THE BIOCHEMICAL BASIS OF TENDERNESS IN BEEF: A Ph.D. PROJECT

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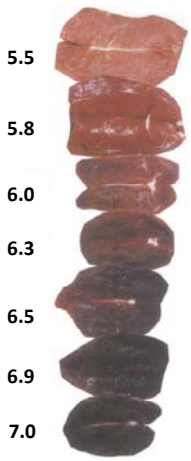
Meat pH is an indicator of eating quality

Ultimate pH Value	Quality	Colour
5.4 – 5.8 (low pH)	Tender meat	
5.8 – 6.2 (intermediate pH)	Inconsistently tender	
> 6.2 (high pH, DFD meat)	Tender meat Microbial spoilage Dark Less flavour	



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Project overview

1. **pH profile of New Zealand beef cattle**
   - Results from a survey of New Zealand beef cattle to determine the pH profile of beef cattle, with specific focus on bull beef.

2. **Tenderness is pH compartmentalised**
   - Why are low and high pH_u meat tender?

3. **Small heat shock proteins and toughness in intermediate pH_u meat**
   - Biochemical basis for toughness in intermediate pH_u beef

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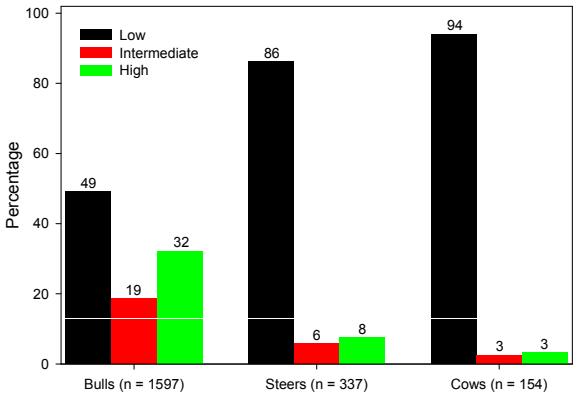
Overall ultimate pH status of beef in New Zealand



Survey over two years and three different seasons on three representative slaughter plants in the North Island.

Ultimate pH_u was measured from the loins samples stored at -1.5°C at 48 hours after slaughter.

Higher proportion of intermediate and high pH_u meat in bulls.

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Overall ultimate pH status of beef in New Zealand

	1990		1993		1994			2009		
	n	Mean pH_u	n	Mean pH_u	n	Mean pH_u	% low pH_u	n	Mean pH_u	% low pH_u
All beef					2969	5.8	69	2088	5.8	58
Cows					934	5.7	69	154	5.5	94
Steers	80	5.9	65	5.8	542	5.6	91	337	5.6	86
Bulls	**80**	**6.3**	**85**	**6.2**	**766**	**6.2**	**29**	**1597**	**6.0**	**49**

Currently, about half of New Zealand bull beef is intermediate or high pH_u.

BUT

There has been a progressive decline in intermediate and high pH_u bulls over the years.

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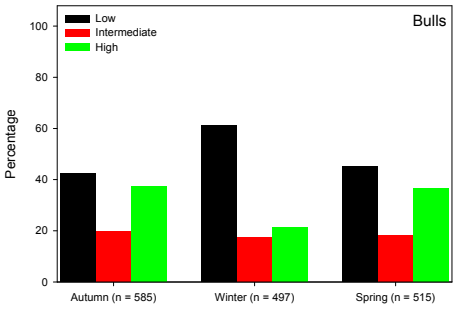
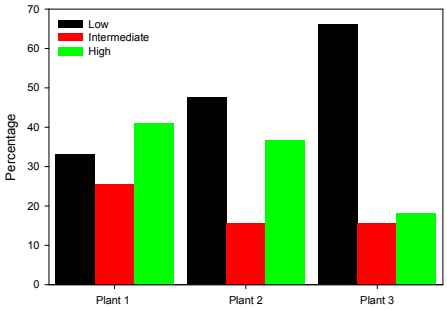
Plant and seasonal variation in the ultimate pH of bull beef





The incidence of intermediate and high pH_u meat was lower in winter. Overall, Plant 3 had the least percentage of intermediate and high pH_u bull beef.

Variation could be due to several factors:

1. Animal handling – on farm, transport, lairage
2. Meteorological conditions – rainfall, temperature
3. Seasonal nutritional quality of pasture

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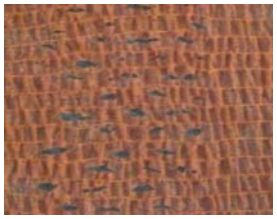
Tenderness in meat is due to degradation of muscle during ageing

At slaughter



7 days *post mortem*

28 days *post mortem*

Enzyme degradation of key myofibrillar and associated proteins is the cause of *post mortem* tenderness

This is why meat is **AGED**

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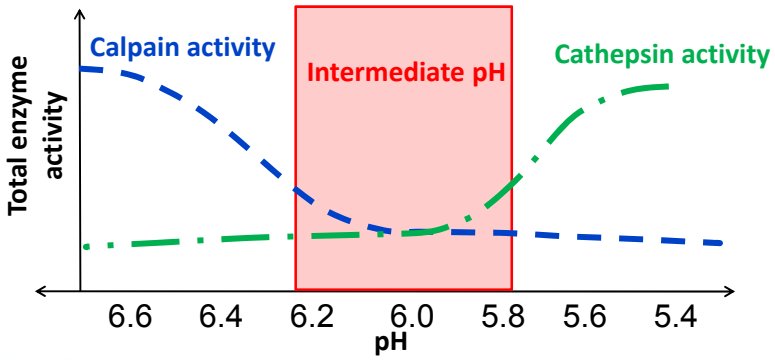
Dynamics of calpains and cathepsins

- Calpains optimal at near neutral pH
- Cathepsins optimal at more acidic pH levels



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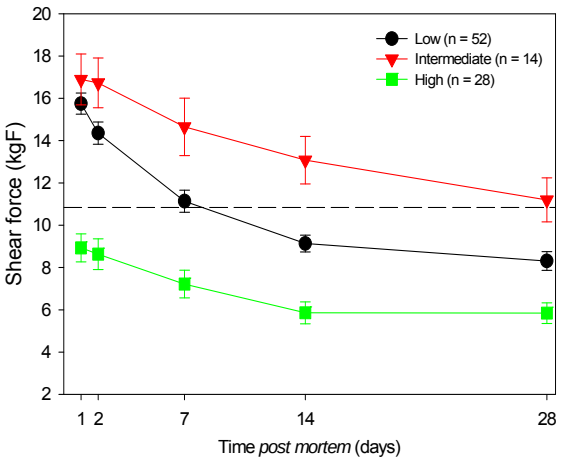
The problem with intermediate pH_u meat



On average, intermediate pH_u takes longer to attain acceptable tenderness.

Intermediate pH_u meat is more variable in tenderness and a proportion of intermediate pH_u will still be tough even after extended ageing

High pH_u is already acceptably tender at 1 day *post mortem*.

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2. Meat tenderness is pH compartmentalised

5.5 | 5.8 6.0 | 6.3 6.5 6.9 7.0

Low pH_u

TENDER

Intermediate pH_u

INCONSISTENTLY TENDER

High pH_u

TENDER

Why are high and low pH_u meat tender?

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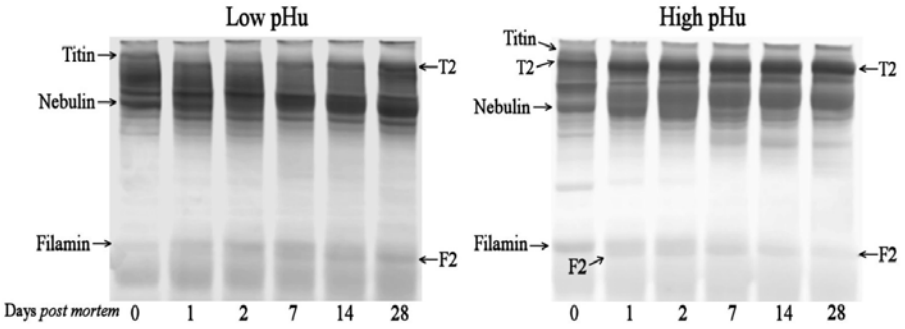
Tenderness in low and high pH_u meat is pH compartmentalised



Tenderness in high pH_u meat attributed to the rapid degradation of large proteins such as titin and filamin by the enzyme μ-calpain.

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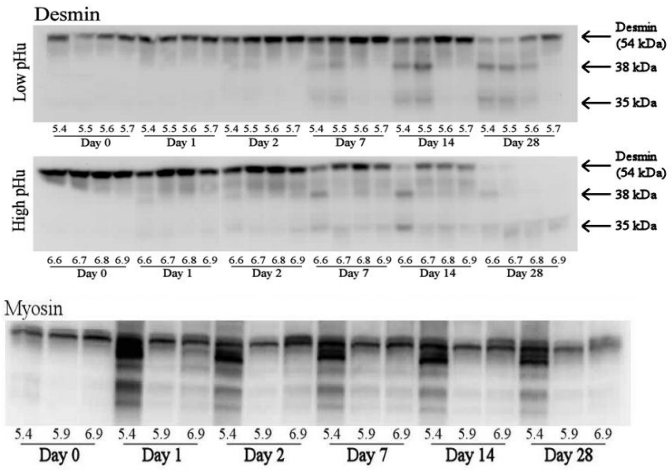
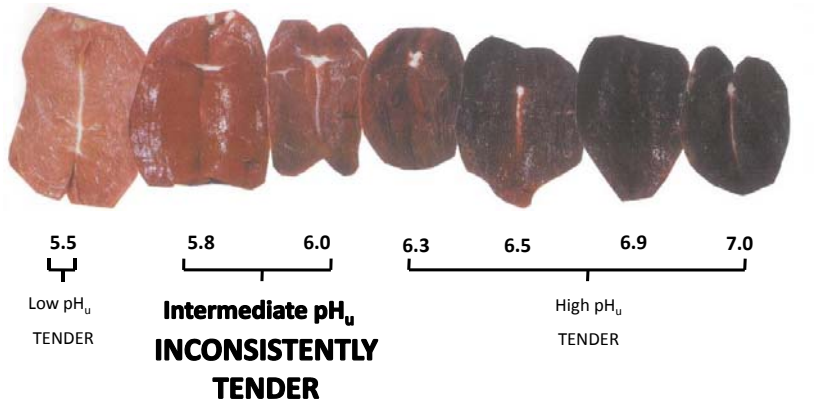
Tenderness in low and high pH_u meat is pH compartmentalised



Tenderness in low pH_u meat due to a combination of the degradation of large proteins by μ-calpain and smaller proteins by cathepsins at latter ageing periods.

3. Small heat shock proteins and toughness in intermediate pH_u meat



Why is intermediate pH meat inconsistently tender?

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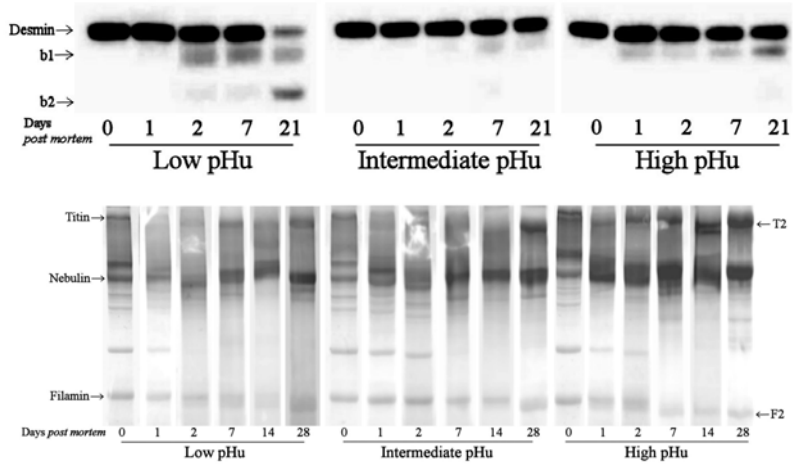
The slow and less extensive degradation of proteins in intermediate pH_u meat results in toughness



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Small heat shock proteins and tenderness

	sHSP Expression and Meat Tenderness	Reference
1	Changes in HSP27 significantly correlated with shear force	Hwang *et al.* (2005)
2	HSP27 and αβ-crystallin down-regulated in most tender beef samples as measured by a sensory panel.	Bernard *et al.* (2007)
3	HSP27 levels in muscle early *post mortem* explained up to 89% of overall sensory tenderness of bull beef	Morzel *et al.* (2008)
4	Higher expression of HSP27 in tougher beef	Kim *et. al* (2008)
5	Higher levels of αβ-crystallin in intermediate pH_u bull beef	Pulford *et al.* (2009)

Small heat shock proteins:

- Abundant in muscle cells
- Involved in protein repair – muscle damage
- Expression amplified in stressed cells
- Assist in proper assembly of proteins in living cells

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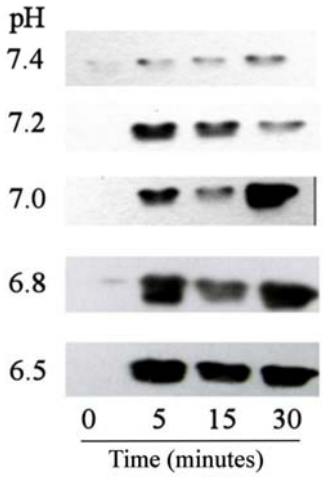
αβ-crystallin increasing interacts with myofibrils as pH decreases



- Increasing association of sHSP with myofibrils with decreasing pH
- Possibly greater sHSP associated with the myofibrils in the intermediate pH_u meat

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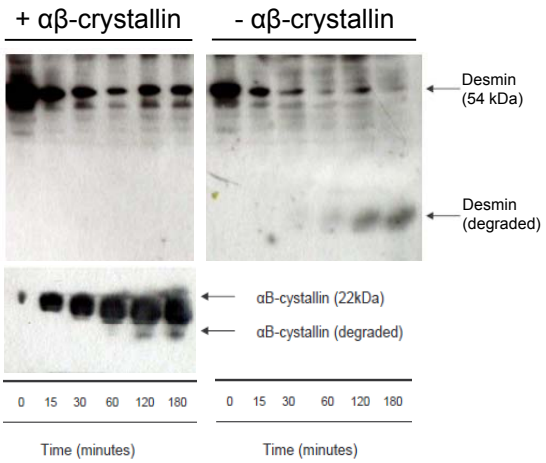
αβ-crystallin protects myofibrillar proteins from μ-calpain induced degradation



- αβ-Crystallin reduced extent of desmin and titin (not shown) degradation by μ-calpain
- αβ-Crystallin may act as an alternative substrate that competitively inhibits μ-calpain degradation of muscle proteins
- This results in the less extensive degradation of the muscle structure leading to meat toughness

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Summary

1. **pH Survey of New Zealand beef cattle**
   - Compared with previous studies, there has been an overall improvement in the pH profile of beef cattle.
   - High prevalence of intermediate and high pH_u bull beef – 19% and 32% respectively.
   - Variation in the pH profile between seasons and plants.

2. **Tenderness is pH compartmentalised**
   - Rapid tenderisation of high pH meat due to the faster and more extensive degradtaion of large myofibrillar proteins (titin, filamin) and desmin by the enzyme μ-calpain.
   - The slower rate of tenderisation in low pH meat due to the slower degradation rates of large myofibrillar proteins by μ-calpain and smaller proteins (desmin) by cathepsins.

3. **Small heat shock protein and toughness in intermediate pH_u beef**
   - αβ-crystallin reduced the enzyme degradation of desmin and titin
   - Increasing association of sHSP with myofibrils as pH declined
   - Potential for sHSP protection of myofibrillar proteins from degradation optimal in intermediate pH beef.

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Conclusion

- High incidence of intermediate and high pH bulls suggest they may be more susceptible to stress during transport and lairage.
- The degradation of proteins that are less abundant in muscle (titin, filamin, desmin) may contribute more to meat tenderness compared with more abundant muscle proteins such as myosin (43% of muscle protein).
- Will optimising processing conditions to maintain muscle at high pH levels for longer lead to the degradation of muscle proteins resulting in meat tenderness in intermediate pH_u meat?
- Is electrically stimulating muscle inducing the increased expression of small heat shock proteins leading to their contribution tough meat as observed in intermediate pH_u beef?

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