of almost 0.5 million additions per year. The parent publisher, Elsevier, has digitized as much of the pre 1995 journal owned-content as possible, bringing articles from as far back as 1823 (The Lancet) to the desktop. Never has in-depth literature searching been so comprehensive and easy to find. http://www.sciencedirect.com/

Google Scholar: Provides a search of scholarly literature across many disciplines and sources, including theses, books, abstracts and articles. http://scholar.google.com/

CONFERENCES AND INDUSTRY MEETINGS (2013):

Icomst: ICOMST (International Congress of Meat Science and Technology) is the premier conference for meat science related discussion and learning. This year, the program covers many aspects of this topic. The focus will be on the latest developments in muscle and meat science including novel meat sources, meat sustainability, animal welfare and slaughter, muscle biology and biochemistry, microbiology and chemical hazards, advanced preservation techniques, meat based functional foods. Also, a new approach of this year is to address engineering applications in meat industry and specific hot topics important to the industry and meat scientist and finally the congress will end with a panel session on the congress theme. http://www.icomst2013.org/t/index.php/home

Pangborn Sensory Science Symposium: http://www.pangborn2013.com/

Meat Science Education and Training

MSA Meat Science Training Course: MSA with University of New England and Murdoch University Scientists John Thompson and Graham Gardner will host a five day 'MSA Meat Science' training course in the MLA Brisbane office, week commencing 17th June 2013 til the 21st June 2013. The course explains the scientific elements behind factors affecting the eating quality of red meat, from production through to consumer. For further information, follow the link to http://www.mla.com.au/Marketing-beef-and-lamb/Meat-Standards-Australia/Training and follow the prompts to MSA Meat Science.

Intercollegiate Meat Judging (ICMJ): AMPC has been a major sponsor of the ICMJ program since 2004. Now in its 24th year, the ICMJ program aims at exposing and encouraging tertiary students into careers in the meat industry. These aims are facilitated by two competitions each year: a schools competition this year held in Tamworth; and a University competition and training course hosted this year by Charles Sturt University and Teys Australia in Wagga Wagga, NSW. For further information about how processors can be involved, follow the links to the AMPC Factsheet http://www.ampc.com.au/site/assets/media/Factsheets/Business-Development-Capability-Extension-Education-Training/19-Australian-intercollegiate-meat-judging-association-FINAL.pdf and the ICMJ website link http://www.icmj.com.au/ or alternatively contact the AMPC office to discuss.

MEAT SCIENCE RELATED ASSOCIATIONS:

American Meat Science Association: http://www.meatscience.org

American Society of Animal Science (ASAS) http://asas.org/

The British Society of Animal Science http://www.bsas.org.uk/

The European Federation of Animal Science (EAAP): http://www.eaap.org/

INDUSTRY ORGANISATIONS

The Sheep Industry CRC: http://www.sheepcrc.org.au/

The CRC for Beef Genetic Technologies: http://www.beefcrc.com/