Prediction of the sensory quality of bovine meat based on multiscale image analysis approach

Mohammed El Jabri[1,2], Saïd Abouelkaram[3] & Daniel Roux[2]

[1] ADRIA Développement, Créac'h Gwen, F-29196 Quimper

[2] Laboratoire de Mathématiques, Université Blaise Pascal, F-63177 Aubière

[3] INRA, UR370 Qualité des Produits Animaux, F-63122 Saint Genès Champanelle

Introduction

- Bovine meat quality,
- The main criterion of quality for consumers: **Tendreness,**
- Purpose: Evaluation of meat tenderness using image analysis,
- Part of the study: Artificial vision process.

Outline

- Intramuscular Connective Tissue (IMCT),
- Discrete wavelet transform: «à trous» algorithm,
- Multiscale Vision Model (MVM),
- Detection of significant structures,
- Image analysis and data preparation,
- Prediction of bovine meat tenderness.

Intramuscular Connective Tissue

Epimysium

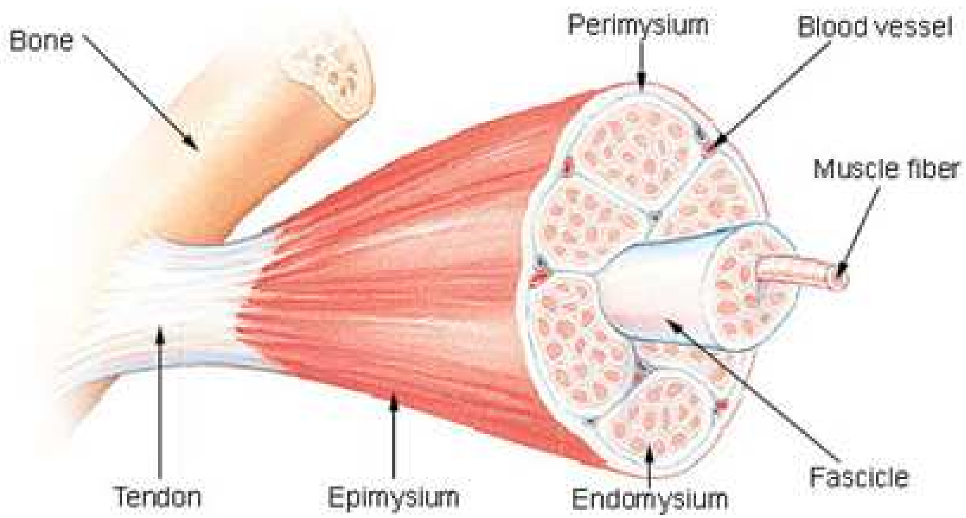
- Trimmed by the butcher,
- Is not consumed,

Perimysium

- 90% of connective tissue,
- Plays a major role,

Endomysium

- It doesn't seem involved in the variability of meat texture.



Discrete wavelet transform

« A trous » algorithm

- The discrete approach of the wavelet transform can be done with the special version of the so called **« à trous » algorithm**.

- It allows the computation of **successive approximations** by smoothing:

$$c_{j+1}(k,k') = \sum_{l,m\in \mathbb{Z}} h_{l,m}\, c_j(k + l2^j, k' + m2^j)$$

- The approximation c_{j+1} is obtained from the approximation c_j with convolution by the filter h and a step of 2^j between coefficients creating « holes » in the filter hence the name of the algorithm.

Discrete wavelet tranform

« A trous » algorithm

- Similar recurrence can be obtained for **wavelet planes**:

$$w_{j+1}(k,k') = \sum_{l,m\in Z} g_{l,m}\, c_j(k + l2^j, k' + m2^j)$$

- The wavelet plane at scale "j+1" is given by difference between approximations with resolution scales "j" and "j+1".

$$w_{j+1}(k,k') = c_j(k,k') - c_{j+1}(k,k')$$

Multiscale Vision Model (MVM)

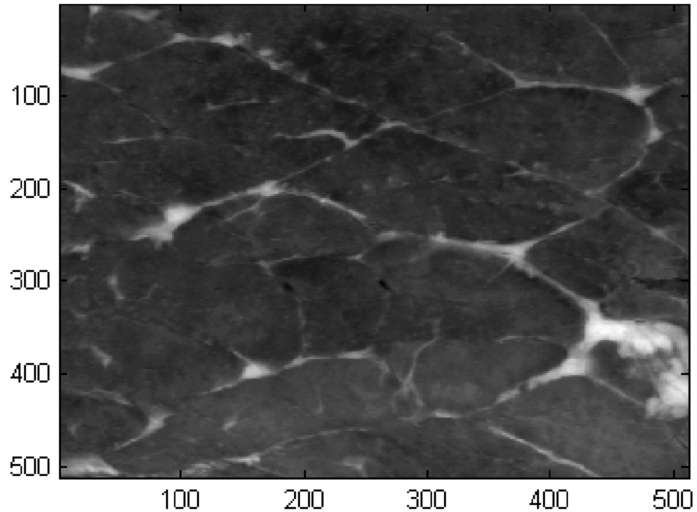
- For bovine meat image analysis, we chose to implement **"à trous" algorithm.**

- Fourth-order binomial filter was chosen:

$$h(0)= 3/8,\ h(\pm1)=1/4,\ h(\pm2)=1/16,\ h(n)=0 \text{ if } |n|>2$$

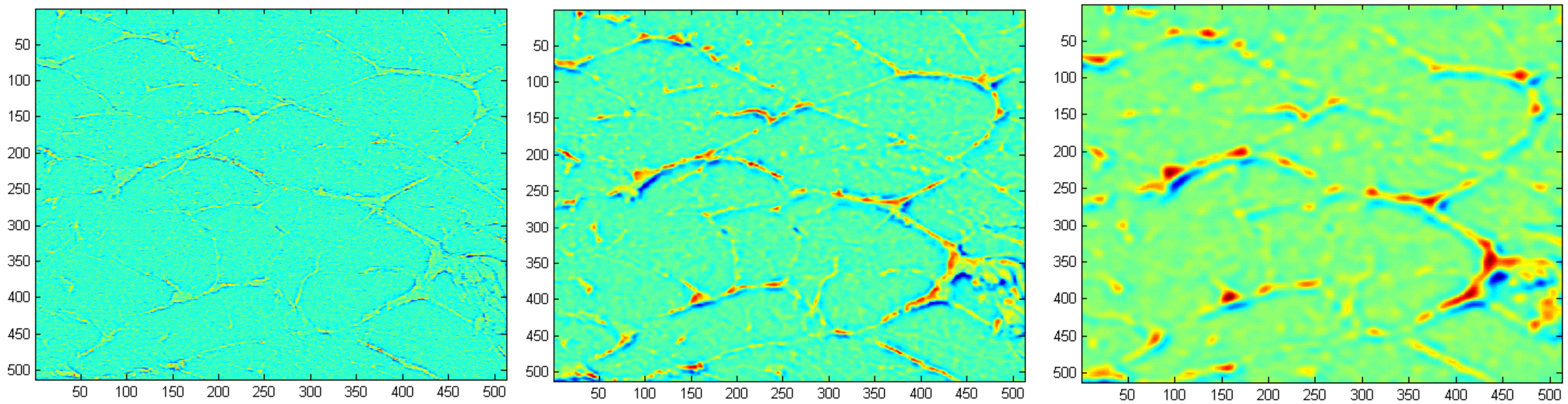
- **Example** of an analysed meat image:

Acquired under **visible polarized lighting**



Multiscale Vision Model (MVM)

« A trous » algorithm results



(a) **(b)** **(c)**

The first three wavelet planes obtained by « **à trous** » algorithm, using fourth-order binomial filter **h**.

Detection of significant structures

- It consists to threshold the wavelet planes with a threshold ***S*** properly determined by the noise model.

- For each wavelet plane $\mathbf{w_j}$ only the values greater than ***S*** were retained.

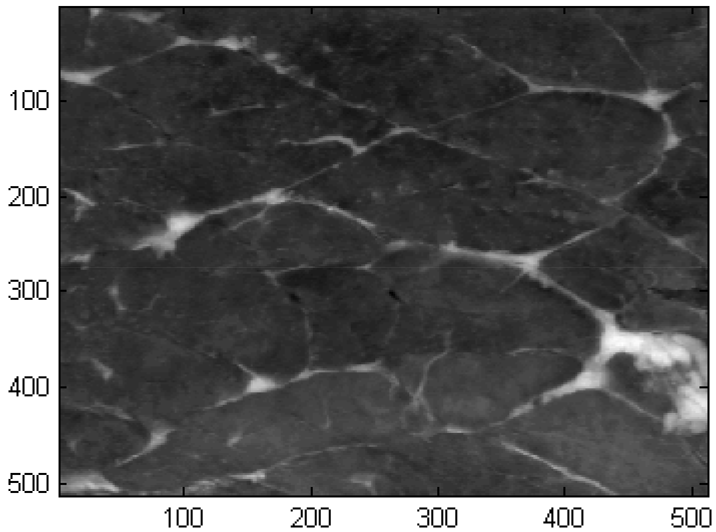
- Universal threshold (Donoho et al., 1995) was applied: $S = \sigma\sqrt{2\log(n)}$

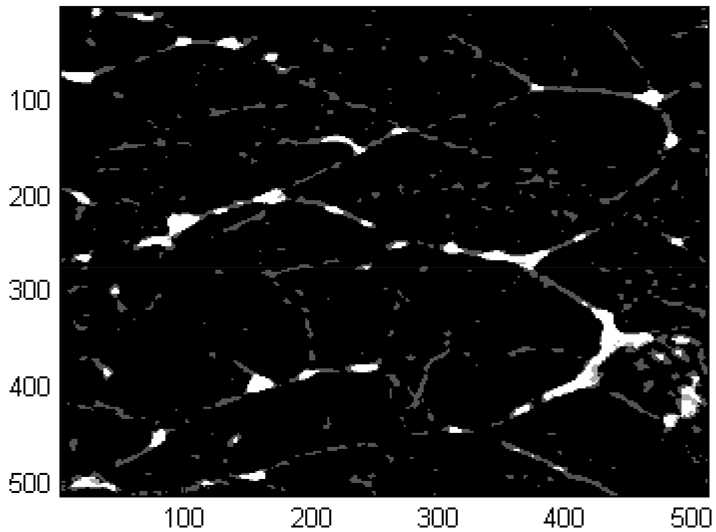
- The standard deviation of the noise is estimated from the first wavelet plane $\mathbf{w_1}$:

$$\hat{\sigma} = \frac{MED(|w_1|)}{0.6745}$$

Detection of significant structures

Segmentation result





Example of a segmented meat image acquired by a visible polarized lighting system.

Image analysis and data preparation

Data extraction

- Segmented images were then binarized,
- Whole set of data representes object surfaces in pixel,
- Calculated using a quantification algorithm based on neighberhood-pixels (**8-connectivity**).

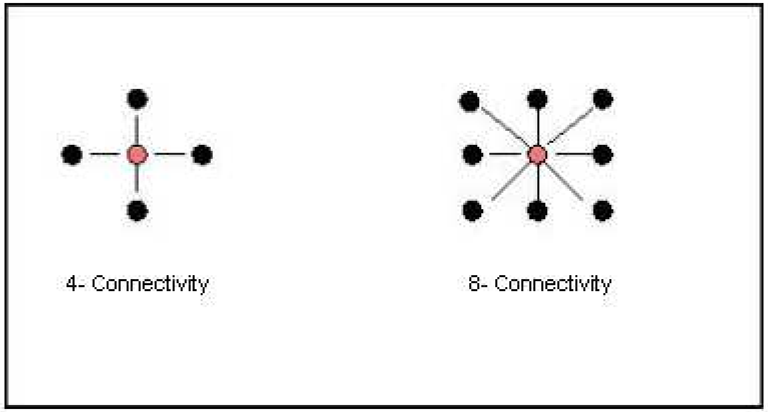


Image analysis and data preparation

Data preparation

- T transformation data: $Y = T(X_{ik})$ with $T = Log$,

X_{ik} is the surface of kth object in the image i, $1 \leq k \leq n_i$

n_i is the number objects in the image i,

- Information retained: distribution of object surfaces belonging to the **perimysium**

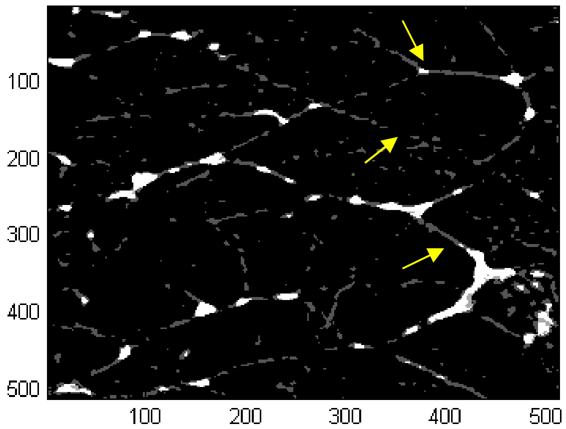


Image analysis and data preparation

Data discertisation

- **Number of classes:** $n_c = 1 + Log_2(N)$ (*Sturgers* formula)

- **Class limits:** classification according to the arithmetic progression, with ratio **r,**

$$r = \frac{\max - \min}{1 + 2 + 3 + .. + i + .. + n_c}$$

$$[\min, \ \min + r]$$

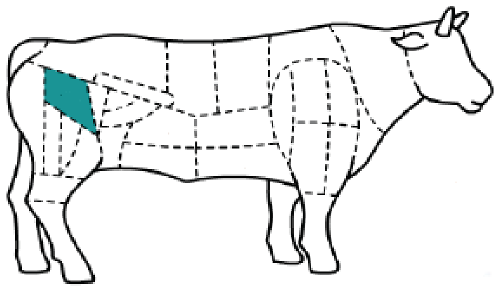
$$]\min + r, (\min + r) + 2r]$$

...

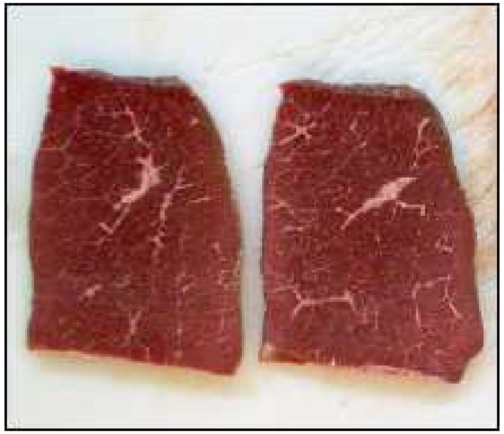
- For each muscle i, we calculate the **proportion of objects** belonging to each class.

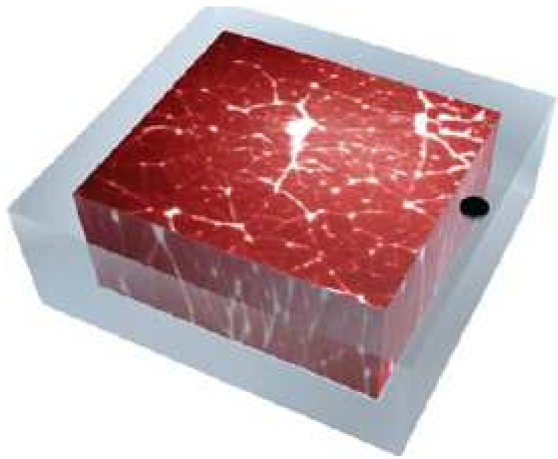
Prediction of bovine meat tenderness

- The analysis were performed on ***Semimenbranosus* (SM)** muscle samples from two cattle breeds: Holstein (n=11) and Salers (n=9).



- Muscle samples (n=20) were cut into 5 x 4.5 x 2 cm^3 cube with largest face.



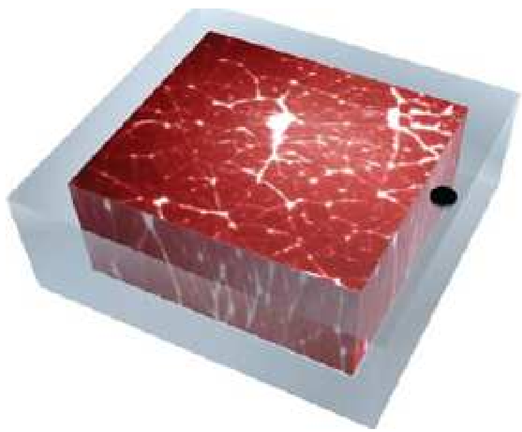


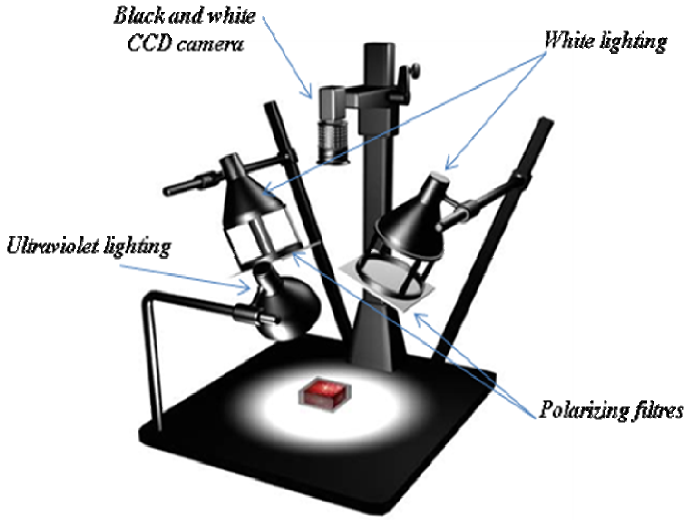
Prediction of bovine meat tenderness

- Images of SM slices were acquired under visible lighting,

- Photographic measurement bench equipped with a black and white camera model (MACC7, Sony),

- Two white light lamps with polarized filters were used.





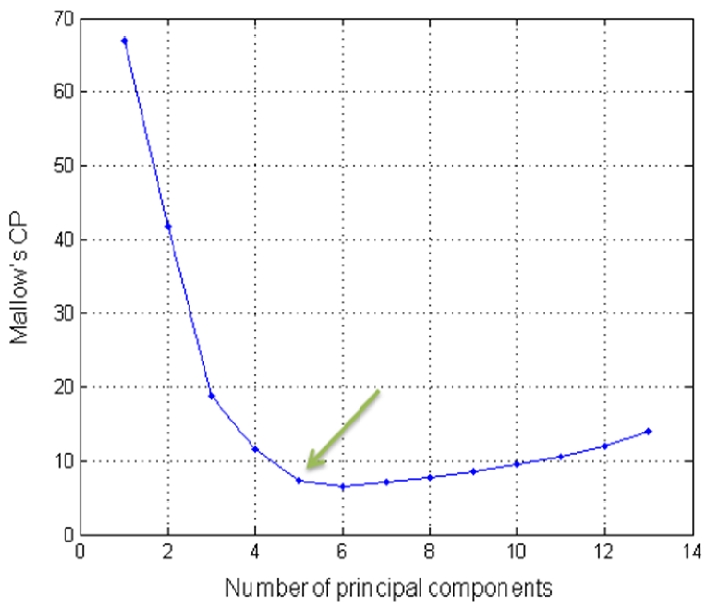
- The tenderness was evaluated by a trained panel using the recommended method of (Dransfield et al., 2003)

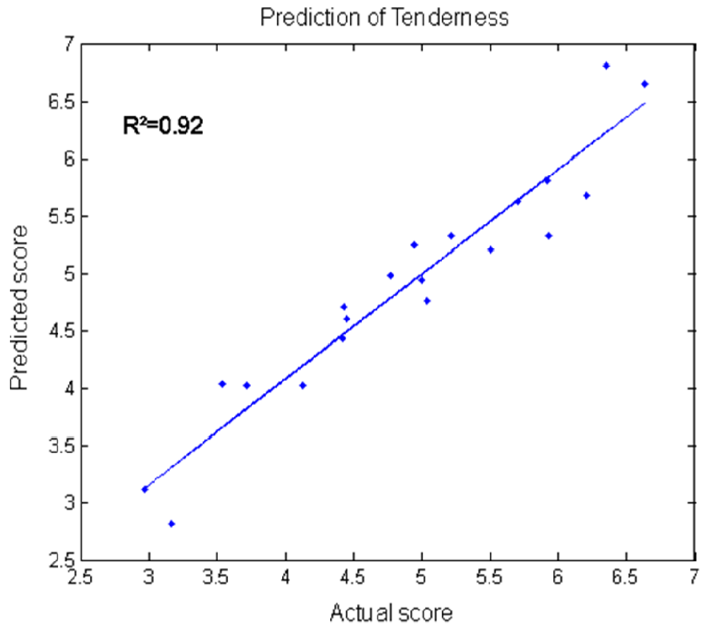
Prediction of bovine meat tenderness

- Principal Component Regression (PCR) analysis was applied to data issued from image processing steps.

- Five variables were selected from thirteen.

- Their linear combination has good prediction of meat tenderness (R^2 = **0.92**).





Conclusion

- The analysis was performed on bovine **raw meat** images,

- The tenderness was assessed by a trained taste panel on **cooked meat,**

- Simple imaging equipment was used : **Polarized white lighting** system,

- Image analysis approach was developped, based on a **multiscal image analysis,** allowing a good estimation of IMCT,

- The information extracted from the images represent the **distribution** of Intramuscular Connective Tissue (IMCT) , which contributes significantly to the intrinsic hardness of meat,

Conclusion

- The data analysis was carried out using the ***Sturgers*** technique (number of classes) and the **arithmetic progression** method (length of classes),

- Principal Component Regression was applied (PCR). Five principal components were selected for the final model allowing to predict **92%** of tenderness variability,

- This model depends on both image segmentation and object sizes classification,

- It would be interesting to test large data set with this method, including other animal biological factors as breed, sex and age.