Incorporating meat quality in sheep breeding programmes: *potential of non-invasive technologies*

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Introduction

- Genetic selection for lamb meat quality rare
- Difficult / expensive/ time consuming to measure
  - Direct tests:
    - post-mortem - on relatives, difficult to standardise
    - destructive - expensive, not possible on-line
  - Predictive tests:
    - mainly post-mortem; often destructive / invasive / slow
- Other potential hindrances:
  - Data feedback from abattoir; reliable traceability
  - On-line implementation

Species	Type	Country	Trait	Heritability	Reference
Bos taurus	Taurine	USA	Marbling	0.57 ± 0.13	(Wheeler *et al.*, 2001a)
			LT SF[1]	0.22 ± 0.12	
			Juiciness	0.09 ± 0.11	
			Flavour	0.07 ± 0.11	
			IMF	0.55 ± 0.14	
	Taurine	Australia	LT SF	0.11 ± 0.06[2]	(Johnston *et al.*, 2003)
			Juiciness	0.15 ± 0.06	
			Flavour	0.05 ± 0.06	
			MQ4	0.13 ± 0.06	
	Zebu[3]	Australia	LT SF	0.31 ± 0.09	
			Juiciness	0.20 ± 0.08[4]	
			Flavour	0.23 ± 0.08	
			MQ4	0.32 ± 0.09	
	Taurine	Australia	IMF	0.38 ± 0.04[5]	(Reverter *et al.*, 2003)
	Zebu	Australia	IMF	0.39 ± 0.03[5]	
Gallus gallus	Broiler	France	Ultimate pH	0.49 ± 0.11	(Le Bihan-Duval *et al.*, 1999)
			Lightness	0.75 ± 0.08	
			redness	0.81 ± 0.04	
			yellowness	0.64 ± 0.06	
			IMF	0.08 ± 0.04	(Zerehdaran *et al.*, 2004)
Ovis aries	Merino	Australia	Meat pH	0.27 ± 0.09	(Fogarty *et al.*, 2003)
			Lightness	0.14 ± 0.07	
			redness	0.02 ± 0.06	
			yellowness	0.04 ± 0.06	
	Composite	France	IMF	0.22	(Moreno *et al.*, 2001)
Sus scrofa	Large White/ Landrace	Australia	Meat pH	0.14 ± 0.04	(Hermesch *et al.*, 2000)
			Lightness	0.29 ± 0.06	
			Drip Loss	0.23 ± 0.05	
			IMF	0.35 ± 0.06	
	Duroc/ Landrace	USA	Meat pH	0.14 ± 0.08	(Lo *et al.*, 1991)
			IMF	0.52 ± 0.13	
			Cooking loss	0.06 ± 0.06	
			Tenderness[6]	0.17 ± 0.08	
			Off flavour	0.03 ± 0.06	
			Consumer acceptance	0.34 ± 0.11	

[1] *Longissimus thoracis* shear force; [2] SE of heritability given as a range of 0.04–0.08 for the table see original reference; [3] Mixture of purebred zebu (e.g. Brahman) and breeds with some zebu ancestry; [4] SE of heritability given as a range of 0.07–0.09 for the table see original reference; [5] SE personal communication A. Reverter; [6] this is the objective measure of tenderness, for taste panel tenderness, $h^2 = 0.45 \pm 0.12$.

Genetic control of meat quality

From: J.P. Kerry and David Ledward:
Improving the Sensory and Nutritional Quality of Fresh Meat
Elsevier, 2009

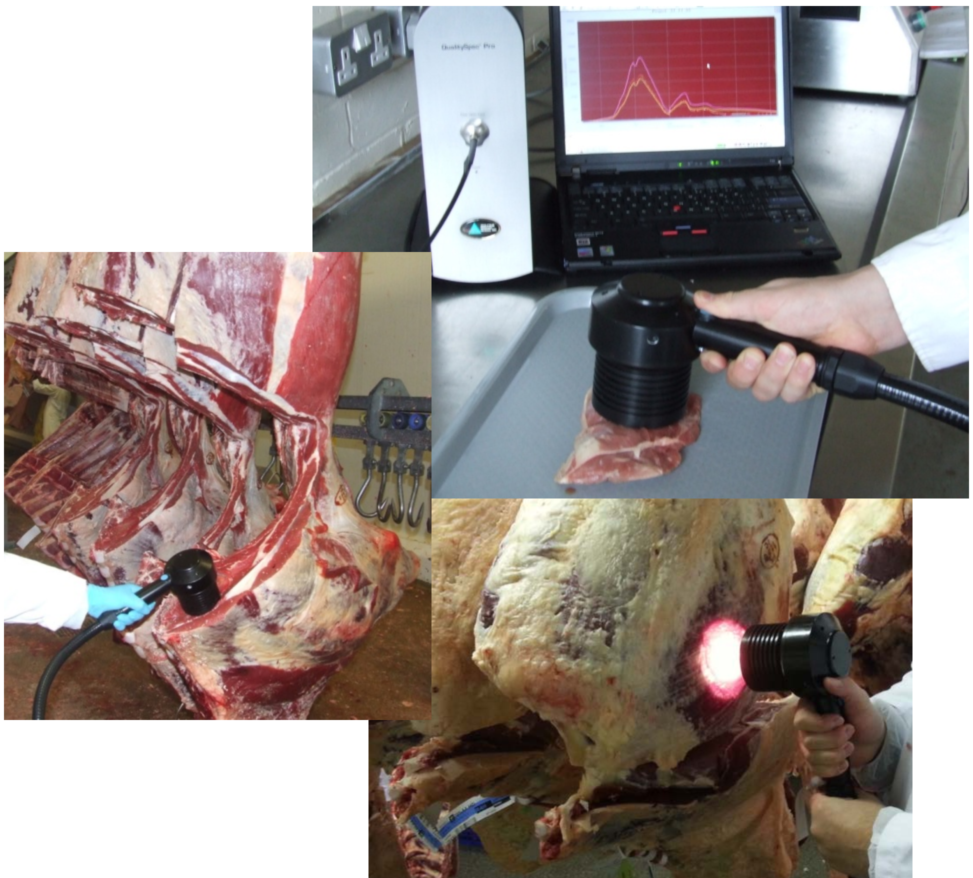
Introduction

- Few examples of commercial implementation
  - large scale progeny tests (NZ, Australia)
  - genomics
  - (SRUC “More taste, less waste” industry-led project)

- Accurate phenotypes are key
  - rapid, routine, non-destructive, non-invasive, cost-effective
  - Imaging technologies?

Non-invasive *post-mortem* predictors

- Visible and Near Infra-red spectroscopy (VISNIR)



Predicts:

- Colour
- Cooking loss
- Composition
- IMF; fatty acids
- Mechanical tenderness
- Sensory traits

Pros:

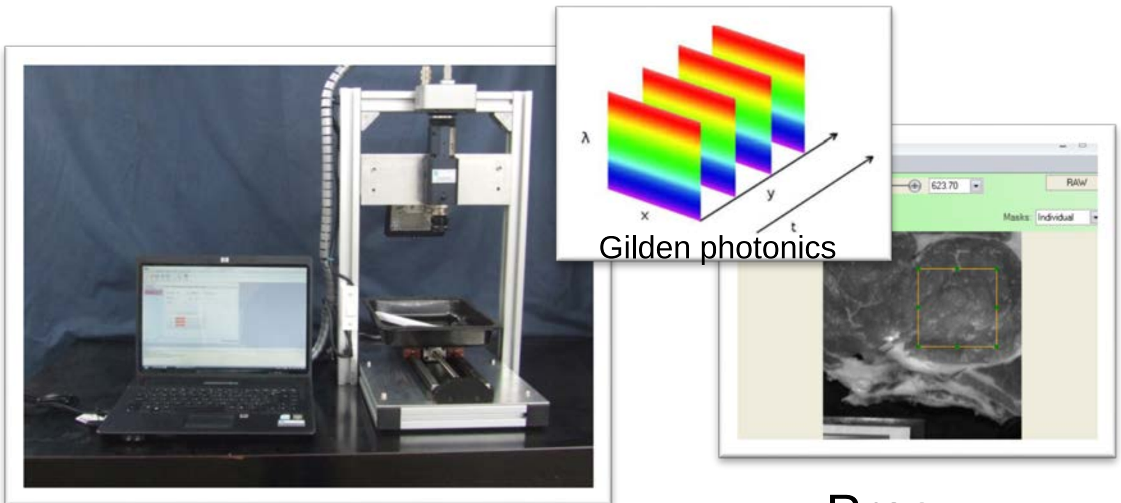
- Fast, non-invasive, cost-effective, on-line
- High R^2 for colour & composition

Cons:

- $R^2 << 1$ for technological/ sensory traits (Prieto et al., ‘09)
- predictions complex

Non-invasive *post-mortem* predictors

- Hyperspectral imaging
- Raman spectroscopy



Predict:

- Colour
- Cooking loss
- Mechanical tenderness
- Composition; IMF
- Fatty acid composition
- Sensory traits

Pros:

- non-invasive, cost-effective
- wealth of information
- R^2 >0.8 for several traits[1]

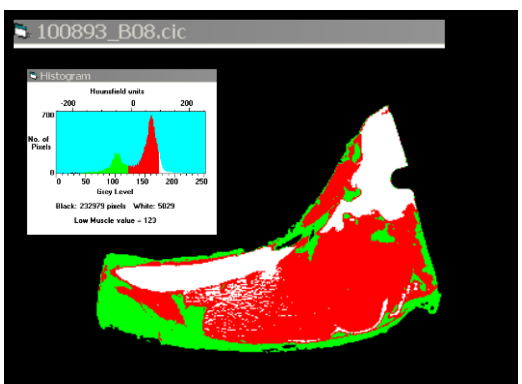
Cons:

- practicality in plant
- predictions complex
- price?

[1]review by Xiong et al., 2014

Non-invasive *post-mortem* predictors

- X-ray computed tomography (CT)



Predicts:

- IMF
  - beef (R^2=0.71–0.76)[1]
  - pork (R^2 = 0.63-0.83)[2]
  - lamb (R^2= 0.36)[3]
- fatty acid profile (R^2=0.61–0.75)[1]
- low accuracy for tenderness and sensory traits

Pros:

- fast; non-invasive; packaged meat
- simultaneously predicts composition

Cons:

- $R^2 << 1$
- portability
- price

[1]Prieto et al., 2010
[2]Font-i-Furnols et al., 2013
[3]Lambe et al., 2009

Non-invasive *in-vivo* predictors

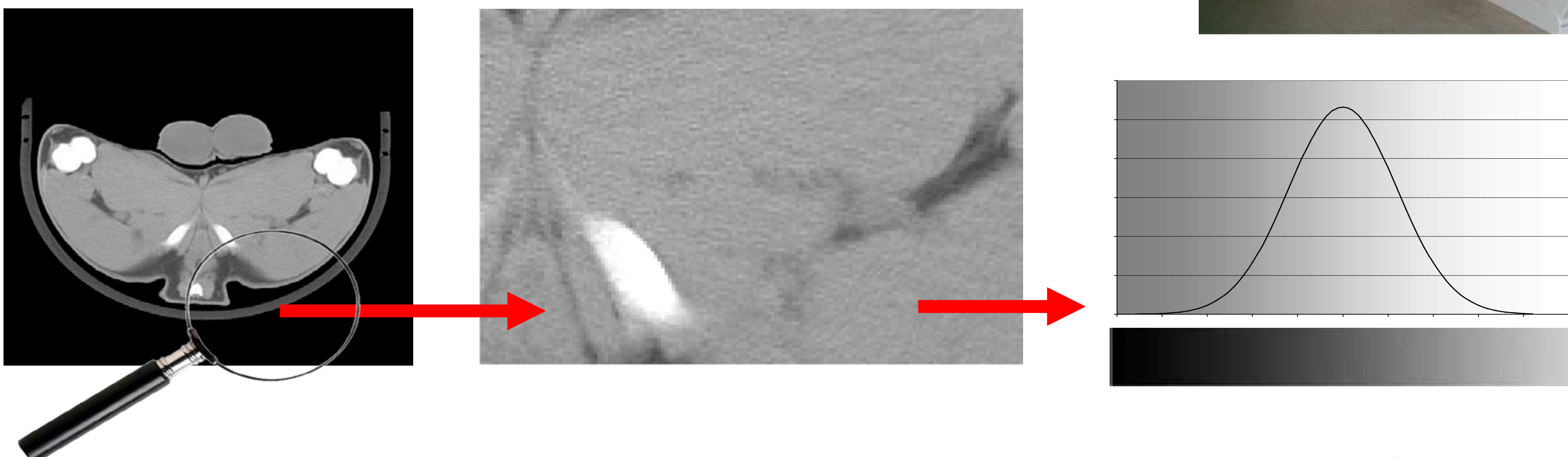
- Ultrasound
  - predicts IMF in pigs and beef cattle with mod-high accuracy (Newcom et al. ‘02; Aass et al., ‘06,’09)

  - not successful in sheep

http://bovineengineering.com/intra_mus_fat_ultra.html

Non-invasive *in-vivo* predictors

- X-ray computed tomography (CT)



- CT tissue density distributions reflect IMF levels in live lambs ($R^2 > 0.6$)
- Does not accurately predict mechanical tenderness or taste panel traits

Clelland, 2015; Lambe et al., 2008, 2009

Previous research: lamb IMF vs MQ

- Acceptable levels for IMF (loin)
  - > 2-3% grilled red meat / lamb[1]
  - > 5% for “better than every day” eating quality[2]
  - SRUC slaughter lamb mean IMF:
    - Texel 1.4-1.6%
    - Texel X Mule 2.2%
    - Scottish Blackface 2.3%

- Concerns about fat reduction for eating quality

[1]Savell and Cross, 1988; Heylen et al., 1998; [2] Hopkins et al., 2006

Genetic control of CT-IMF

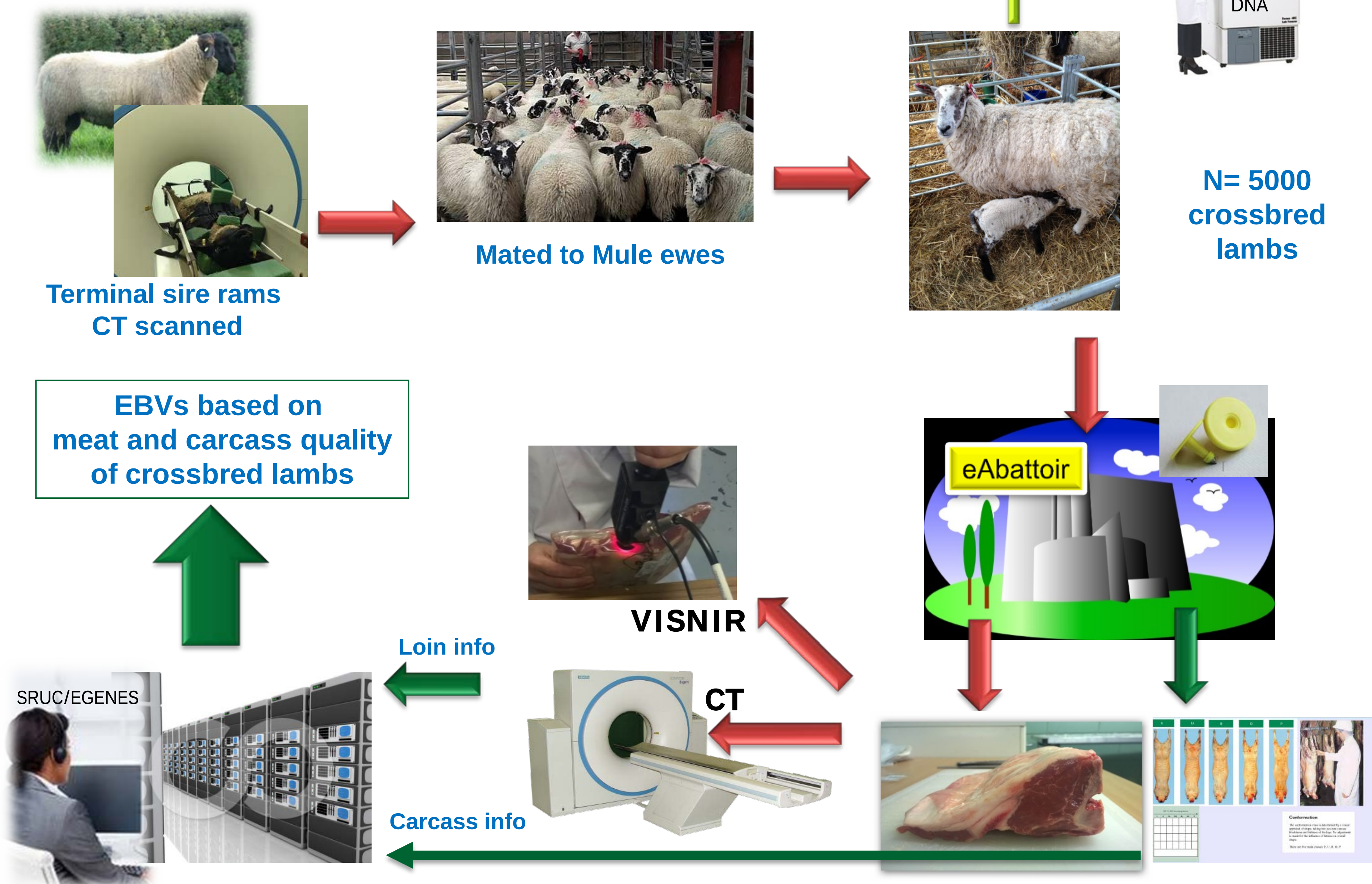
- Data set from UK terminal sire breeding programme
  - ~2000 Texel ram lambs over 12 years
  - CT and performance records:
    2-stage selection for carcass composition
- Genetic analysis of CT-predicted IMF (ASReml):
  - heritability = 0.31 (s.e. 0.07)
  - genetic correlation with total carcass fat = 0.68 (s.e. 0.08)

Clelland et al., 2015

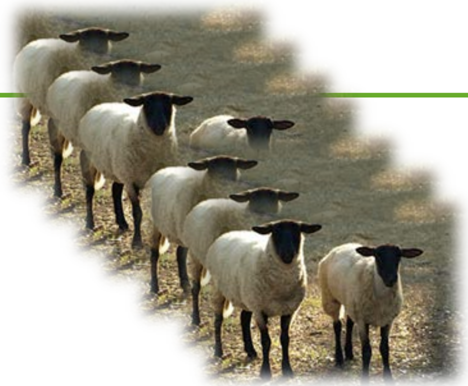
More taste, less waste

Industry led research project with SRUC as lead research partner

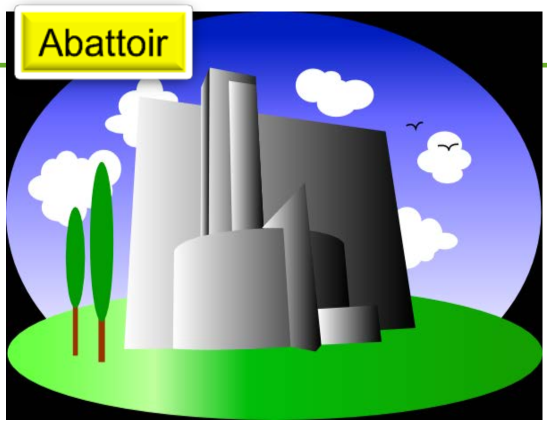
More taste, less waste project

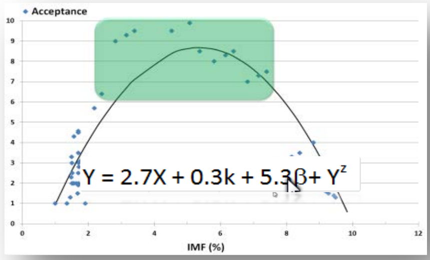


More taste, less waste project – WP1



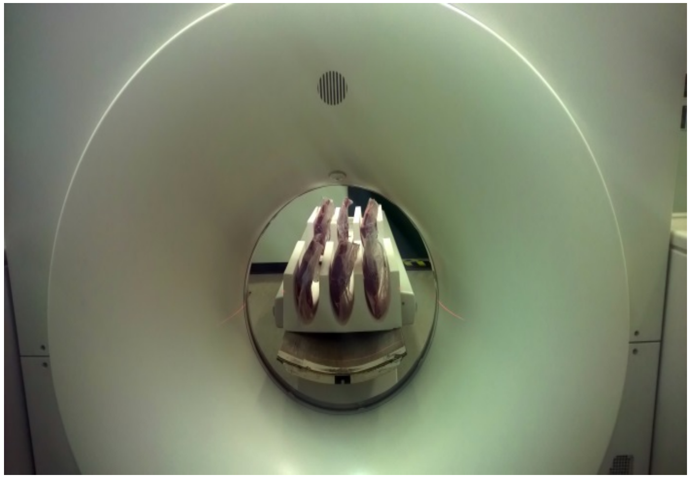
N= 300 across all specs





Prediction equations & correlations;
windows of acceptability

(Multiplex) CT to predict meat quality in lamb meat cuts



Trait	Accuracy of prediction (R^2)
IMF	0.36
Shear Force	0.03
Texture (TP)	0.08
Flavour (TP)	0.09
Juiciness (TP)	0.06
Liking (TP)	0.10

Prediction equations combining CT traits and weights of loin & carcass

Best single CT predictor of all traits = % fat in sample (estimated by CT)

	CT-predicted IMF converted to % band				
IMF % band	1-2%	2-3%	3-4%	4-5%	Total
1-2%	**5**	17			22
2-3%	3	**70**	55		128
3-4%		34	**83**	1	118
4-5%		2	23	**1**	26
>5%		1	2		3
Total	8	124	163	2	297

54% samples – band correct

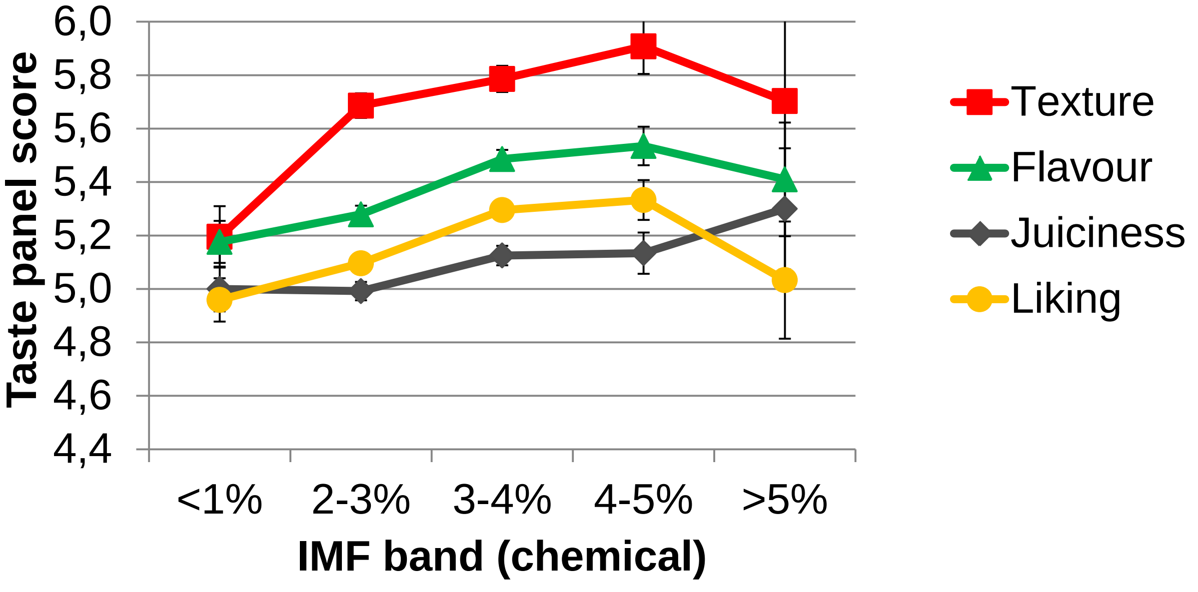
63% samples with IMF<3% = < CT band 3-4%

25% samples with IMF >3% = < CT 3-4%

IMF influences sensory traits

Sensory traits significantly affected by IMF level:

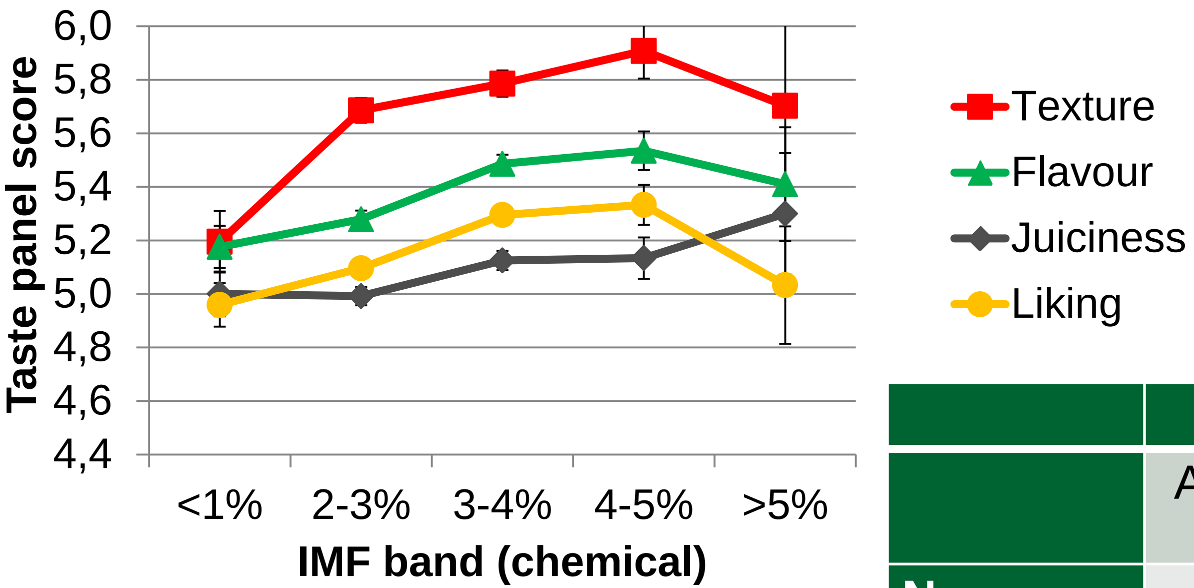
- Assessed by chemical IMF extraction



IMF influences sensory traits

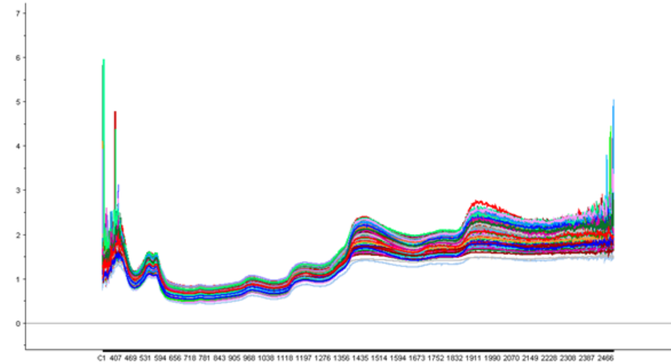
Sensory traits significantly affected by IMF level:

- Assessed by chemical IMF extraction OR predicted by CT



	CT-predicted IMF band			
	Adj-R^2	<3%	>3%	P value
N		132	165	
Texture	7.0	5.55	5.85	<0.001
Flavour	3.8	5.29	5.45	<0.001
Juiciness	4.4	4.98	5.15	<0.001
Liking	5.7	5.08	5.28	<0.001

VISNIR to predict MQ in lamb meat cuts



- Spectra from 500-2400 nm used in analysis
- Median spectra of 10 replicates used
- Unscrambler (v10.3) multivariate analysis software

VISNIR to predict MQ in lamb meat cuts

	Unpackaged		Vacuum-packed	
	R^2_{Cal}	R^2_{Val}	R^2_{Cal}	R^2_{Val}
IMF	0.35	0.23	0.23	0.18
ShF	0.03	0.01	0.11	0.04
Texture	0.03	0.01	0.07	0.06
Flavour	0.02	0.01	0.05	0.02
Juiciness	0.01	0.01	0.01	0.003
Overall liking	0.008	NA	0.001	NA

[3]R^2_{Cal}=Coefficient of determintion of calibration.
[4]R^2_{Val}=Coefficient of determination of validation.

Discussion – More taste, less waste

- Can we increase accuracies to predict IMF *post-mortem?*
  - VISNIR on fresh cut meat; analysis method
  - CT on whole carcasses

- Project has produced:
  - high accuracy *in-vivo* phenotypes for IMF
  - moderate accuracy *post-mortem* phenotypes for IMF
  - data set to develop SNP-keys for genomic selection

- A combination of *in-vivo*, *post-mortem* and genomic predictors could be used to develop a sustainable breeding programme including lamb meat quality traits

General discussion

- Clear breeding goals required
  - MQ and other traits – multi-trait selection index
  - genomic selection + phenotyping

- Need to overcome the barriers to practical implementation and routine phenotyping

- Move from R&D to commercial implementation

Danish Meat Research Institute

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