Application of computed tomography and hyperspectral images for enhanced meat quality evaluation

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Meat quality evaluation

- **Carcass meat quality** - whole carcass quality and partial cuts quality. Meat yield, bones, fat tissue, cuts composition. Country-dependent systems.
- **Meat science and meat quality** - quality is difficult to define because it is a combination of nutritional, sensory and technological components.

  Destructive laboratory ISO methods – fat, protein, moisture, ash, fatty acids, amino acids, water holding capacity, drip loss, pH, and e.t.c
- **Eating meat quality** - quality defined by consumer – tenderness, juiciness, flavor and overall liking. Easy for cooking.
- **Destructive vs non-destructive methods** – time, technology, accuracy

The aim of this study - is to evaluate the predictive capabilities and accuracy of CT, NIRS and HSI to assess the quality of beef meat.

Meat quality evaluation

KNOWLEDGE TRANSFER by GREENANIMO project

France (INRAE) – **Scotland** (SRUC) – **Bulgaria** (Trakia University)

Scientific training: 2021 - 2023

Local economic impact: Science – Business - Education

- **France** – experience with Carcass grading and slaughterhouse meat quality evaluation – prof. Jean-Francois Hocquette;
- **Scotland –** experience with “in live” and “on carcass” CT scanning with Computer tomography for meat quality evaluation – prof. Rainer Roehe and Nicola Lambe;

Materials and Methods

Meat samples: black angus - superior in quality beef meat cuts with marbling.

3 different steaks were purchased from city market in Stara Zagora (January – April 2023):

- **Denver steaks;**
- **Top-sirloin steaks;**
- **Frat-Iron steaks**

Laboratory analyses (ISO) – fat; moisture/dry matter; ash content;

Denver steak

Top-sirloin steak

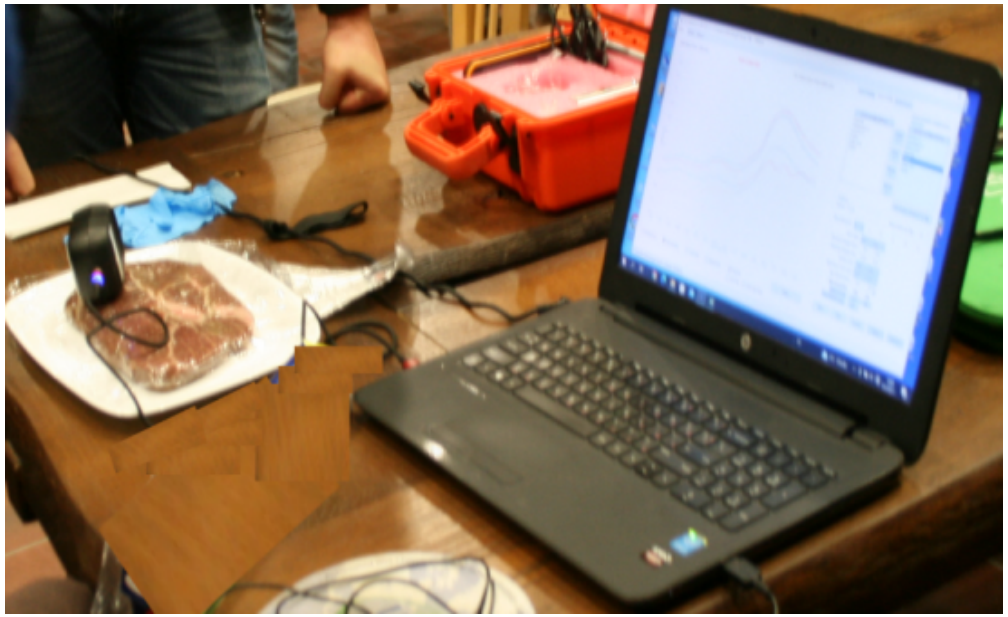
Frat-Iron steak

Materials and Methods

Spectral analysis

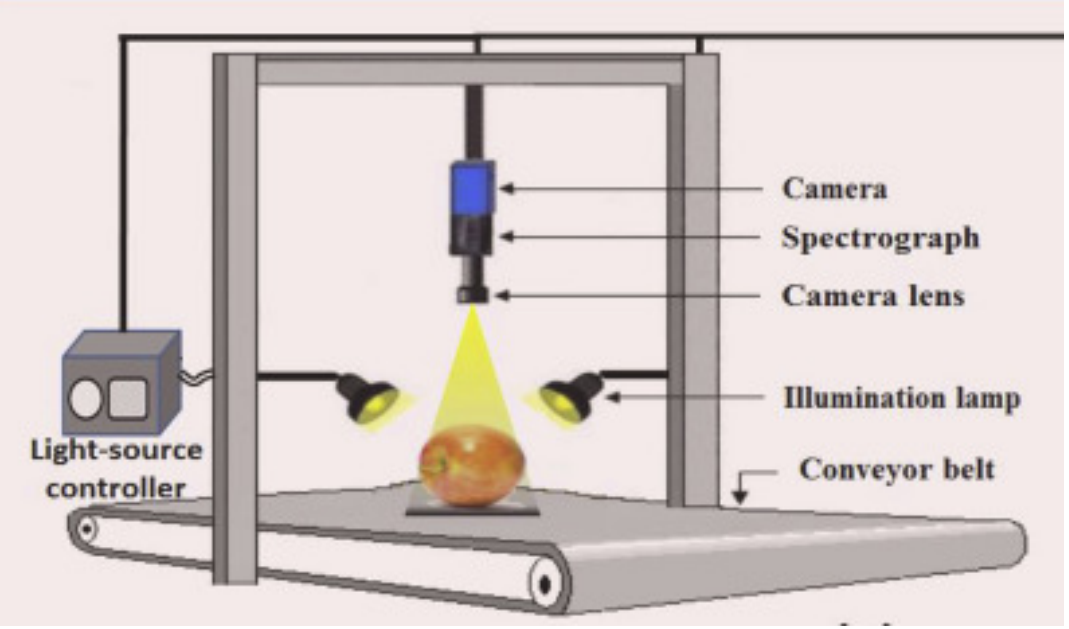
- Hyperspectral camera – AVT Goldeye CL-008, (Spectral Imaging, Finland), spectral range 900-1700nm, Software *Spectronon* (Resonon Inc.) for data processing; Hyperspectral images were made on both sides of the meat sample.
- NIRS mobile device (pocket-sized NIR spectrometer GRAINIT) at Faculty of Agriculture, spectral range 900-1700 nm.
- Software *Pirouette* 4.5 (Infometrix, Inc.)

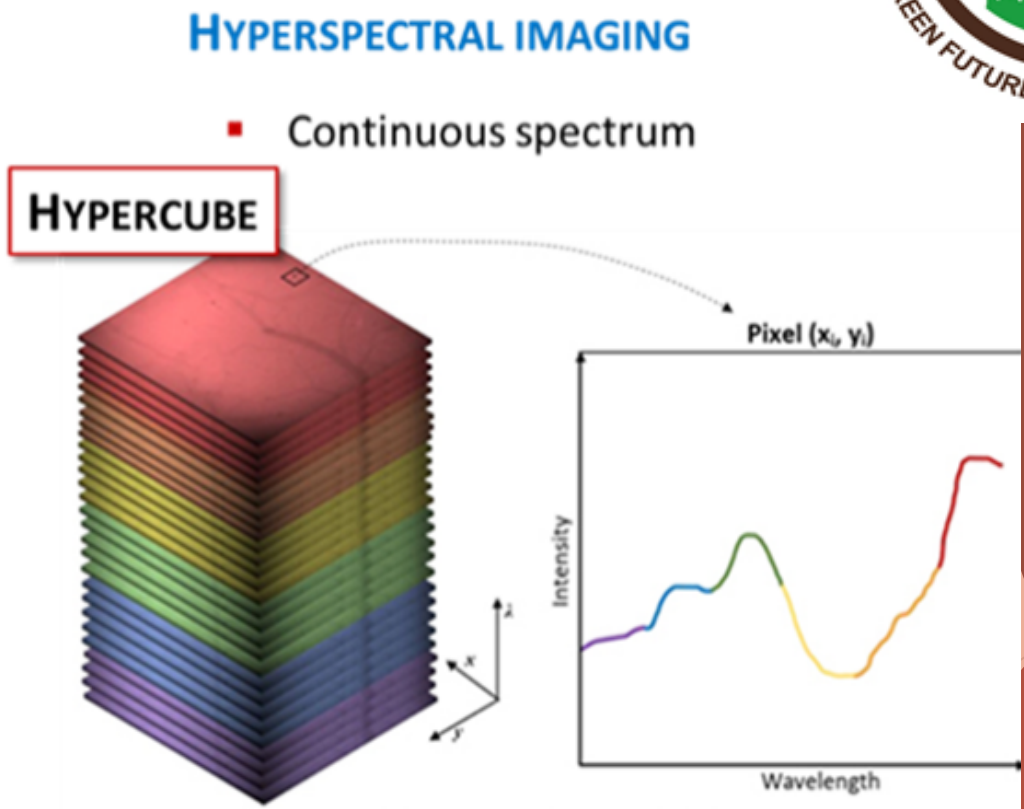
1) PLS models were developed for quantitative determination.
2) Soft Independent Modeling of Class Analogy (SIMCA) - classification



Materials and Methods

Hyperspectral imaging and NIR spectra





A hyperspectral imaging system produces three dimensional (3-D) hypercubes including two-dimensional spatial data and one-dimension spectral data, forming a stack of images at continuous wavelengths.

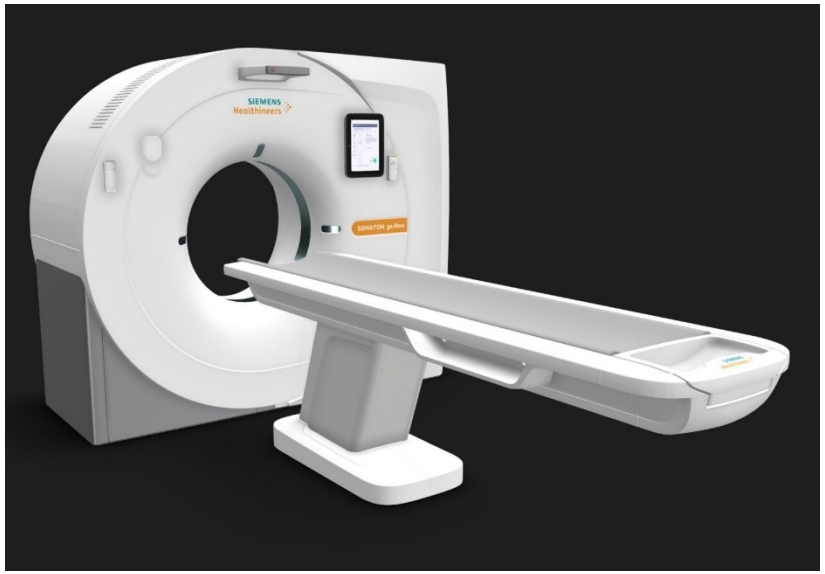
Materials and Methods

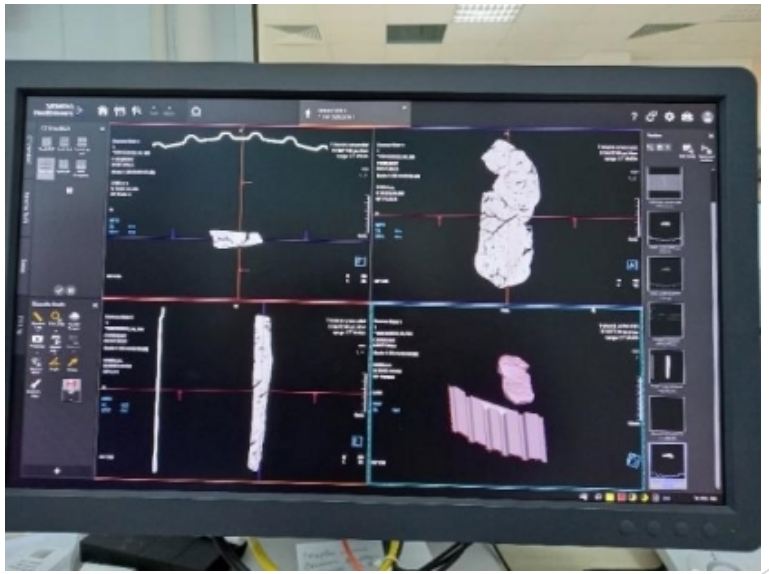
CT tomography

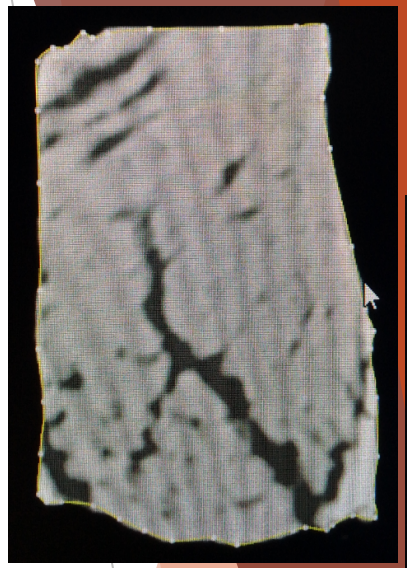
- **CT tomography** – Siemens (Somatom Go, Germany) at Fac. Veterinary medicine

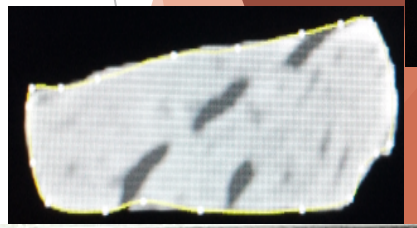
  (16/32 slice scanning CT, in 1 mm thickness of slides)

- Image from 2D to 3D reconstructions – **Software IQ Viewer** 3.2 professional
- Mean±SD of **Hounsfield units (HU) per cm²** of the scanned area of meat were determined for 5 random slices from each sample section.









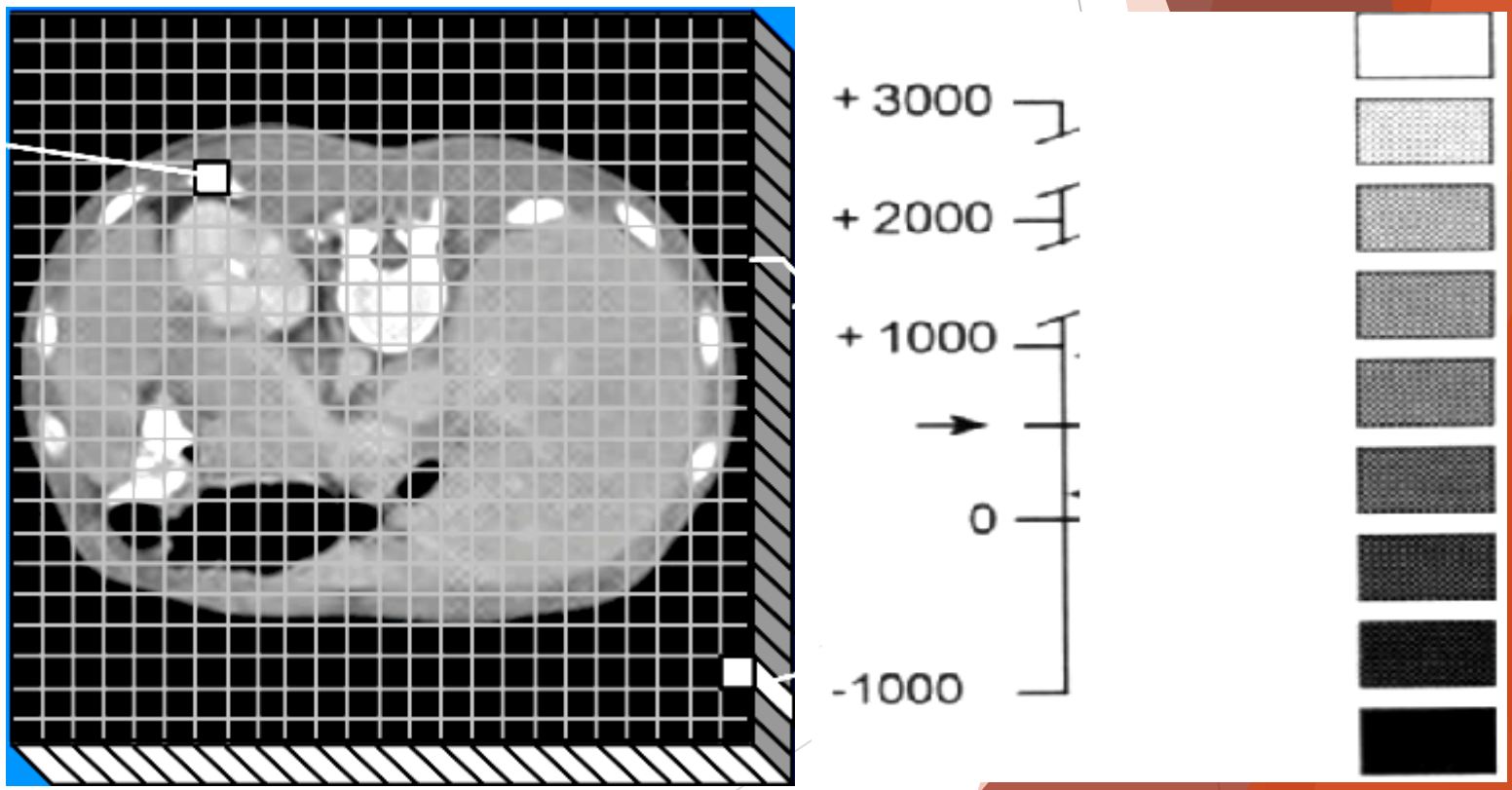
Properties:

	Property	Value
1	Area	88.5 sq.cm
2	Maximum Value	118
3	Mean Value	66.2729
4	Minimum Value	-62
5	Pixels	25100
6	Std. Deviation	24.1571

X-ray computer tomography

CT visualization - each Hounsfield Unit (HU) are coded using 2^{12} or 2^{16} degrees of greyness.

Substance	HU
Air	−1000
Lung	−500
Fat	**−100 to −50**
Water	0
Cerebrospinal fluid	15
Kidney	30
Blood	+30 to +45
Muscle	+10 to +40
Grey matter	+37 to +45
White matter	+20 to +30
Liver	+40 to +60
Soft Tissue, Contrast	+100 to +300
Bone	+700 (cancellous bone) to +3000 (dense bone)



Results

Laboratory results – classical ISO methods

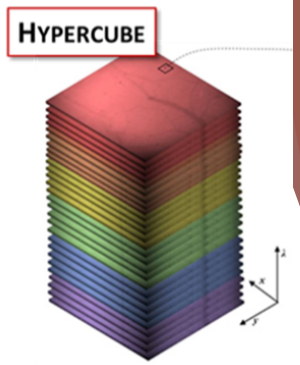
Black angus beef meat cuts with marbling (Denver steak, Top-sirloin, Frat-Iron steak – chemical composition (MEAN±SD))

Sample	Dry matter, %	Moisture, %	Fat, %	Ash, %
Denver steak	31.67±0.84	68.35±0.84	11.42±3.24	1.48±0.17
Top-sirloin	29.30±1.22	70.70±1.22	5.68±1.75	1.18±0.17
Flat-Iron steak	31.59±2.21	68.41±2.21	11.21±4.02	1.19±0.21

Predictive capabilities of the HIS, NIRS and CT were evaluated as fast and non-destructive methods for estimation of the chemical composition of meat, which could be useful as quality monitoring in the meat industry.

- Reference laboratory data: v/s HIS data
- Reference laboratory data: v/s NIRS portable device data
- Reference laboratory data: v/s CT data

Results



Hyperspectral image evaluation – by PLS models (quantitative)

Measured value v/s predicted by HSI

Parameter	PLS factors	SECV	Rcv	SEC	Rcal
DM, %	3	0.286	**0.992**	0.272	0.993
Fat, % Soxhlet	4	0.364	**0.994**	0.339	0.995
Ash, %	6	0.051	**0.969**	0.047	0.976

SECV – Standard error of cross validation, SEC - Standard error of calibration

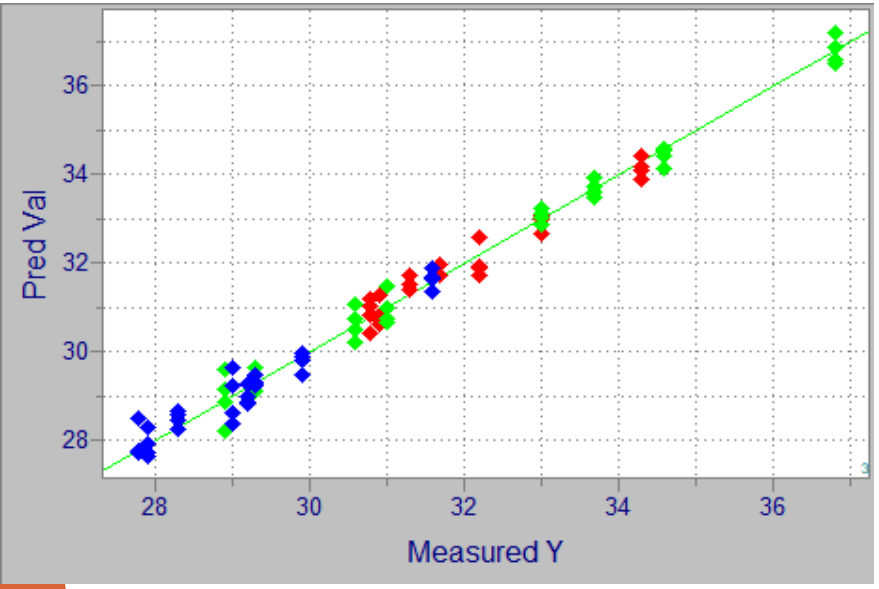


Fig 1: Dry matter

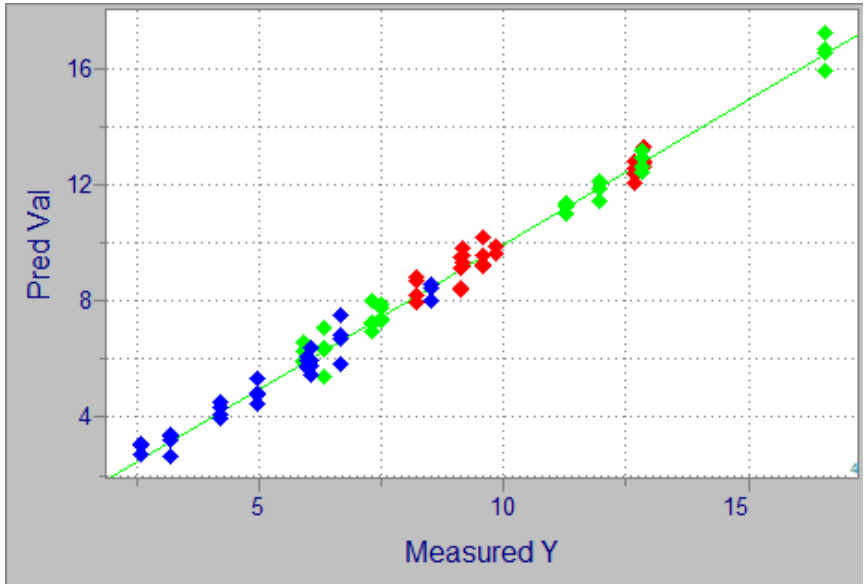


Fig 2: Fat, %

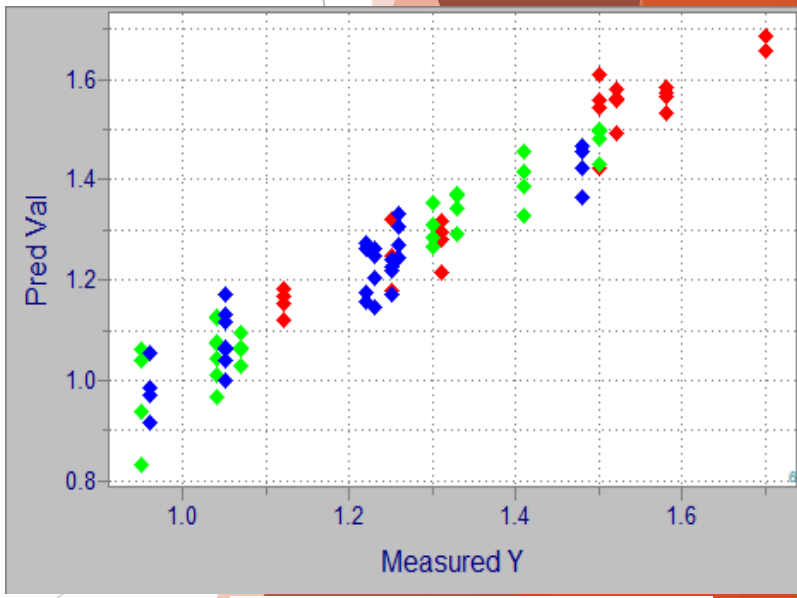


Fig 3: Ash, %

Red: Denver steaks; Blue: Top Sirloin steaks; Green: Flat Iron steaks;

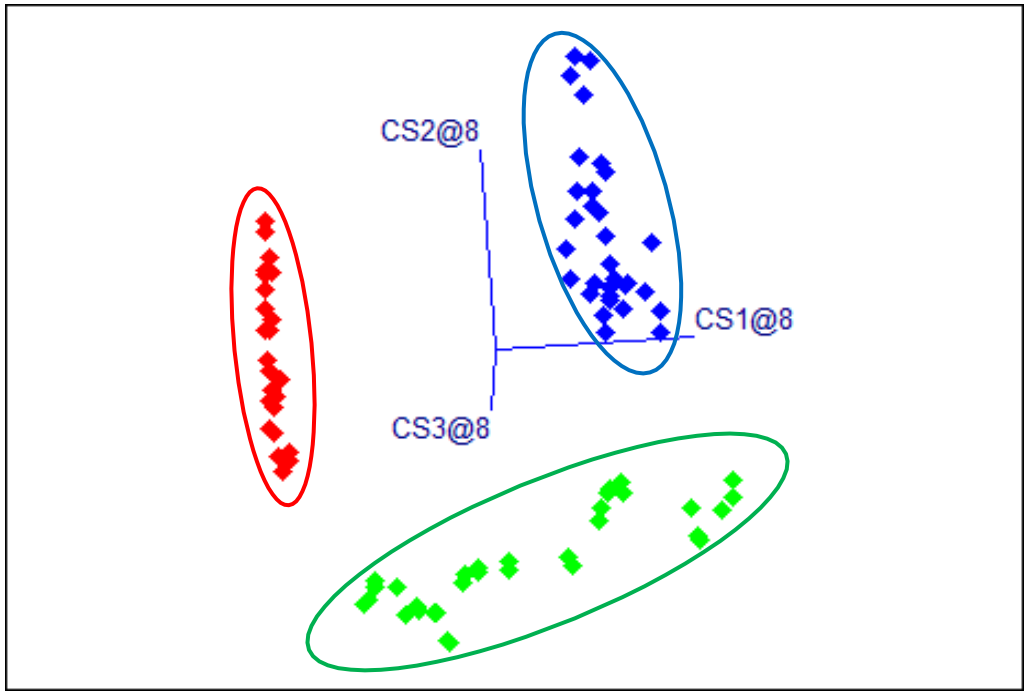
Results

Hyperspectral image evaluation – by SIMCA model (qualitative)

(Soft Independent Modeling of Class Analogy)

Type of steak classification based on HSI spectra 900-1700 nm

Interclass distance	CS1@8	CS2@8	CS3@8
CS1	0.00	7.50	13.53
CS2	7.50	0.00	6.53
CS3	13.53	6.53	0.00



Red: Denver steaks

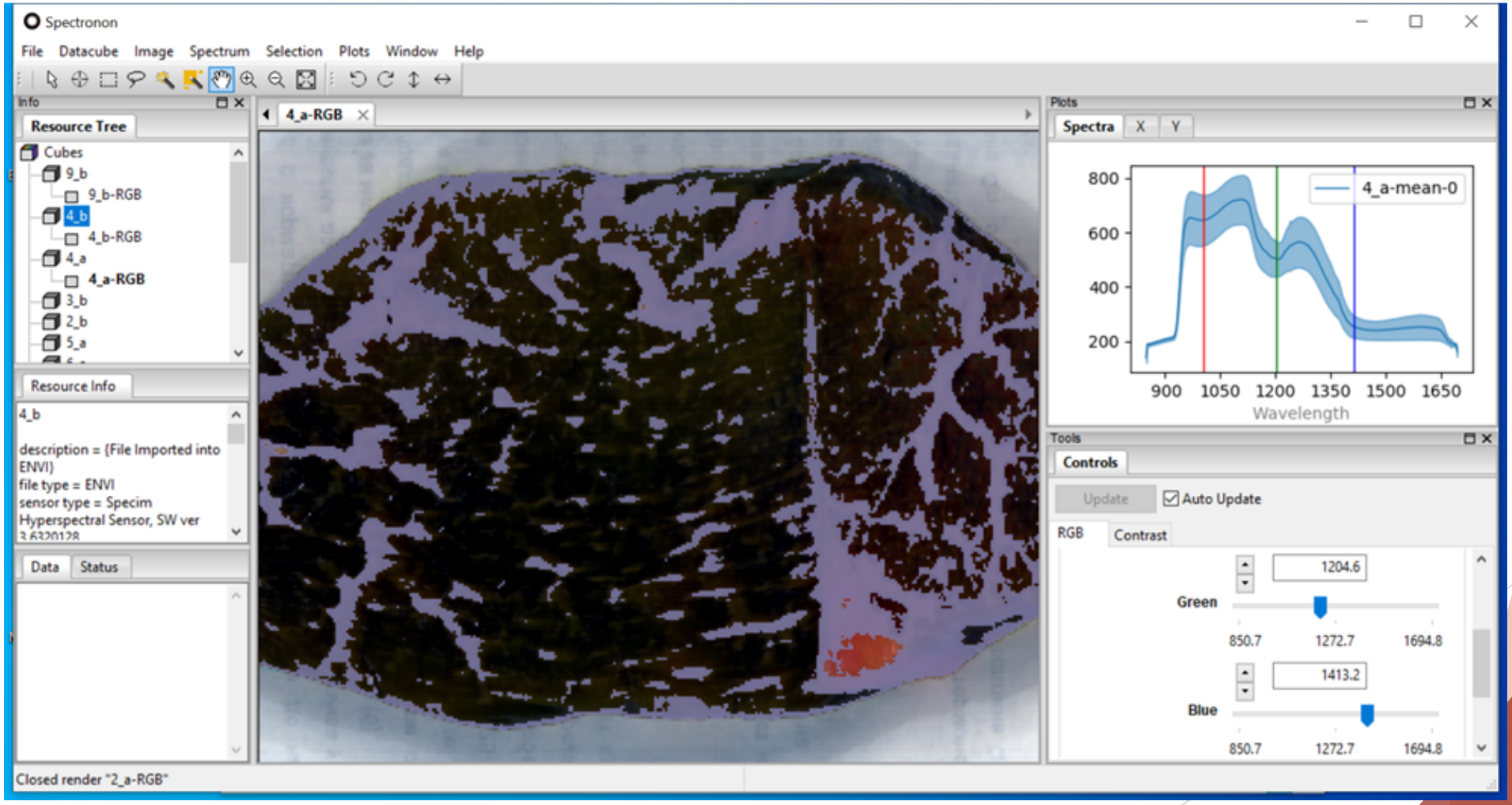
Blue: Top Sirloin steaks

Green: Flat Iron steaks

Fig 4: SIMCA classification models

Results

Hyperspectral Image evaluation – marking spectrally similar pixels, RGB image reconstruction.



Results

NIRS mobile GRAINIT data evaluation – PLS models (quantitative)

Measured value v/s predicted by NIR spectra 900-1700 nm

Parameter	PLS factors	SECV	Rcv	SEC	Rcal
DM, %	5	0.479	**0.963**	0.463	0.966
Fat, % Soxhlet	4	0.702	**0.966**	0.701	0.967
Ash, %	7	0.053	**0.957**	0.051	0.962

SECV – Standard error of cross validation, SEC - Standard error of calibration

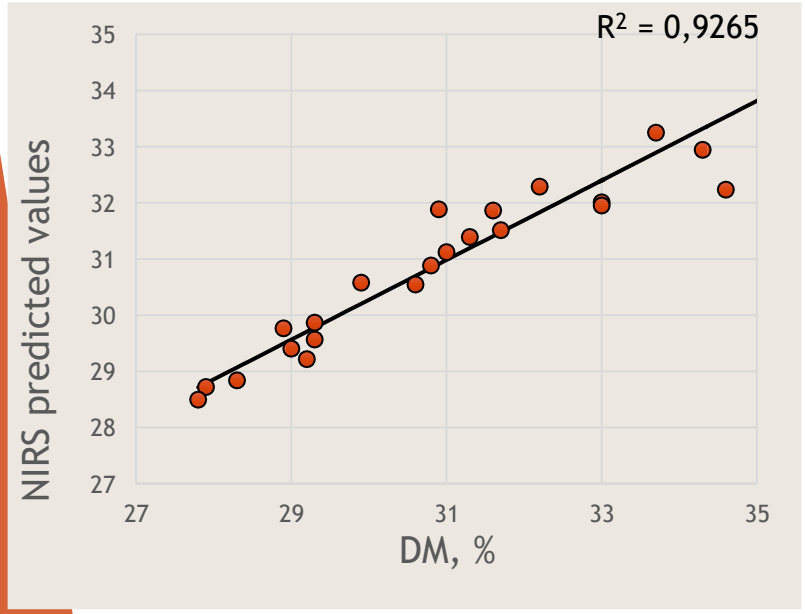


Fig 5: Dry matter

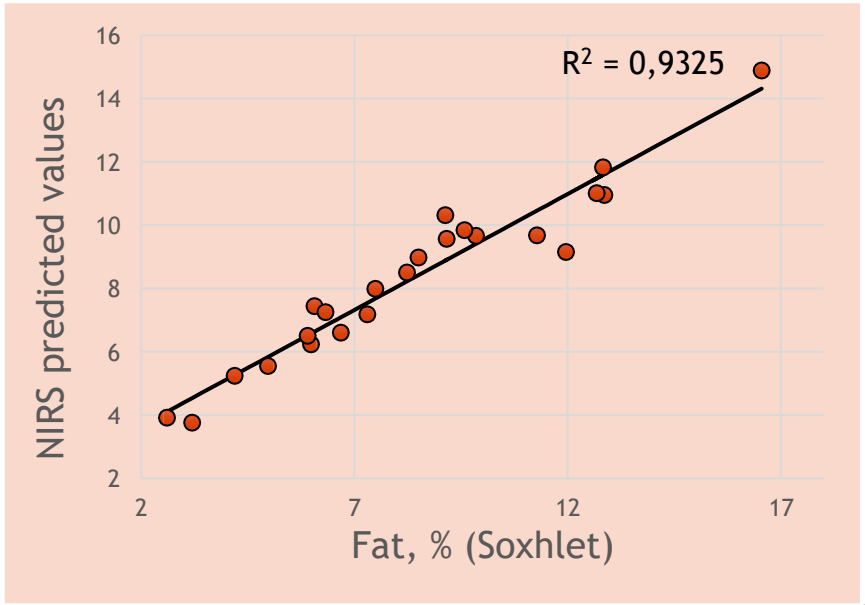


Fig 6: Fat, %

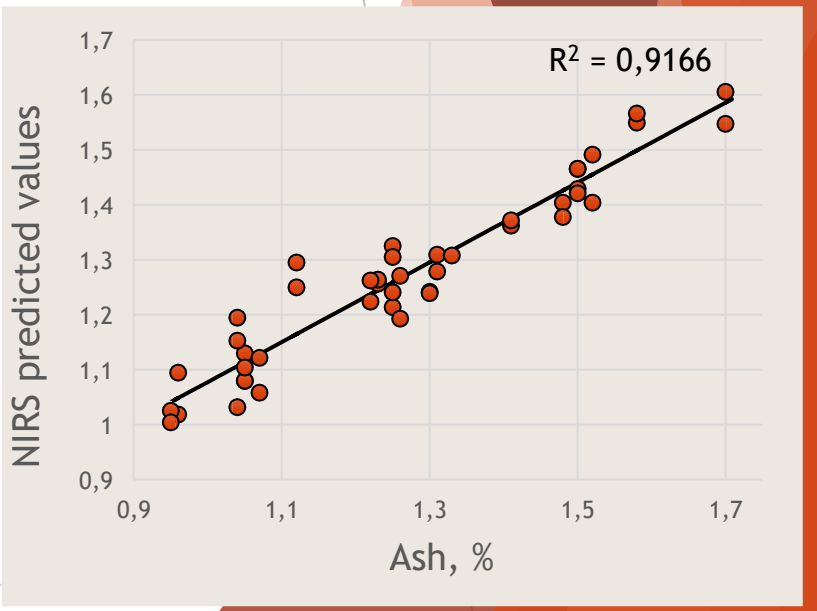


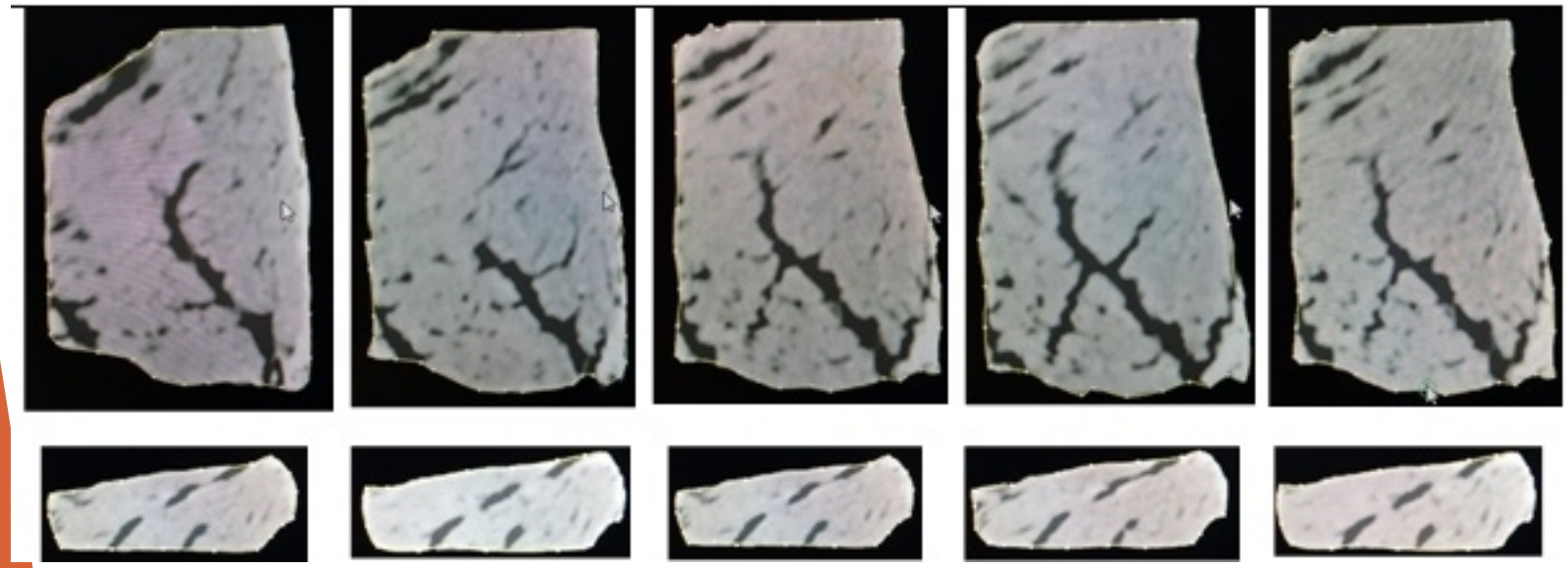
Fig 7: Ash, %

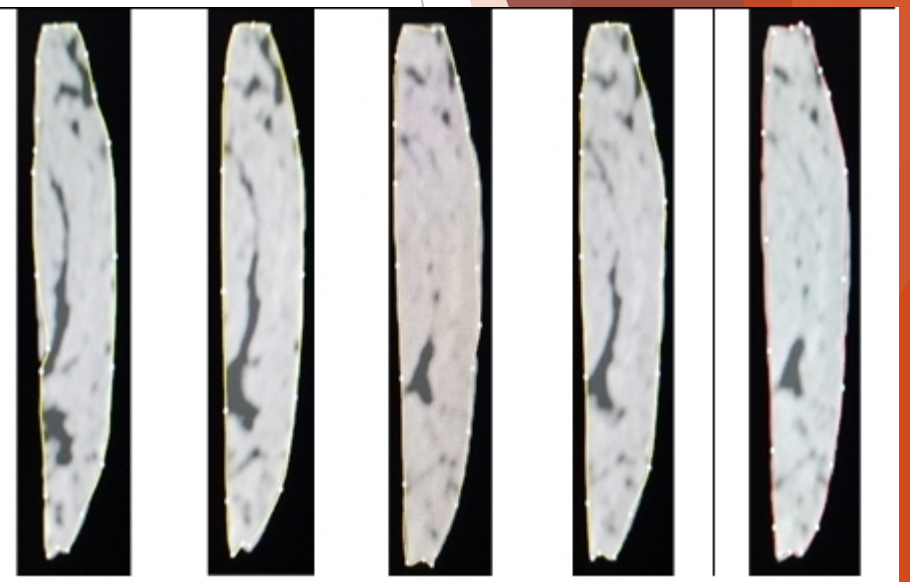
Results

Computed tomography data evaluation

The average values of HU units for 15 different cuts of each examined meat sample were determined.

Differences in the obtained HUs were found between the three investigated stacks.





	Hounsfield units/cm^2
Denver steak	53.97±11.73
Top-sirloin	56.62±14.16
Flat-Iron steak	57.18±10.23

Results

Computed tomography data evaluation –

- Measured value v/s predicted by CT (based of mean of Hounsfield units)
- Good relationship between HU and Dry matter and Fat content.

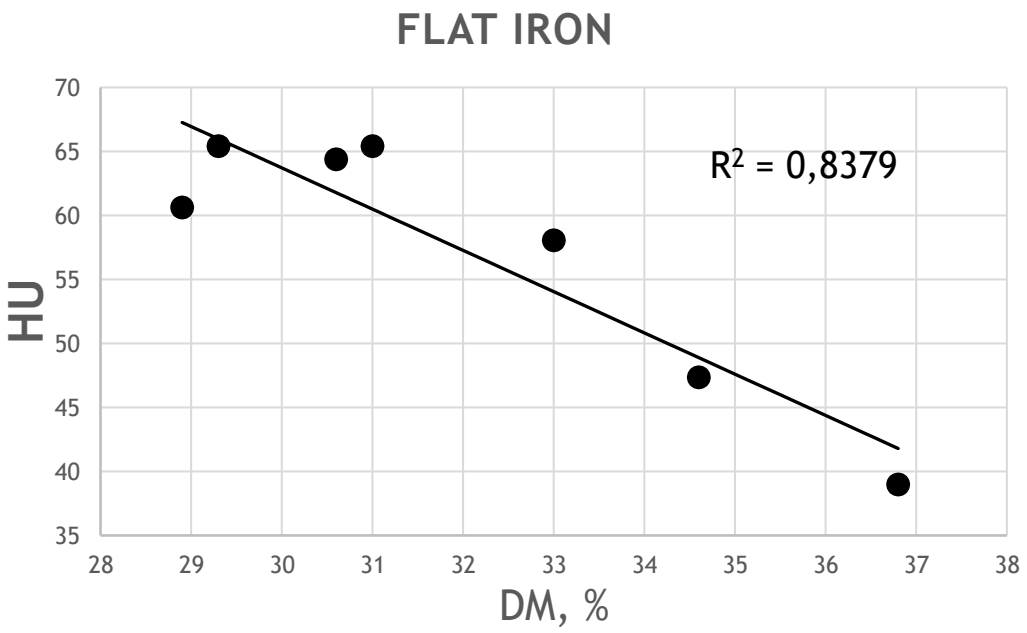


Fig 8: Dry matter

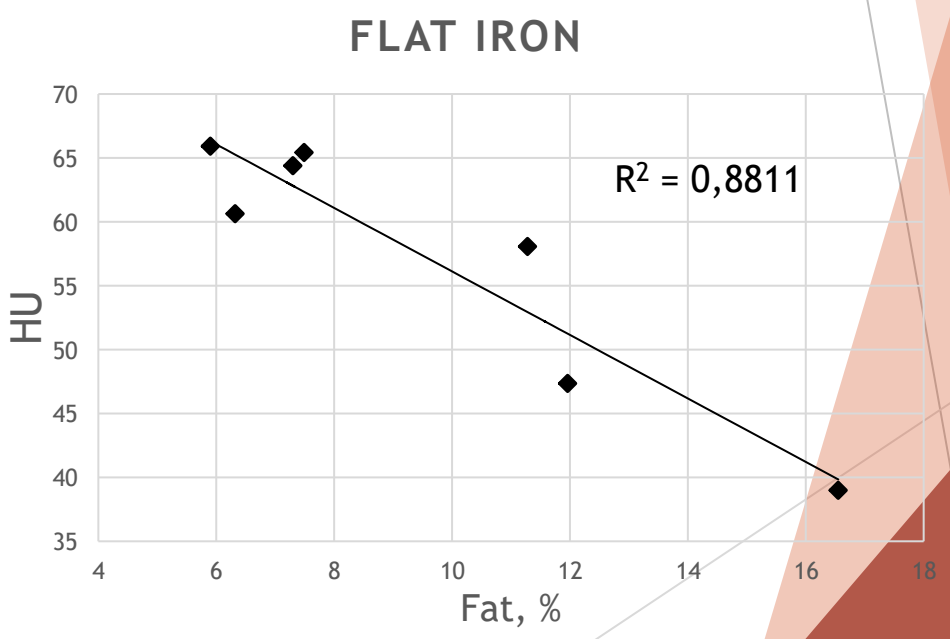


Fig 9: Fat, %

Conclusions

Black angus – superior in quality beef meat (Denver steaks; Top-sirloins; Frat-Iron steaks)

- Equations for estimation of the chemical composition of meat samples based on spectral information in the range 900-1700 nm from the pocket-sized NIR spectrometer or Hyperspectral camera allowed good accuracy of determination.
- Hyperspectral imaging allows reconstruction of RGB images using different wavelengths, to mark spectrally similar pixels, etc. This gives additional information about the quality of the meat.
- CT images and HU could be used for nondestructive meat quality estimation.

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Thank you for your attention!

Questions?!

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