Modelling beef meat quality traits during ageing by early post-mortem pH decay descriptors

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Outline

1. Introduction
   - Meat quality
   - Meat tenderness is a complex trait
2. Material and Methods
   - Data collection
   - Data analysis
3. Results
   - pH/temperature decay descritors
   - Effect of animal/carcass descriptors
   - Modelling meat tenderness
4. Conclusions

Meat tenderness

- Inconsistency in the eating-quality characteristics of meat
  - Is one problem faced by the meat industry worldwide
- Meat tenderness - Most important sensory quality attribute
- If the beef is tender- We are able to evaluate the Juiciness and Flavour
- Consumers are even willing to pay more for beef of higher or guaranteed tenderness

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Meat tenderness

Depends on various physiological factors

- Proteolytic degradation
- Muscle contraction
- Intra-muscular connective tissue
- Marbling
- etc

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Meat tenderness

Critical periods for meat tenderness

- Immediately pre-slaughter
- During slaughter
- Immediately post-slaughter
  - Interaction between the pH and temperature decline
  - Ideal window

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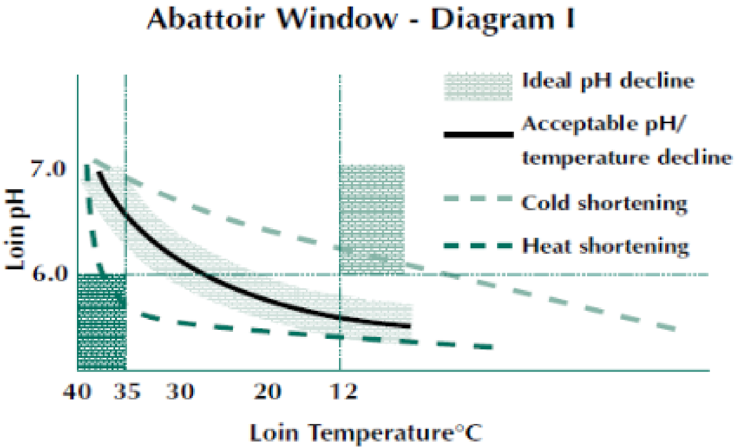
Ideal window



Objectives

1. to model the decrease in temperature and pH during chilling of beef carcasses early post-mortem
2. to evaluate the extent of influence of live-animal/carcass characteristics (i.e., sex, weight, age, breed, class, fat cover, conformation, and transport and lairage time) on the pH and temperature decline rates
3. Classification of beef carcasses into optimal quality (OQ) and cold-shortened (CS) taking into account the ideal window rule
4. Assess the combined effects of early post-mortem pH/temperature decline and animal/carcass characteristics on meat tenderness
5. The ultimate aim is to build practical models that can be used to predict the minimum ageing period of a beef carcass

Animals

Study 1: Modelling pH/temperature decline

- 126 beef animals (74 cross-breed and 52 Mirandesa breed)
    - 85 males and 41 females
    - Average age of 10.1 $\pm$ 2.32 months

Study 2: Modelling meat quality

- 51 Mirandesa breed animals
    - 34 males and 17 females
    - Hot carcass weight: 209.7 $\pm$ 65.60 kg

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pH/temperature measurements

Study 1 and 2

- pH and temperature were recorded
  - Intervals of 10 min during 24 h of carcass chilling
  - *longissimus thoracis* muscle at 4^{th} rib level
  - OMEGA wireless receiver/host (UWTC-REC1)

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Meat tenderness

Study 2: Meat samples

- *longissimus thoracis et lumborum* muscle from the 12th thoracic vertebrae to the 3rd lumbar vertebrae
- Meat blocks were vacuum packed (1, 2 or 3) and randomly assigned to one of three ageing periods (3, 8 and 13 days)
- Tenderness
    - Cooked at 70°C until the sample reached an internal temperature of 70°C
    - 1-cm cork-borer to give the maximum number of sub-samples
    - Ten to fifteen replicates of 1 cm2 cross-sectional area
    - TA.XTPlus texture analyser - Warner-Bratzler

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Modelling of pH/temperature decline

- **Exponential Decay** function proposed by Hwang and Thompson (2001)

$$Y_{(t)} = A_{(u)} + (A_{(i)} - A_{(u)}) \times e^{-k \times t}$$

- **where:**
  - $Y_{(t)}$ is the *pH* or *temperature* at time t
  - $A_{(u)}$ is the final *pH* or *temperature*
  - $A_{(i)}$ is the initial *pH* or *temperature*
  - k is the exponential constant of decay
  - t is the time in hours after slaughtering

pH/temperature descriptors

- pH: 1.5, 3.0, 4.5, 6.0 and 24 hours
- Temperature: 1.5, 3.0, 4.5 and 6.0 hours
- timepH6.0: time at $pH = 6.0$
- TemppH6.0: Temperature at pH6.0
- k_{pH}: exponential decay parameter for pH decline
- k_{Temp}: exponential decay parameter for temperature decline

Animal/carcass characteristics considered as regressors

- sex, age, breed
- hot carcass weight (HCW)
- transport time (tTransport), lairage time (tLairage)
- animal class: Calf, Vealer or Yearling

Modelling shear force during ageing

Linear mixed-effects model

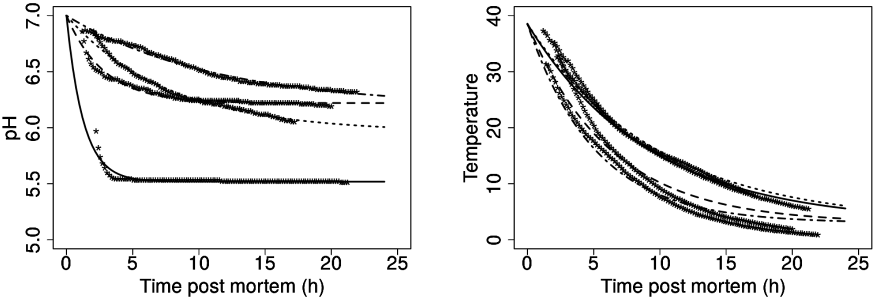
$SF_{ij} = \beta_{0j} + \beta_{1j} \times Ageing_{ij} + \beta_2 \times Ageing_i^2 + \beta_3 \times pH_{ep} + \beta_4 \times k_{pH} \times Ageing_i + \beta_5 \times Sex + \varepsilon_{ij}$

$\beta_{0j} = \beta'_0 + u_j$

$\beta_{1j} = \beta'_1 + v_j$

Random-effects terms u_j and v_j were added to the mean of the intercept β_0 and time slope β_1 to account for random shifts due to carcass j.

pH/temperature decay modelling



Mean, median and range of pH/temperature decline descriptors

Estimated values and model parameters	Mean	Median	Min	Max
$pH_{1.5}$	6.52	6.53	6.01	6.93
$pH_{3.0}$	6.24	6.25	5.62	6.87
$pH_{4.5}$	6.08	6.07	5.45	6.81
$pH_{6.0}$	6.00	5.95	5.38	6.76
pH_{24}	5.78	5.74	5.30	6.51
$Temp_{1.5}$ (ºC)	32.9	33.1	27.2	36.4
$Temp_{3.0}$ (ºC)	27.8	28.0	19.2	33.9
$Temp_{4.5}$ (ºC)	23.7	23.7	13.8	31.5
$Temp_{6.0}$ (ºC)	20.1	20.1	10.1	29.3
k_{pH} (h^{-1})	0.335	0.344	0.079	0.697
k_{Temp} (ºC/h)	0.113	0.101	0.022	0.256
$Time_{pH6.0}$ (h)	4.92	3.85	1.52	20.2
$Temp_{pH6.0}$ (ºC)	24.4	25.7	1.96	35.0

pH at 3 hours

pH at 3.0 h ($pH_{3.0}$)	HCW	-0.001	0.0005	0.036
	Class – Vealer	0.206	0.0690	0.004
	Class – Yearling	0.149	0.1137	0.193
	SEUROP – O	-0.035	0.0904	0.696
	R	-0.072	0.0916	0.436
	U	-0.296	0.1366	0.033
	Class – Calf	6.110^{a}	0.0548	-
	Vealer	6.317^{b}	0.0385	-
	Yearling	6.259^{ab}	0.0916	-
	SEUROP – P	6.343^{a}	0.0694	-
	O	6.308^{a}	0.0579	-
	R	6.272^{a}	0.0598	-
	U	6.047^{b}	0.1180	-

pH decay rate - k_{pH}

pH decay rate (k_{pH})	Class – Vealer	-0.058	0.0266	0.025
	Class – Yearling	0.004	0.0421	0.297
	SEUROP – O	0.018	0.0378	0.624
	R	0.008	0.0383	0.832
	U	0.155	0.0571	0.008
	Class – Calf	0.367[a]	0.0212	-
	Vealer	0.309[b]	0.0161	-
	Yearling	0.371[ab]	0.0363	-
	SEUROP – P	0.298[a]	0.0290	-
	O	0.316[a]	0.0242	-
	R	0.306[a]	0.0250	-
	U	0.453[b]	0.0492	-
Temperature decay rate	HCW	0.001	0.0001	< .0001

Time to $pH_{6.0}$ and Temperature at $pH_{6.0}$

Time to pH 6.0 (h) ($Time_{pH6.0}$)	Fat – 3	1.379	1.0880	0.200
	Fat – 2	4.518^a	0.8060	-
	3	5.896^b	0.7315	-
Temperat.at pH 6.0 (ºC) ($Temp_{pH6.0}$)	HCW	0.039	0.0146	0.009
	Class – Vealer	-2.160	1.8907	0.410
	Class – Yearling	0.332	3.2032	0.918
	SEUROP – O	3.620	2.6400	0.176
	R	6.370	2.5600	0.016
	U	7.200	3.5000	0.044
	Class – Calf	23.54^a	1.2800	-
	Vealer	24.02^a	1.0560	-
	Yearling	29.05^b	2.2900	-
	SEUROP – P	20.73^a	1.975	-
	O	24.36^a	1.755	-

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Temperature decay date - k_{Temp}

Temperature decay rate (k_{Temp})	HCW	-0.001	0.0001	<.0001
	Breed – Mirandesa	0.020	0.0097	0.043
	Gender – Male	0.014	0.0085	0.108
	Class – Vealer	-0.012	0.0078	0.877
	Class – Yearling	-0.028	0.0133	0.831
	Fat – 3	-0.029	0.0070	<.0001
	SEUROP – O	-0.037	0.0094	<.0001
	R	-0.066	0.0095	<.0001
	U	-0.088	0.0141	<.0001
	Breed – Cross	0.102^{a}	0.0055	-
	Mirandesa	0.122^{b}	0.0072	-
	Gender – Female	0.105^{a}	0.0068	-
	Male	0.119^{b}	0.0050	-
	Class – Calf	0.134^{a}	0.0064	-
	Vealer	0.118^{b}	0.0052	-
	Yearling	0.095^{c}	0.0111	-
	Fat – 2	0.109^{a}	0.0053	-
	3	0.080^{b}	0.0057	-
	SEUROP – P	0.143^{a}	0.0072	-
	O	0.105^{b}	0.0061	-
	R	0.076^{cd}	0.0063	-
	U	0.055^{d}	0.0121	-

Compliance discrimination

Algorithm	Predictio n	Reference CS	Reference OQ	Accuracy (95% CI)	Kappa
RLDA	CS	13	1	0.946	0.885
	OQ	1	22	(0.818 – 0.993)	
LDA	CS	13	2	0.919	0.830
	OQ	1	21	(0.781 – 0.983)	
kNN	CS	12	2	0.892	0.770
	OQ	2	21	(0.746 – 0.970)	
SVM	CS	12	2	0.892	0.770
	OQ	2	21	(0.746 – 0.970)	
NSC	CS	10	1	0.864	0.700
	OQ	4	22	(0.712 – 0.955)	

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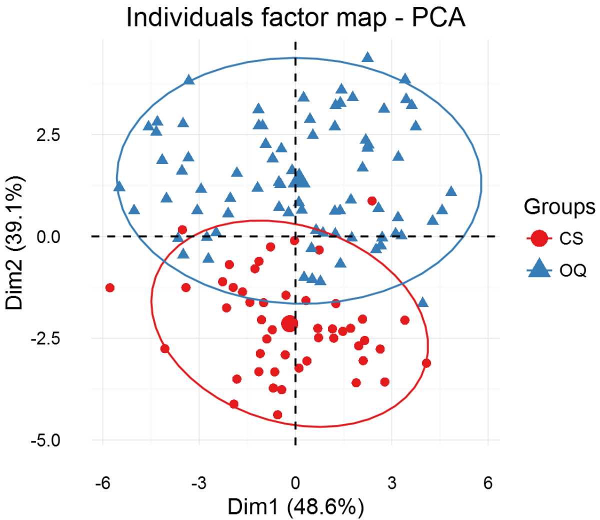
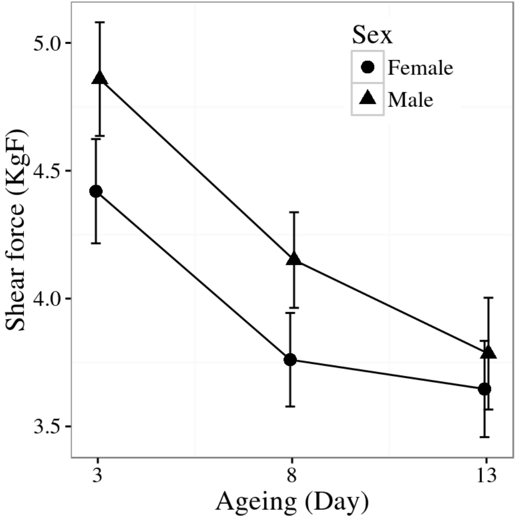
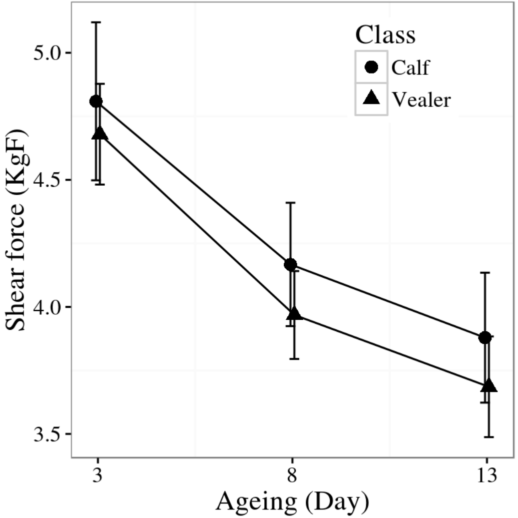
Compliance discrimination



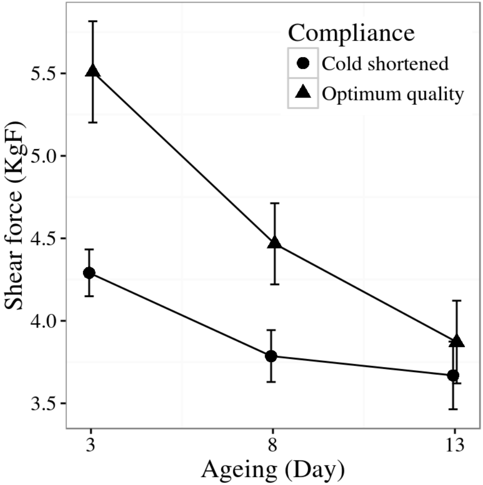
Sex effect on meat tenderness



Class effect on meat tenderness



Compliance


Compliance
Cold shortened
Optimum quality
Shear force (KgF)
5.5
5.0
4.5
4.0
3.5
3
8
13
Ageing (Day)

Conclusions I

1. Considerable variation in:
    1. rigor time: 1.5 – 20.2 hours
    2. rigor temperature: 2.0 – 35.0ºC
2. Quality of meat tenderness could be either optimal (~61%) or cold-shortened (~39%)
3. A two-dimensional principal component analysis showed that five variables – HCW, k_{pH}, k_T, $pH_{3.0}$ and $T_{3.0}$ hours post-slaughter - can be used to distinguish the beef meat quality into cold-shortened and optimal quality
4. The rate of tenderisation is higher in the early post-mortem carcasses and slows down as ageing time elapses for the carcasses

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Conclusions II

5. Carcasses of low final pH produced the least tender meat throughout the ageing period but with a sharp decline in shear force attained tenderness levels at 13 days post-mortem comparable to those of high pH meat
6. This study clearly shows that a quality control system can be implemented based on the pH/temperature descriptors

THE END! I

THANK YOU FOR YOUR ATTENTION

OBRIGADO PELA ATENÇÃO

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