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IRTA
RECERCA I TECNOLOGIA AGROALIMENTÀRIES

evaluation of live growing pigs of different genotypes and sexes using computed tomography

Ph. D. Thesis
presented by

Anna Carabús i Flores

Director: Maria Font i Furnols, Ph. D.
Tutor: Marimar Campo, Ph. D.

Project INIA-RTA 2010-00014-00-00

First of all…

live pigs

genotypes

sexes

computed tomography

First of all…

Chapter 1
Introduction

Chapter 1. Introduction

Introduction. Part I.

Image analysis techniques to study the composition of live pigs: a review

Anna Carabús, Marina Gispert and Maria Font-i-Furnols
IRTA-Product Quality, Finca Camps i Armet, 17121 Monells, Catalonia, Spain

Submitted to the Spanish Journal of Agricultural Research

Introduction. Part II.

Applications of computed tomography in the production field and food technology

Anna Carabús[1], Elena Fulladosa[2], Núria Garcia-Gil[2], Marina Gispert[1], Maria Font i Furnols[1]

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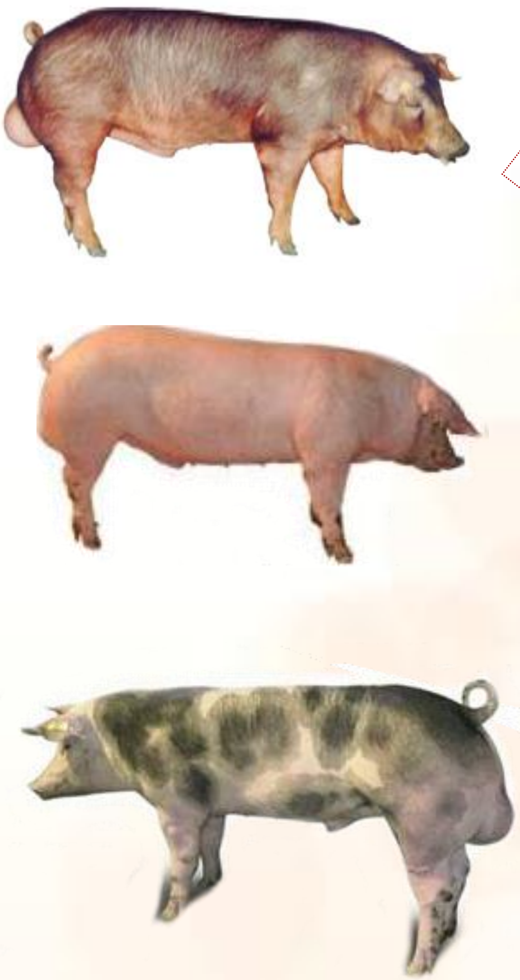
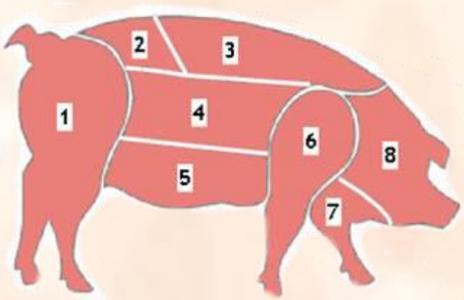
[2]*IRTA-Food Technology, Finca Camps i Armet, 17121 Monells, Catalonia, Spain*

Eurocarne. Núm. 202. Diciembre 2011.

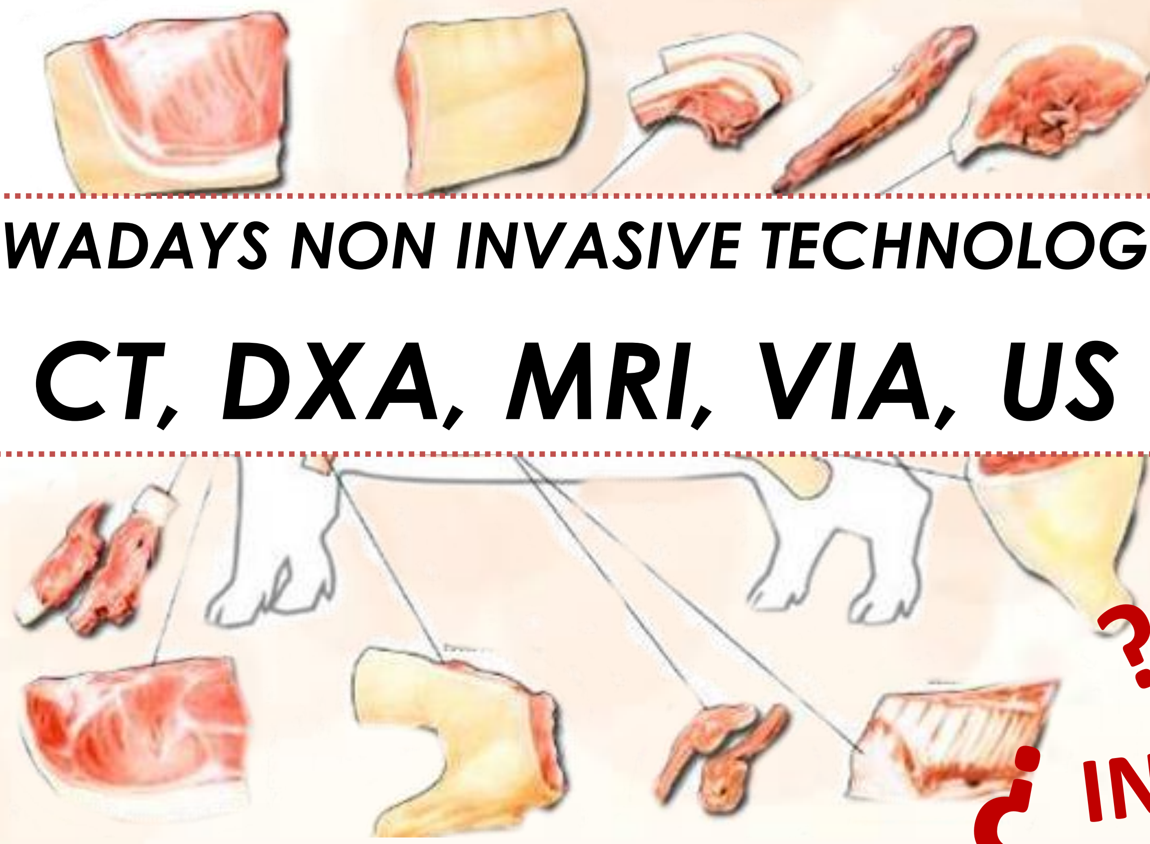
Chapter 1. Introduction





In order
to
obtain

Chapter 1. Introduction



NOWADAYS NON INVASIVE TECHNOLOGIES:

CT, DXA, MRI, VIA, US

¿ IN VIVO ?

? ? ¿ ? ¿

Chapter 1. Introduction

Technologies to evaluate pig composition

Invasive and **non-invasive**

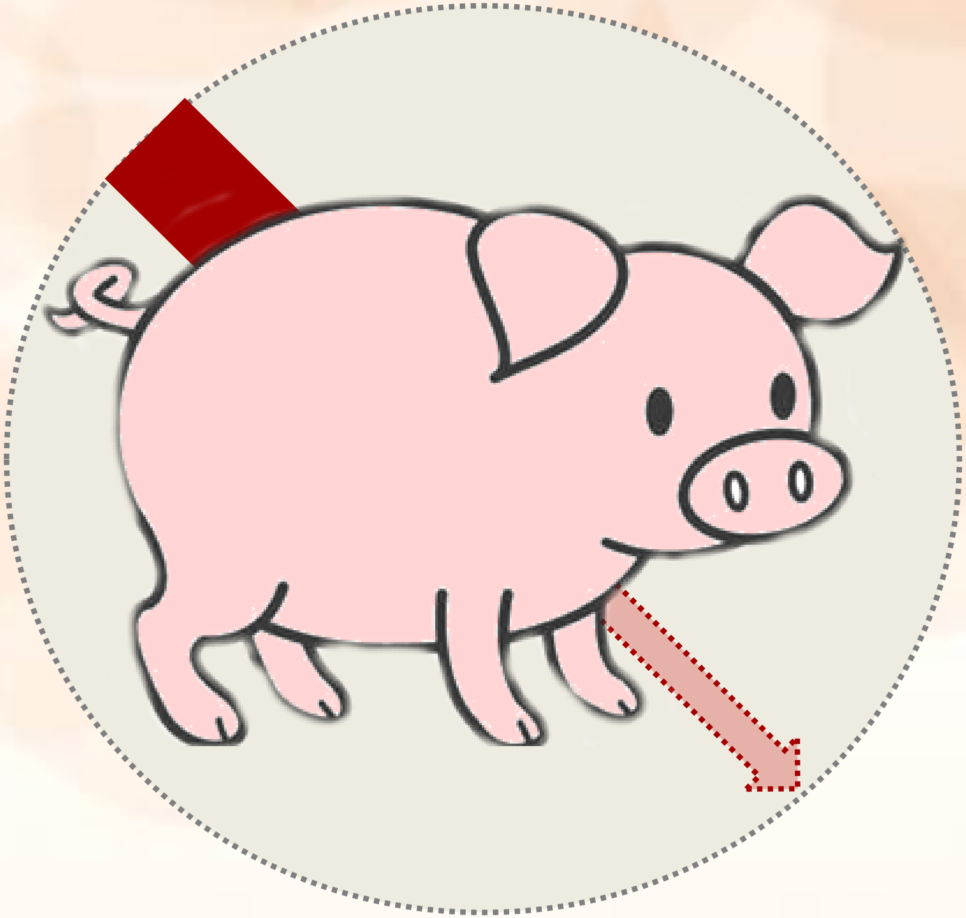
In animal science, a non-invasive technique permits the study an live animal without piercing any tissue.

VIA, US, DXA, MRI and **CT**.

Chapter 1. Introduction

What is CT about?

X-rays are electromagnetic waves that can penetrate matter and lose parts of their original energy. These energy differences can be projected onto an image.



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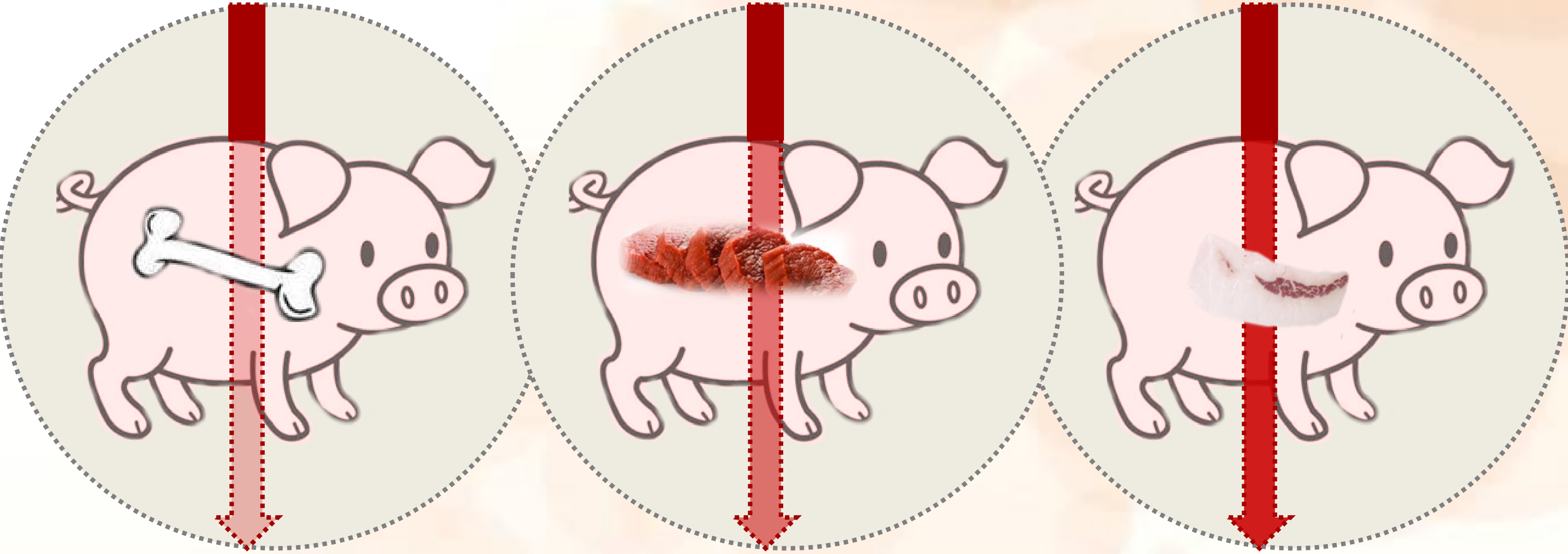

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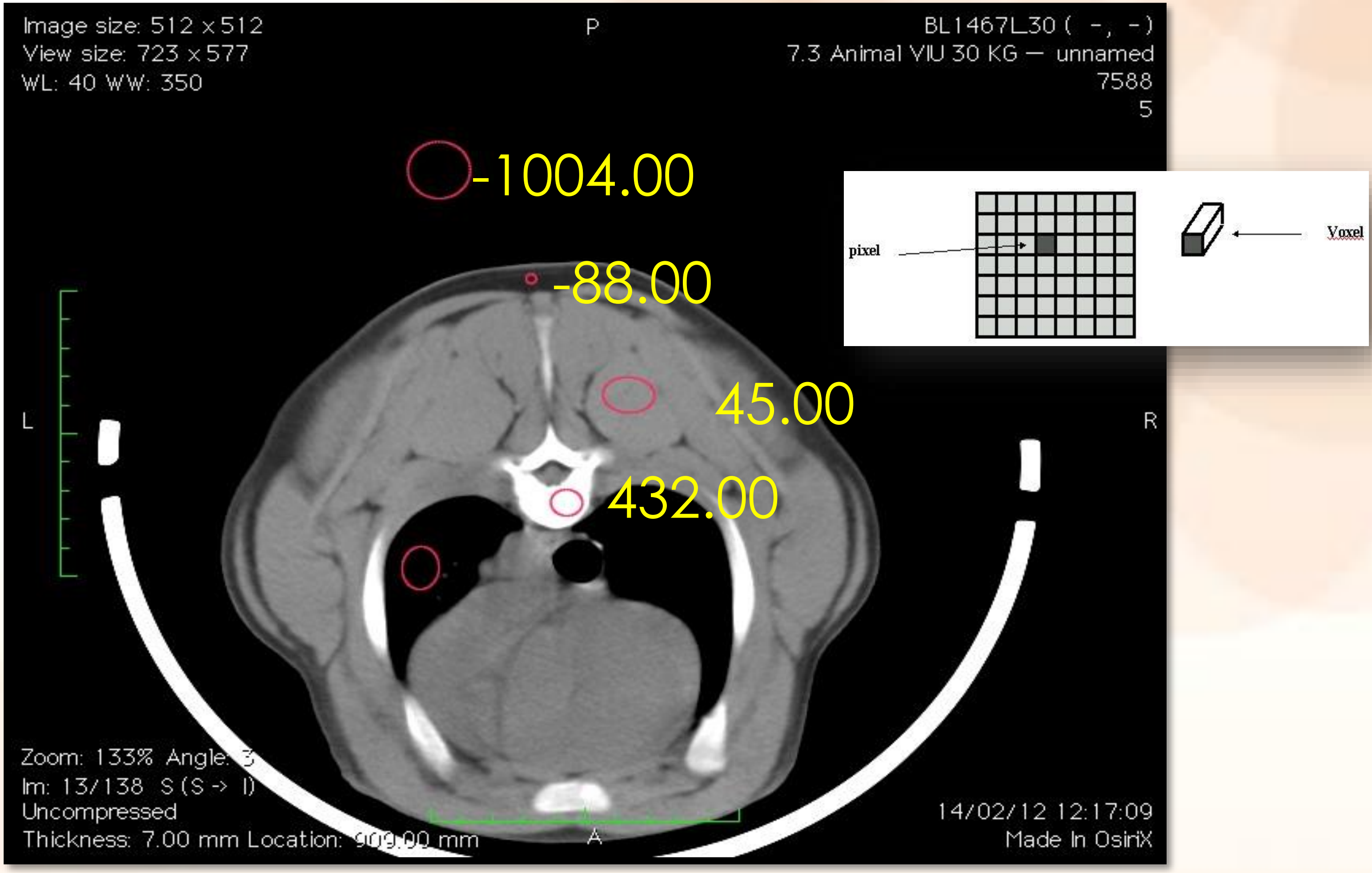
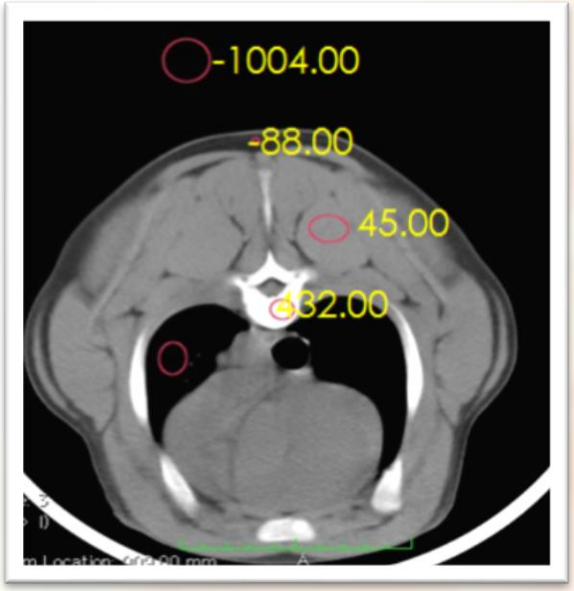
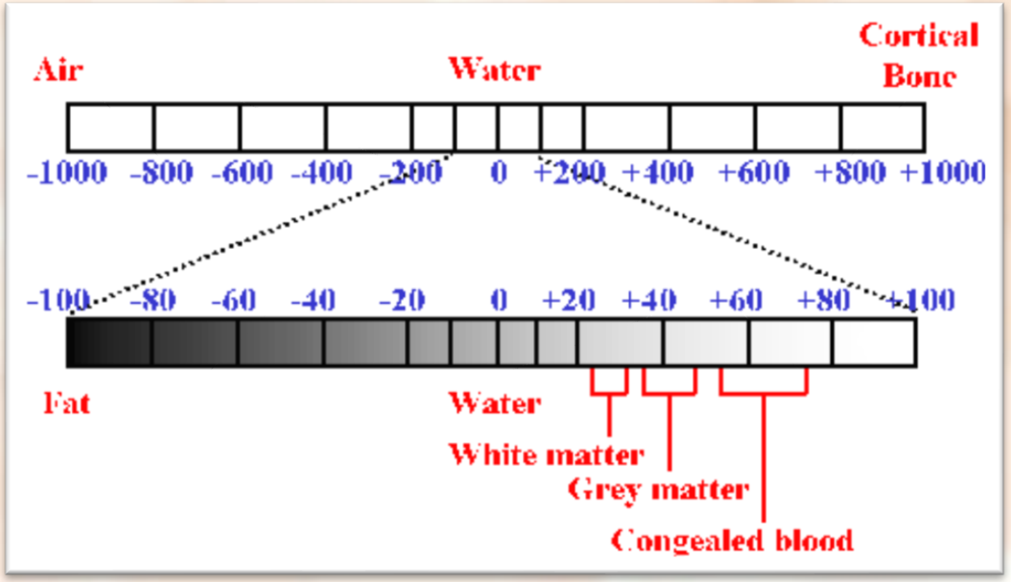


Chapter 1. Introduction

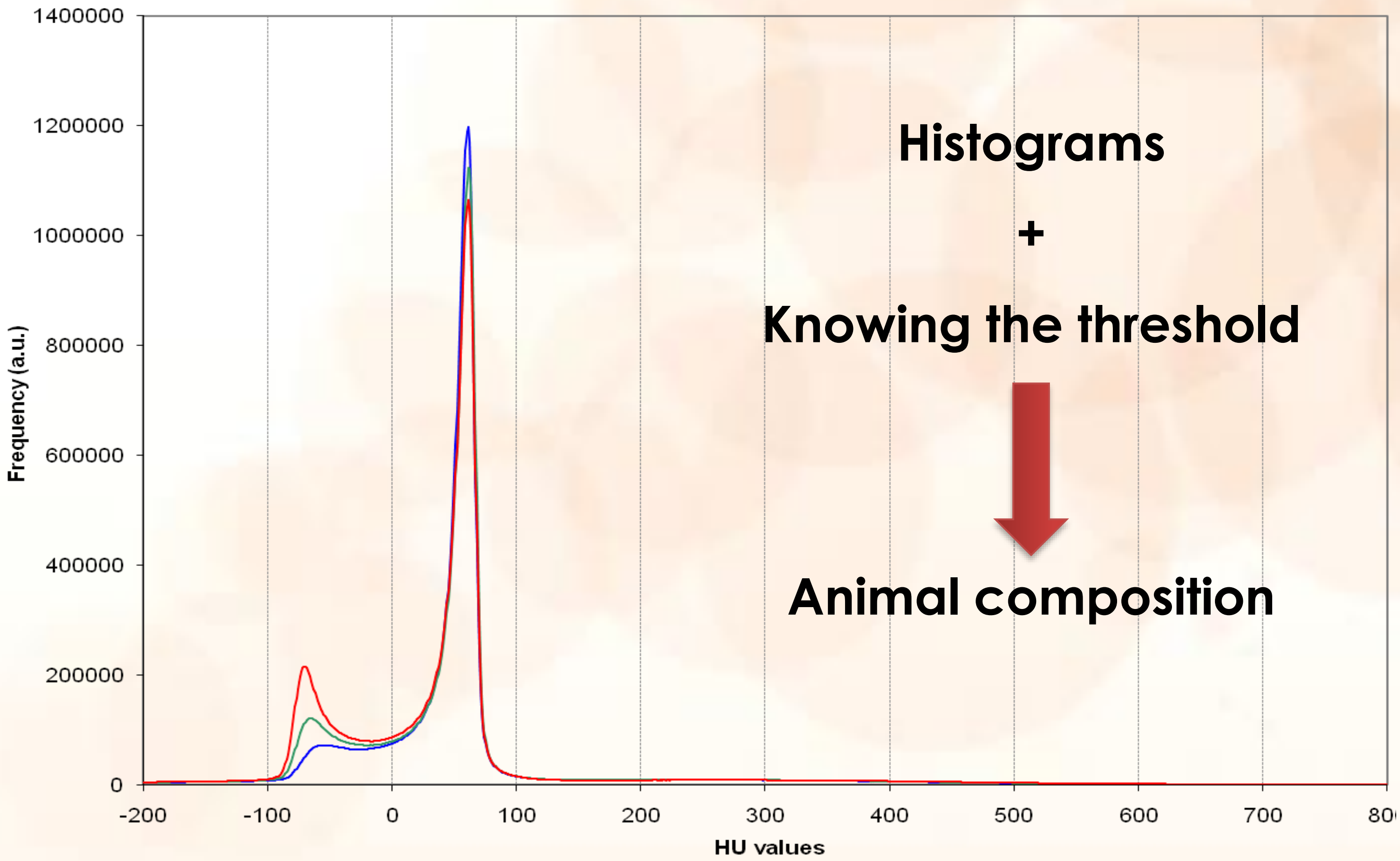
Hounsfield units (HU) and the grey scale





- The CT records the attenuation/brightness of each pixel in HU units
- This number represents de density of the scanned tissue
- Ranges from -1500 to +1500
- The frequency of each pixel (histogram) + thresholding → composition

Chapter 1. Introduction



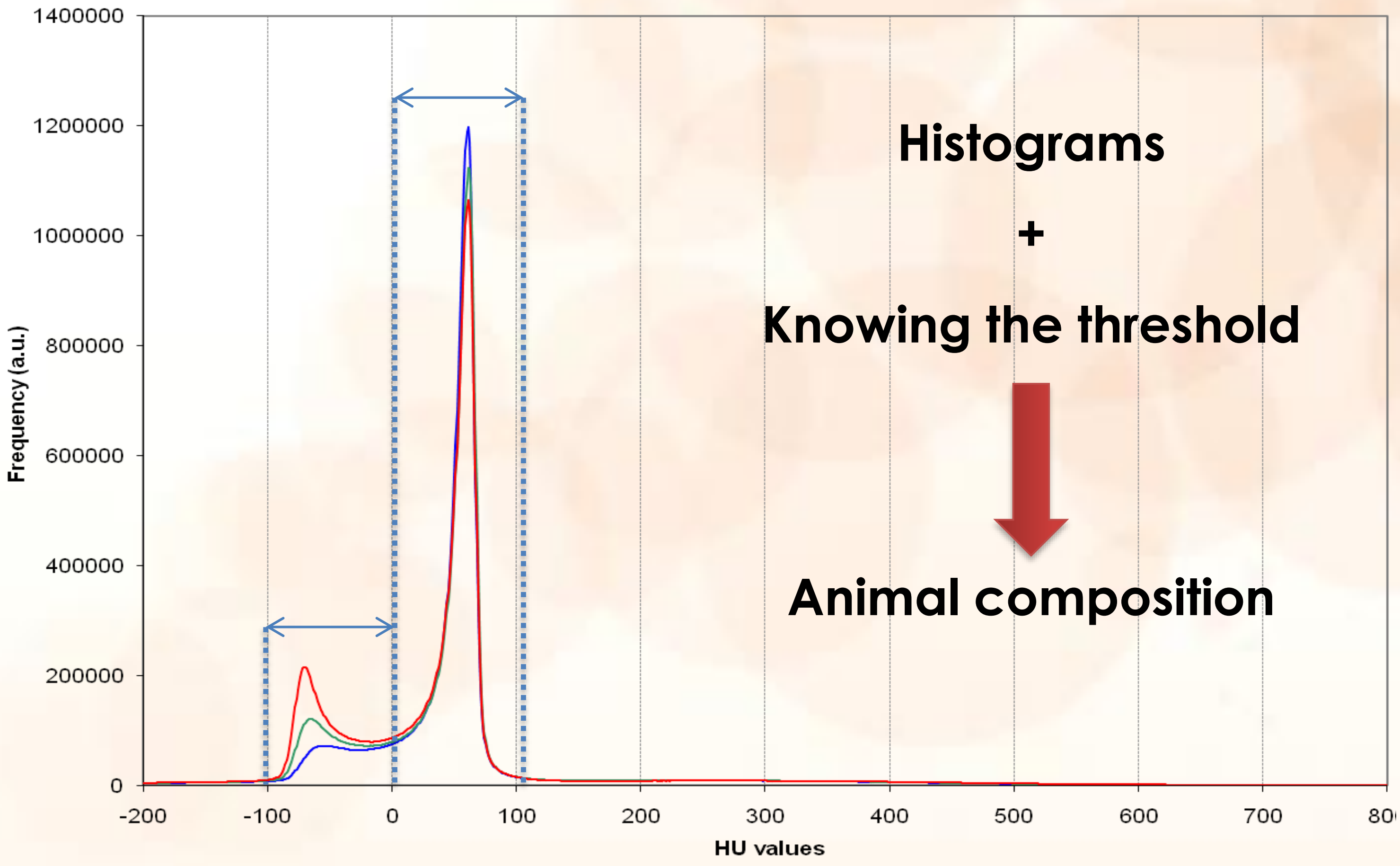
Histograms

+

Knowing the threshold

Animal composition

Chapter 1. Introduction



Histograms

+

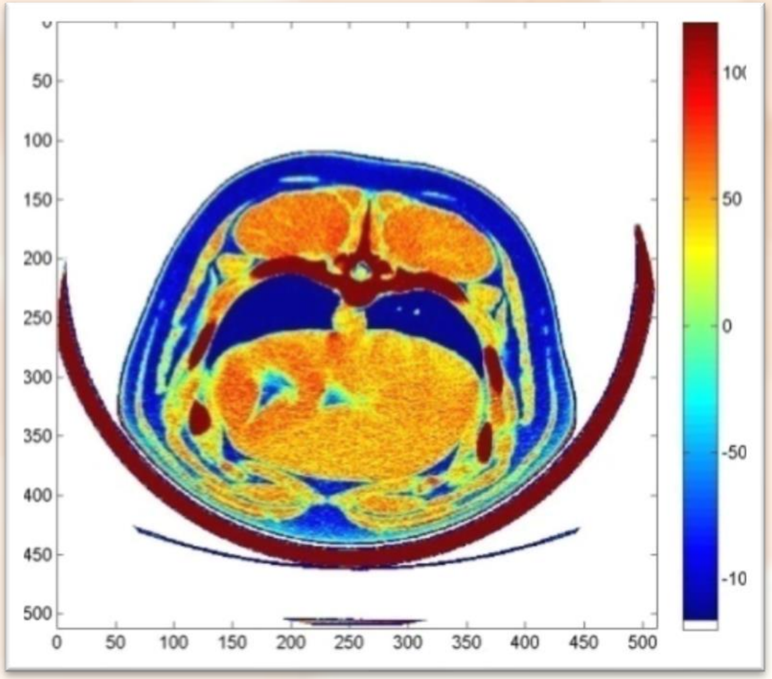
Knowing the threshold

Animal composition

Chapter 1. Introduction

What is a CT?

CT is a device that produces cross-sectional digital images of an object by combining X-ray projections and it informs about the HU value of each voxel



Chapter 1. Introduction

Comparison (advantage and disadvantages) of non-invasive devices

DEVICE	IMAGES	ANAESTHESIA	PRICE	PORTABLE	IMAGE CONTRAST	RADIATION
CT	3D	Yes	Expensive	Yes	Good. Higher than MRI for dense tissues	Yes
DXA	2D	Yes	Intermediate	Yes	Good. Higher than MRI for dense tissues	Yes
MRI	3D	Yes	Expensive	No	Good. Higher than CT for soft tissues	No
VIA	2D	No	Non-expensive	Yes	Lower than CT, DXA and MRI, better than US	No
US	2D	No	Non-expensive	Yes	Poor	No

Chapter 1. Introduction

Utility for livestock animals

- **Breeding and selection**:

  effect of genetic and sex type

- Nutrition: effect of diet
- Health: veterinary diagnostic
- Medicine: animal as a model for human research
- Slaughter plant: carcass and cuts composition
- Processing plants: cutting optimisation and cuts composition

Chapter 2
Objectives

Chapter 2. Objectives

The main objective is to study the **evolution** of **fat** and **lean** tissues of **live pigs** from different genotypes and sexes from 30 to 120 kg by means of **computed tomography** images.

In order to get the final result, different objectives, are planned in between:

Chapter 2. Objectives

- To study the relationship between cross-sectional CT images and dissection measurements (Chapters 4 and 6)

- To estimate carcass composition and cuts composition using CT predictors (Chapters 4 and 6) or potential on-farm predictors (Chapter 6)

- To evaluate variations in the body composition of pigs (Chapters 5 and 7)

Chapter 2. Objectives

- To determine the allometric growth of the main tissues and body parts in relation to their weight and live weight (Chapters 5 and 7)

- To compare and discuss the goodness of equations developed (in Chapter 4 and 6) in order to know which one is better for each occasion and necessity (Chapter 8)

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Chapter 3

Material and methods

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Chapter 3. Material and methods

Experiment 1

Different genotypes

3 commercial types

Experiment 2

Different sexes

The most used sexes

Chapter 3. Material and methods

2

EXPERIMENTS

≠ GEN

(LW x LD)
(LA)

DU x (LW x LD)
(DU)

PI x (LW x LD)
(PI)

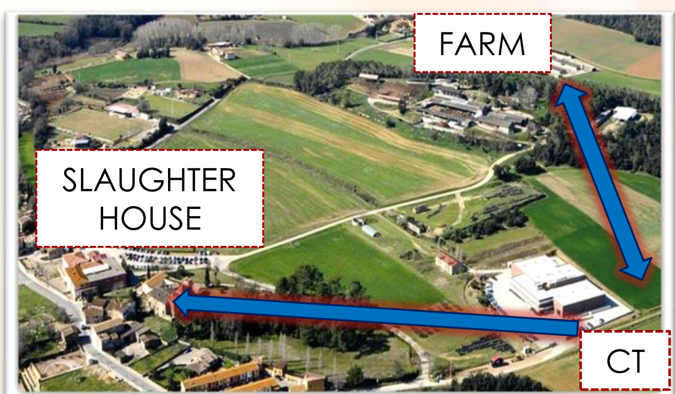
≠ SEX

♀ FEMALE (FE)

♂ ENTIRE MALE

♂ CASTRATED MALE (CM)

♂ IMMUNO CASTRATED MALE (IM)



At 12 and 24 weeks of age

Chapter 3. Material and methods

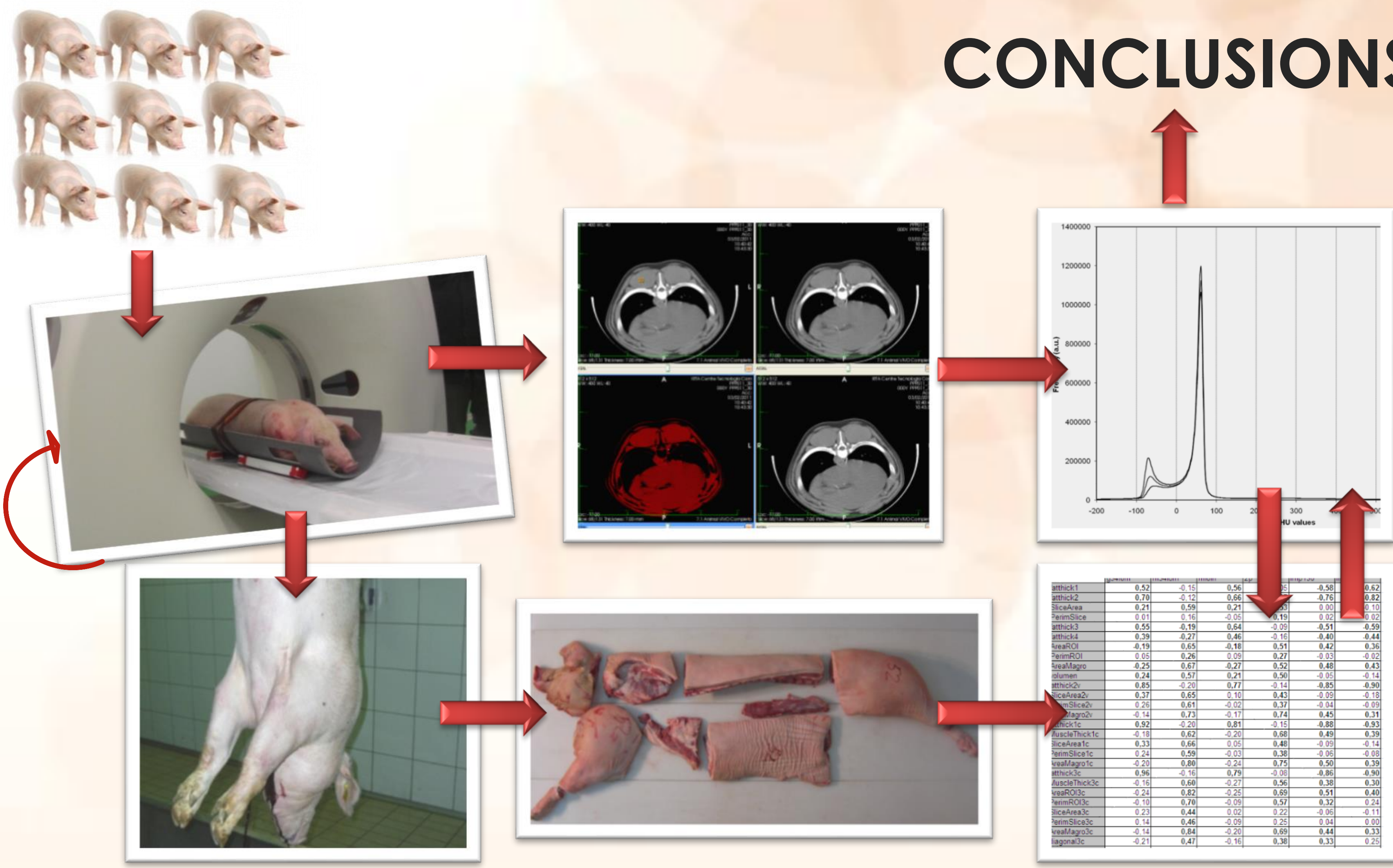
Animals of different GEN scanned (---) and slaughtered (o) at different target weights

Group	n	30 kg	70 kg	100 kg	120 kg
1 (15 each GEN)	45	---	---	---	--- o
2 (5 each GEN)	15	--- o			
3 (5 each GEN)	15		--- o		
4 (5 each GEN)	15			--- o	

Animals of different SEX scanned (---) and slaughtered (o) at different target weights

Group	n	30 kg	70 kg	100 kg	120 kg
1 (24 each SEX)	48	---	---	---	--- o
2 (4 FE, EM, CM)	12	--- o			
3 (4 each SEX)	16		--- o		
4 (4 each SEX)	16			--- o	

Chapter 3. Material and methods



Chapter 3. Material and methods

From the farm to the image analysis…

The transport process…

Chapter 3. Material and methods

The sleeping process…

Chapter 3. Material and methods

Moving in between…

Chapter 3. Material and methods

The scanning process…

Instrumental settings were:

General Electric HiSpeed Zx/I CT

140 kV

145 mA

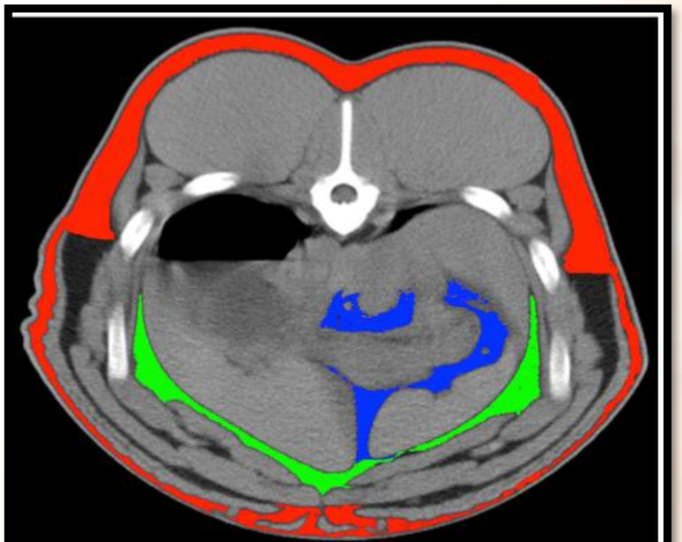
Matrix: 512x512

7 mm thickness (30 kg TBW)

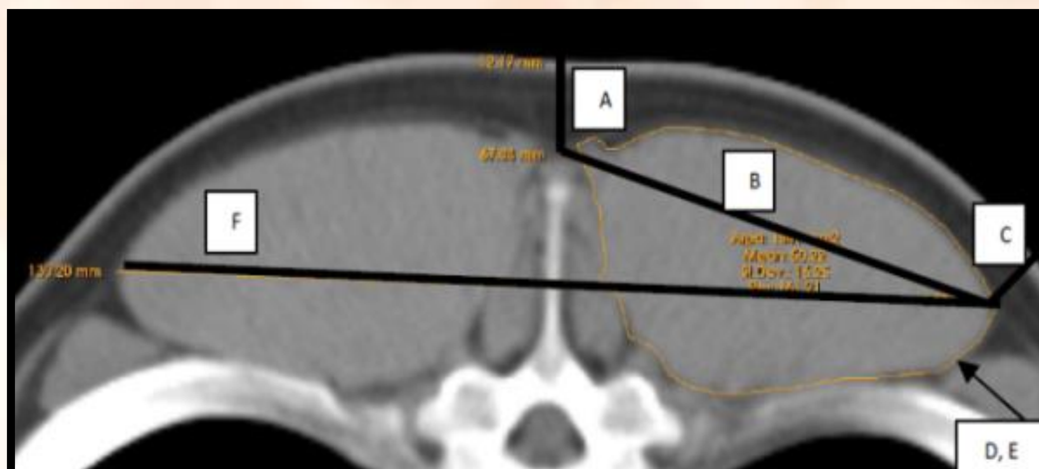
10 mm thickness (70, 100 and 120 kg TBW).

Chapter 3. Material and methods

The image analysis process…



- Acquisition of volume
- Acquisition of phenotypic measures

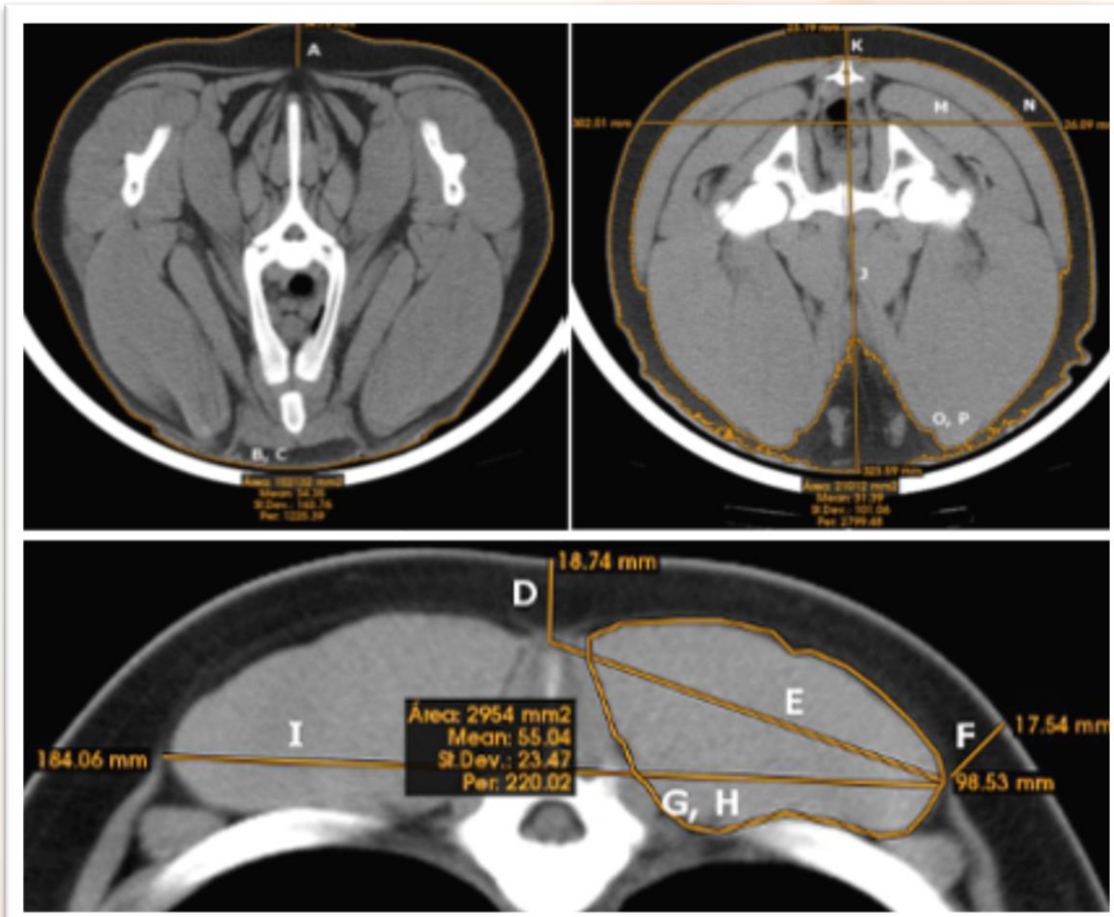


CT predictors

Software: Visual Pork

Chapter 3. Material and methods

•Acquisition of phenotypic measures



- Shoulder (first rib)
- Ham (bone with Z shape)

Loin between:

- 6th-7th last rib
- 11th-12th last rib
- 14th-15th last rib
- 3rd-4th lumbar vertebrae

Components predicted

Equations, using CT predictors, were derived to predict the following variables obtained by dissection:

total amount of ***fat*** (subcutaneous and intermuscular fat of the four primal cuts) and ***lean*** (lean of the four primal cuts + tenderloin), as well as the ***weights of ham, shoulder, belly, loin*** and its subcutaneous fat and also lean and bone of the ham.

Chapter 3. Material and methods

Statistical analyses

Differences between phenotypic measurements
(MIXED Procedure + Akaike's criterion)

Prediction equations
(REG procedure + decomposition of the MSPE error)

Allometric growth
*(MIXED procedure + logY=log a + b*log X)*

Comparison of the prediction equations
(Decomposition of the MSE error)

- *As an extra… Estimation of mature body weight (MBW)*
  (NLIN procedure + $Y(t) = a.\ e^{(-be)^{\wedge}(kt)}$)

Statistical analysis were performed using SAS software (version 9.2, SAS Institute Inc, Cary, NC, USA)

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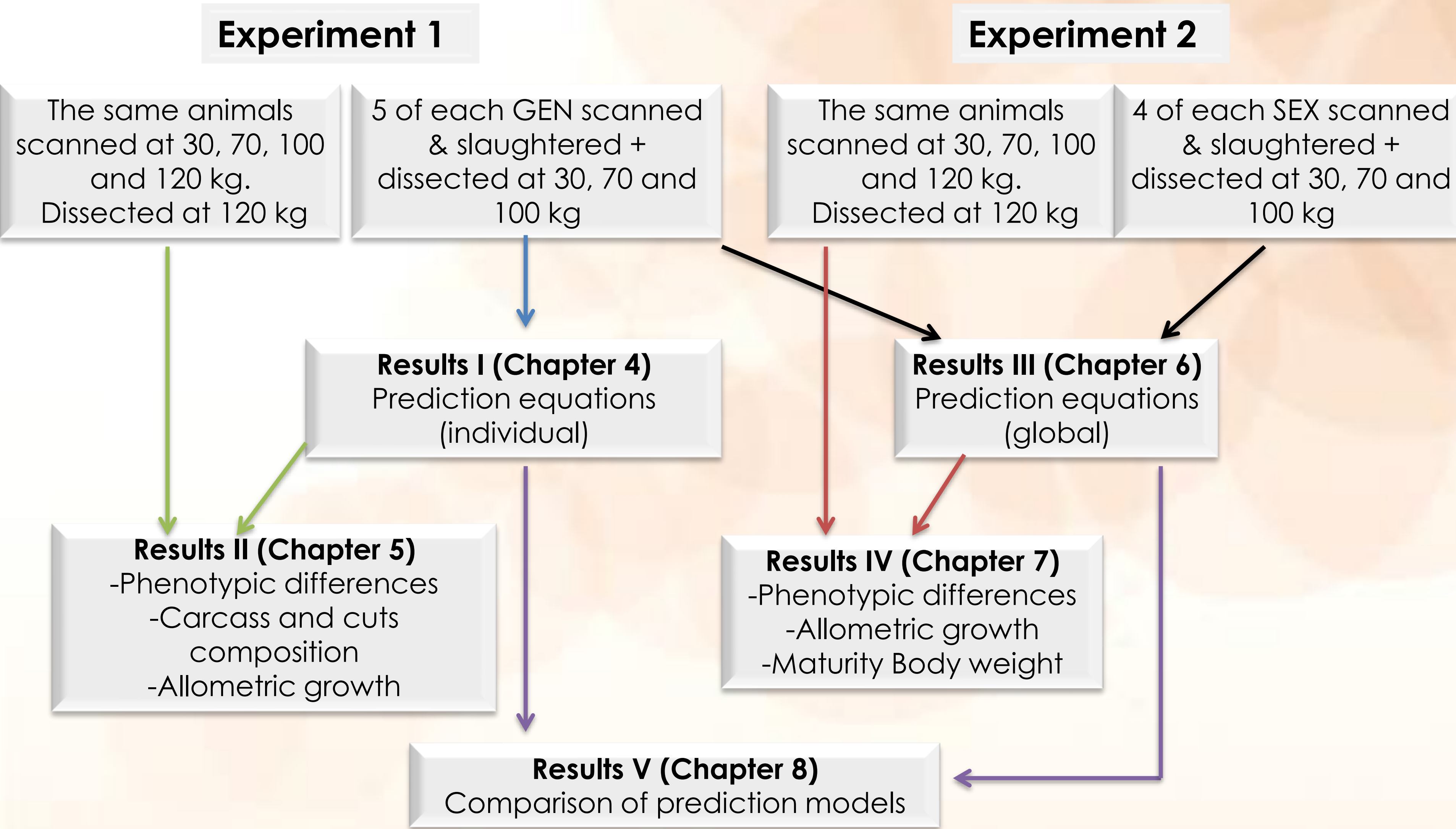
Results Presentation



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Chapter 4
Results I

The content of this chapter is published in Animal (2015), 9:1, 166-178.

Chapter 4. Results I

Estimation of carcass composition and cut composition from computed tomography images of live growing pigs of different genotypes

Animal (2015), 9:1, 166-178

Maria Font-i-Furnols[1], Anna Carabús[1], Candido Pomar[2] and Marina Gispert[1]

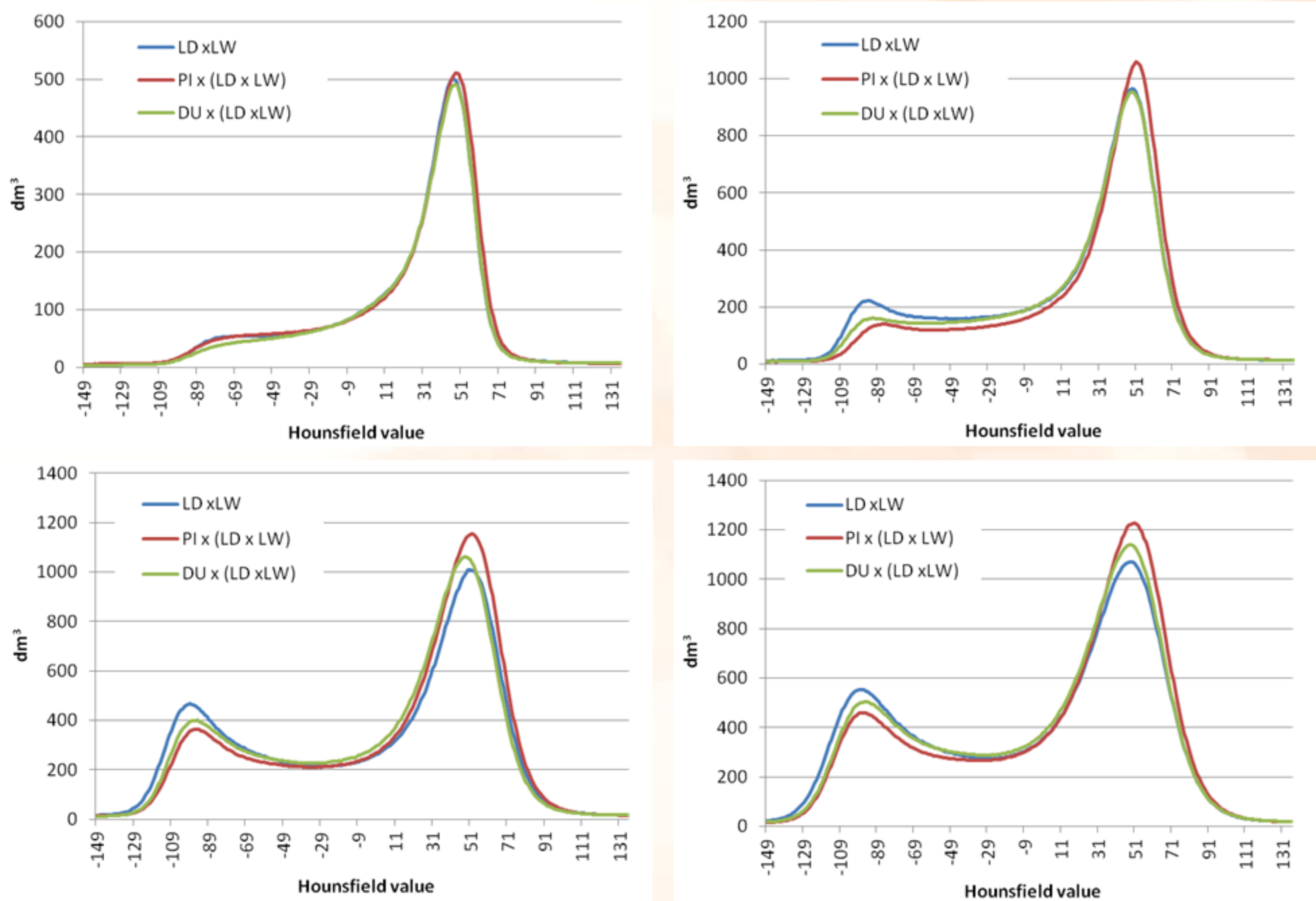
[1] *IRTA-Product Quality, Finca Camps i Armet, 17121 Monells, Catalonia, Spain*
[2] *Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, 2000 College Street, Sherbrooke, QC, J1M 1Z3 Canada*

This chapter deals with:

- *Selection of HU volume distribution*
- *Comparison of prediction models*

Chapter 4. Results I

Selection of Hounsfield volume distribution



- *2 peaks*

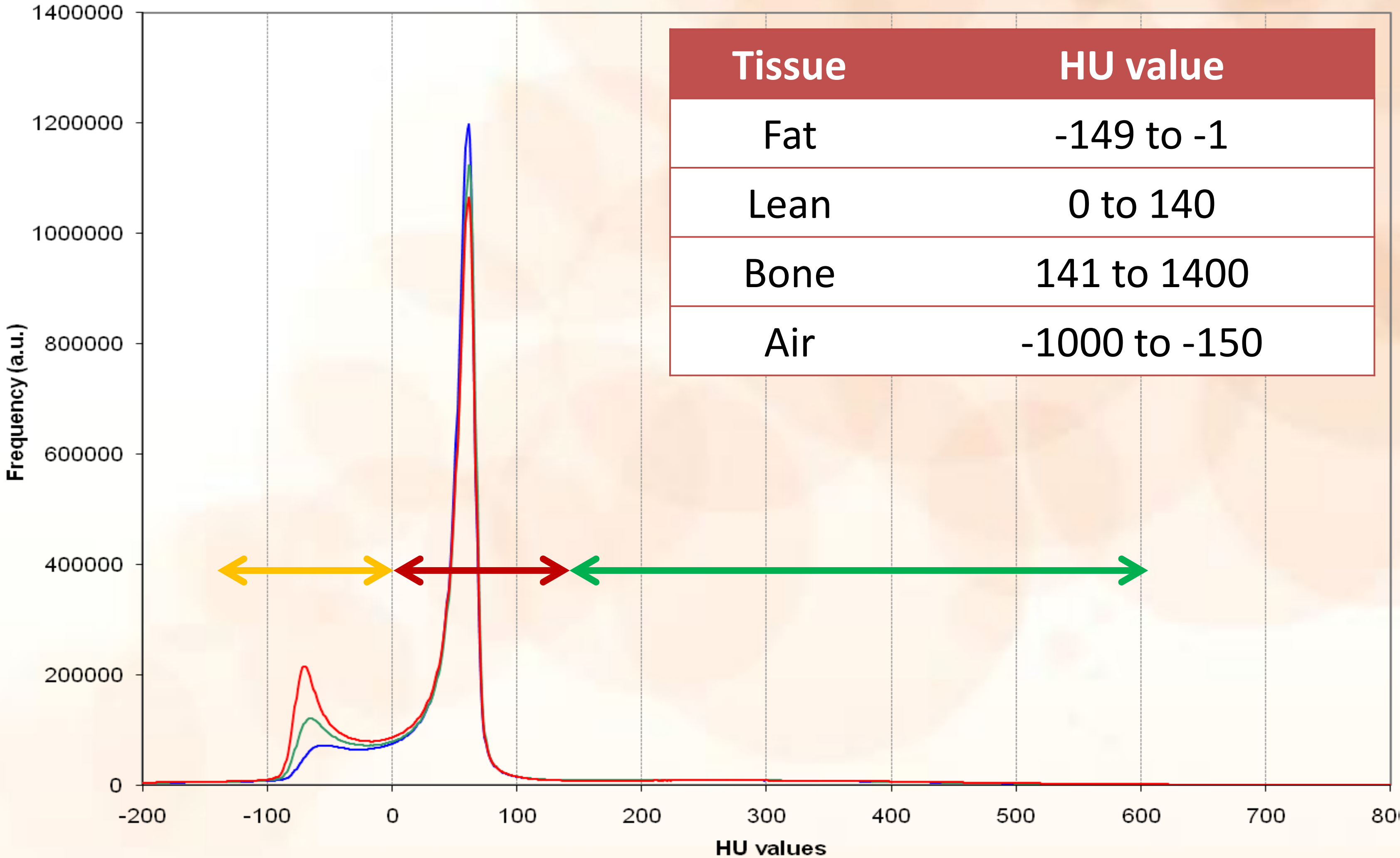
Higher with higher weights

Deposition of fat at late stage of life

Differences in shape depending GEN:

- ***For the lean: PI>DU>LA***
- ***For the fat:***
- ***LA>DU>PI***

Chapter 4. Results I



Tissue	HU value
Fat	-149 to -1
Lean	0 to 140
Bone	141 to 1400
Air	-1000 to -150

Chapter 4. Results I

Comparison of prediction models

Linear regressions using CT volumes or CT ratios of volumes as predictors.

Quadratic regressions using the previous CT volumes or CT ratios of volumes and their squared value as predictors.

Allometric equations ($y = a \cdot x^b$ linearized as $\log y = \log a + b \cdot \log x$), in which CT predictors were chosen as for the previous regression models.

Linear regression using CT volumes, CT ratios of volumes, and direct physical measurements recorded on loin and ham images as predictors.

Chapter 4. Results I

Coefficients of variation of calibration (CVc) and validation (%) (CVp) of different prediction models

	(kg)		Lineal			Quadratic			Allometric			Lineal + linear measurements		
	Mean		CV_c	CV_p		CV_c	CV_p		CV_c	CV_p		CV_c	CV_p	
Lean meat %	60.03		2.16	2.41		2.08	2.50		2.14	2.39		1.41	1.73	*
Lean	14.532		2.68	2.83		2.57	2.85		2.59	2.73	*	2.39	2.85	
Fat	5.489		5.13	5.70		4.80	5.57		5.38	5.98		4.72	5.50	*
Bones	1.922		4.52	4.91	*	4.49	5.34		4.57	4.95		4.52	4.91	

Linear models using CT tissue volumes as predictors, allometric models or linear models using CT tissue volumes and physical measurements, were in general **more robust** than quadratic models.

Chapter 4. Results I & discussion

The volume of the tissues of the animal has a high relationship with the amount of lean and fat and when predicting the %lean, the addition of linear measurements increases greatly the prediction (carcass relation)

Viscera were non-determinant for the results

-Fasted animals

-Constant relative weight of white viscera and organs

(Font i Furnols *et al.*, 2012, 2015; Landgraf *et al.*, 2006)

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Chapter 5
Results II

The content of this chapter is published in the Livestock Science (2015), 170:181-192

Chapter 5. Results II

In vivo computed tomography evaluation of the composition of the carcass and main cuts of growing pigs of three commercial crossbreeds

Livestock Science (2015), 170:181-192

Anna Carabús[1], Marina Gispert[1], Albert Brun[1], Pedro Rodríguez[2] and Maria Font-i-Furnols[1]

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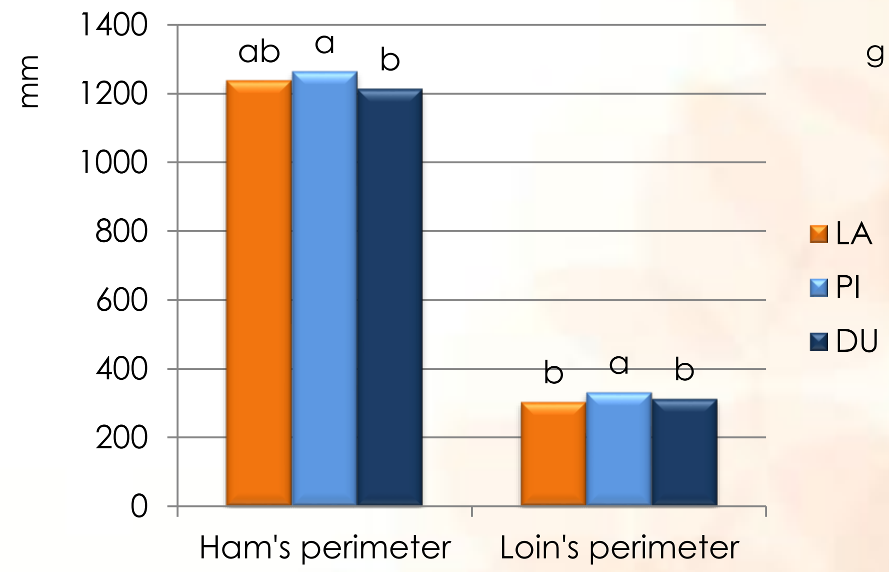
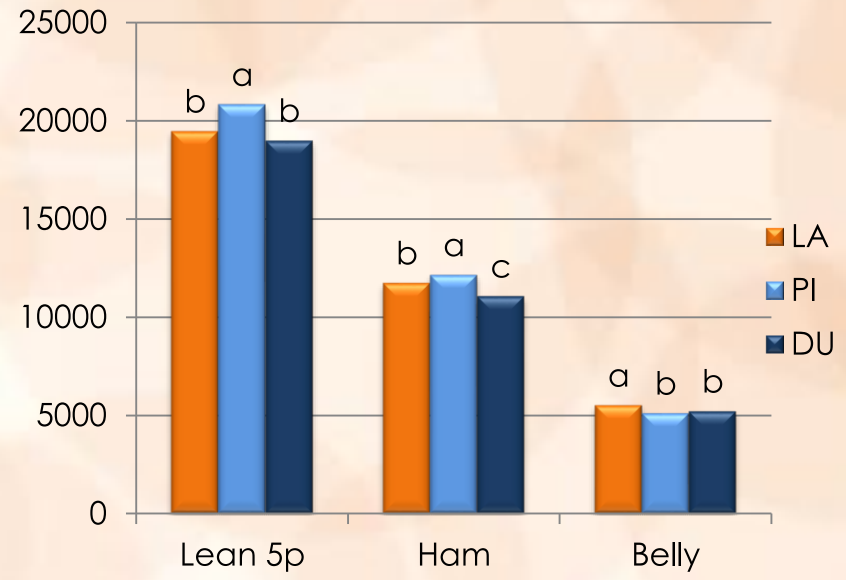
[2] *IRTA-Animal Welfare, Veïnat de Sies, 17121 Monells, Catalonia, Spain*

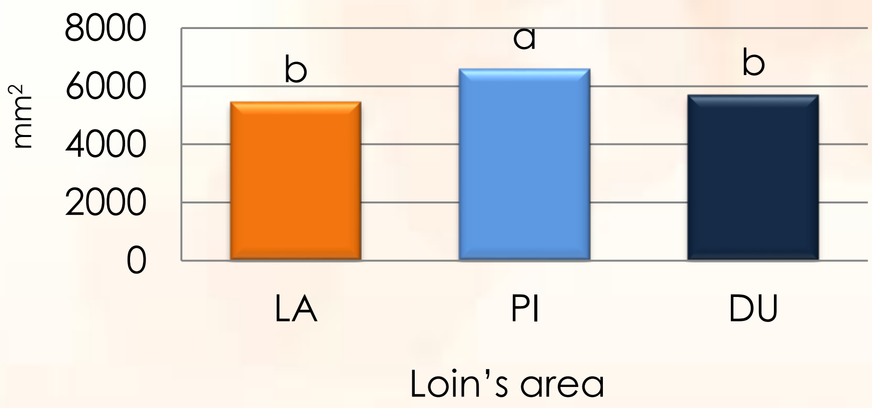
This chapter deals with:

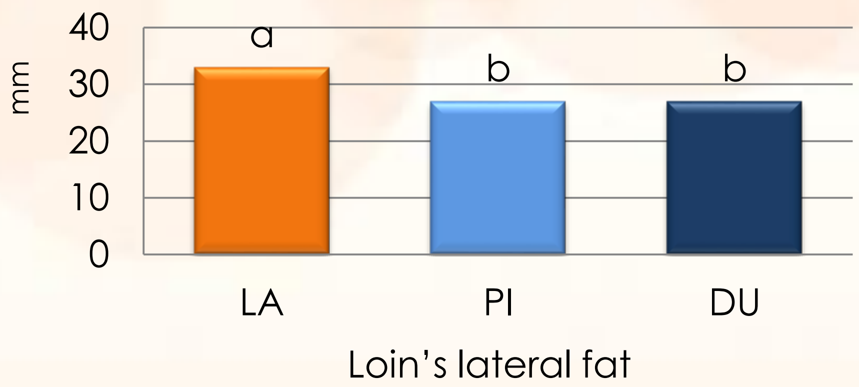
- *Phenotypic differences of animals of three genotypes*
- *Allometric growth*

Chapter 5. Results II





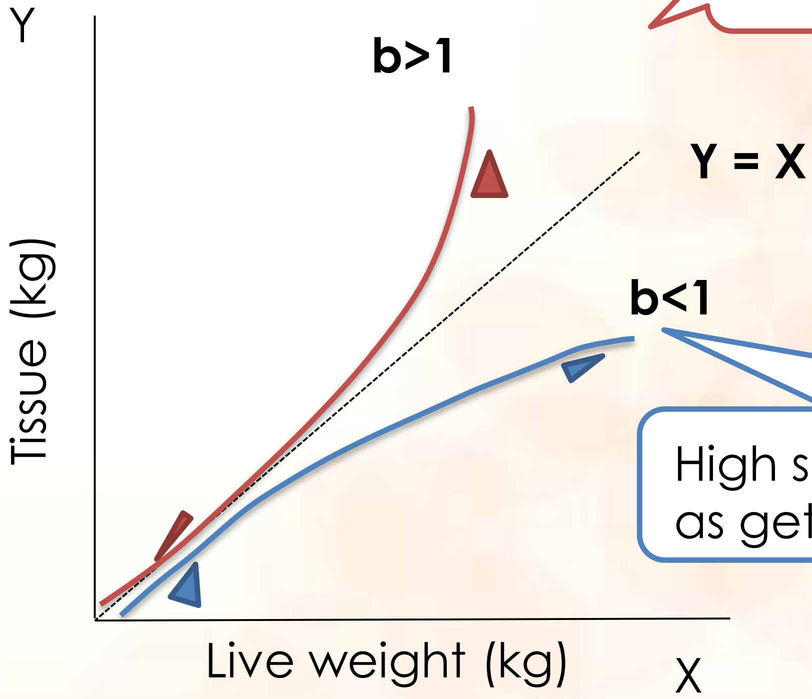




P<0.05

Chapter 5. Results II

Small slope at the beginning, bigger slope as getting more weight → Late deposition



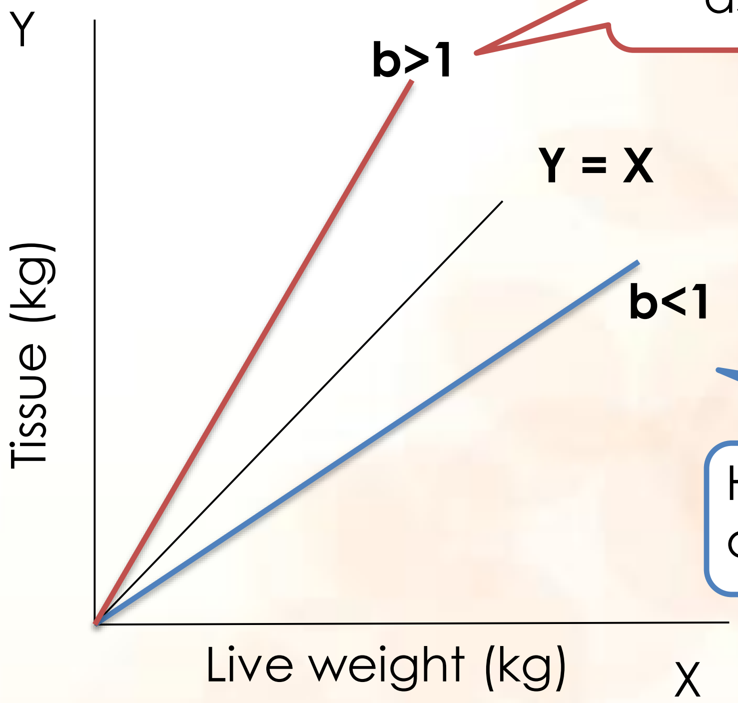
Log Y = log a + b * log X

High slope at the beginning, decreasing slope as getting more weight → Early deposition

Allometric function; $Y = aX^b$

Chapter 5. Results II

Small slope at the beginning, bigger slope as getting more weight → Late deposition



$$Log\ Y = log\ a + b * log\ X$$

High slope at the beginning, decreasing slope as getting more weight → Early deposition

Allometric function; $Y = aX^b$

Chapter 5. Results II

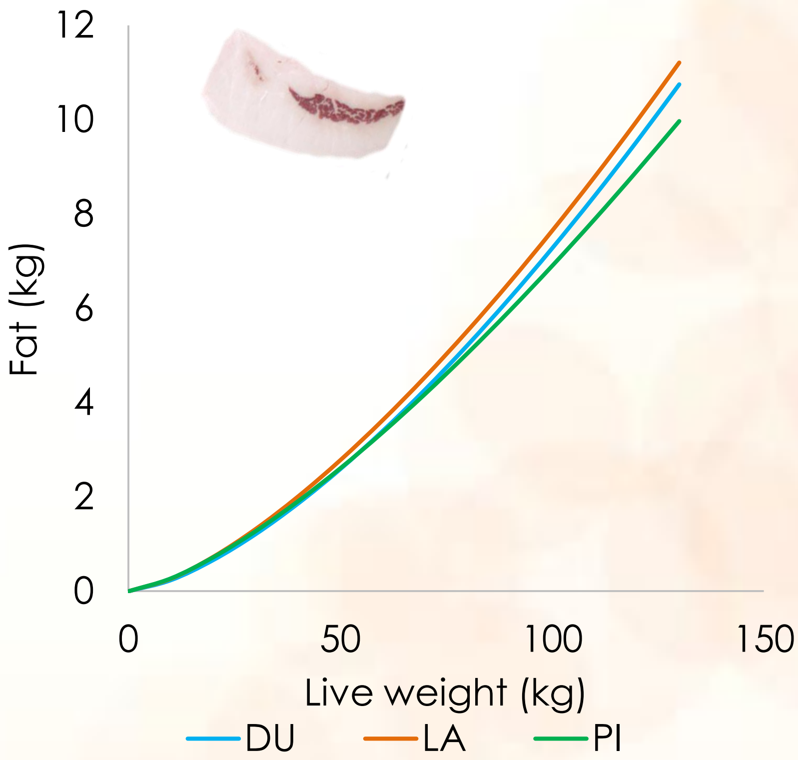
Allometric parameters for carcass and cuts composition

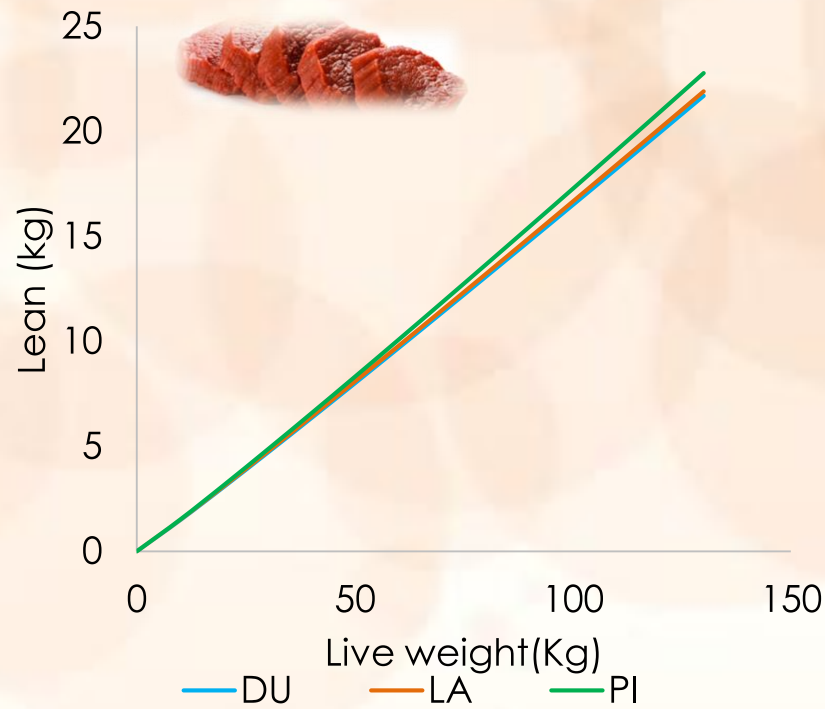
Parameters	b		
	LA	PI	DU
Carcass			
Fat (4 main cuts)	1.59[a]	1.48[b]	1.42[b]
Lean (5 main cuts)	0.97	0.95	0.93
Bone (4 main cuts)	0.80[a]	0.76[b]	0.81[a]
Ham			
Weight	1.09[a]	1.00[b]	1.00[b]
Lean	0.97[a]	0.92[a]	0.87[b]
Fat	1.59[a]	1.43[b]	1.45[b]
Bone	0.77[a]	0.74[b]	0.75[ab]

$P<0.05$

4 main cuts: loin, ham, shoulder and belly
5 main cuts: 4 main cuts + tenderloin

Chapter 5. Results II & discussion





Allometric growth of fat and lean

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Chapter 5. Results II & discussion

Loin, ham and shoulder area:

PI > DU and LA

Subcutaneous fat of the loin, ham and belly:

LA ≥ DU > PI

• Leanness of the DU → Feed characteristics and variability among DU population (Cilla *et al.*, 2006)

It is confirmed that lean presented **b = 1** in all the cases (carcass and cuts), indicating a growth in the same speed as the body weight (Wagner *et al.*, 1999)

In general, **LA showed the latest deposition of fat (b>1)**. It is also a genotype with larger carcasses, so bigger bellies (the fattest cut).

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Chapter 6
Results III

The content of this chapter is published in the Journal of Animal Science (2015), 93:1-10
Selected as a “Latest Breaking Abstract” at the ASAS Congress in Kansas City 2014

Chapter 6. Results III

Predicting fat, lean and the weights of primal cuts for growing pigs of different genotypes and sexes using computed tomography

Journal of Animal Science (2015), 93:1-10

Anna Carabús[1], Roberto D. Sainz[2], James W. Oltjen[2], Marina Gispert[1] and Maria Font-i-Furnols[1]

[1]*Department of Product Quality, IRTA, Finca Camps i Armet, 17121 Monells, Catalonia, Spain*
[2]*Department of Animal Science, University of California, Davis, CA 95616, USA*

This chapter deals with:

- *Predicting models using CT and potential on-farm predictors*
- *Use the same equation for all the animals*

Selected as a "Latest Breaking Abstract" at the ASAS Congress in Kansas City 2014

Chapter 6. Results III

PREDICTORS FROM THE CT

Volume of fat , Volume of lean, Volume of bones, Air, Subcutaneous fat **---** The subcutaneous fat thickness in the middle of the vertebral column and perpendicular to the skin (A)
Area **---** The area (mm^2) of the whole shoulder (B)
Perimeter **---** The perimeter (mm) of the shoulder (C)
Subcutaneous fat **---** Subcutaneous fat thickness (mm) in the middle of the vertebral column and perpendicular to the skin (D)
Width **---** Maximum width (mm) of the right loin (E)
Lateral fat **---** Lateral fat thickness (mm) of right loin eye perpendicular to the skin, at the bottom of the width (E) and in the right side of the loin (F)
Area **---** Right loin eye area (mm^2) (G)
Perimeter **---** Right loin perimeter (mm) (H)
Maximum length **---** Maximum length of the two loins (mm) (I)
Height **---** Maximum vertical height of the ham (J)
Subcutaneous Fat **---** Subcutaneous fat thickness (mm) at the top of the ham and perpendicular to the skin (K)
Fat area **---** Area of the ham's subcutaneous fat (mm^2) (L)
Width **---** Ham's width (mm) above the bones (M)
Lat. Fat --- Lateral fat thickness (mm) at the previous level (N)
Area **---** Area of the whole ham (mm^2) (O)
Perimeter **---** Perimeter (mm) of the whole ham (P)

Chapter 6. Results III

Area --- The area (mm^2) of the whole shoulder (B)
Perimeter --- The perimeter (mm) of the shoulder (C)

Subcutaneous fat

--- Subcutaneous fat thickness (mm) in the middle of the vertebral column and perpendicular to the skin (D)
Width --- Maximum width (mm) of the right loin (E)

Lateral fat

--- Lateral fat thickness (mm) of right loin eye perpendicular to the skin, at the bottom of the width (E) and in the right side of the loin (F)

Area --- Right loin eye area (mm^2) (G)

Perimeter --- Right loin perimeter (mm) (H)

Maximum length --- Maximum length of the two loins (mm) (I)

Height --- Maximum vertical height of the ham (J)
Fat area --- Area of the ham's subcutaneous fat (mm^2) (L)
Width --- Ham's width (mm) above the bones (M)
Lateral Fat --- Lateral fat thickness (mm)
Area --- Area of the whole ham (mm^2) (O)

Perimeter --- Perimeter (mm) of the whole ham (P)

Chapter 6. Results III

Prediction equations using CT predictors

Prediction equations using potential on farm predictors

The same equation for the whole population

(different genotypes + different sexes)

Chapter 6. Results III

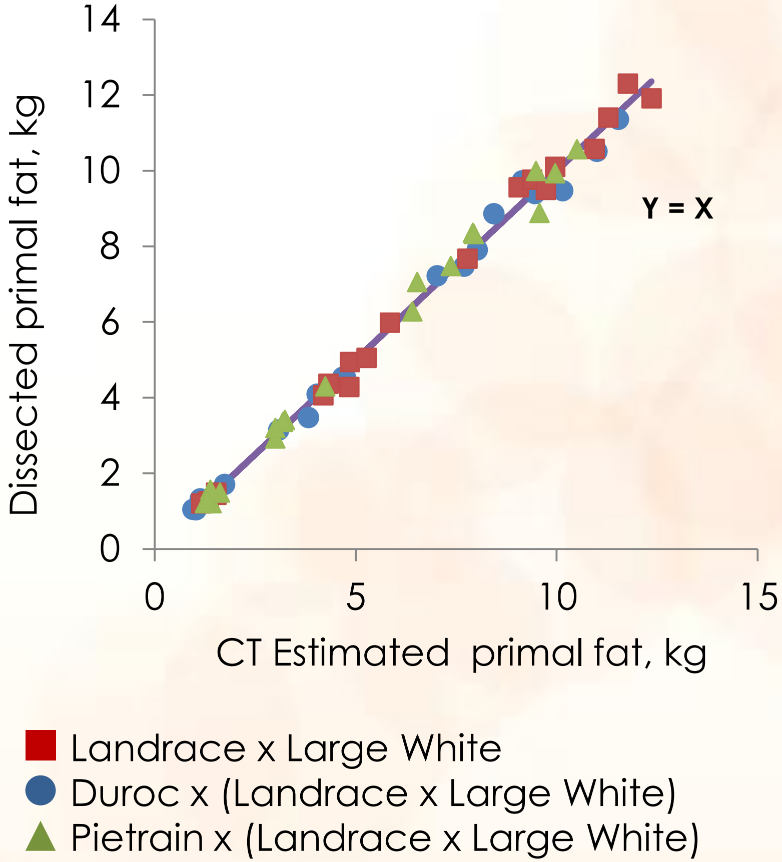
The same equation for the whole population

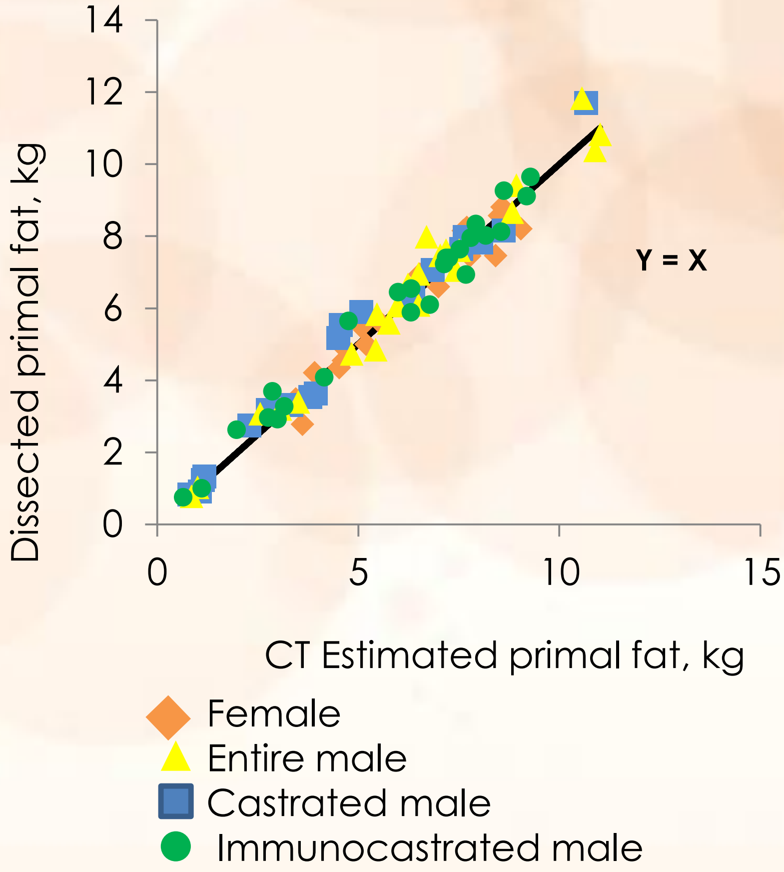
Dependent variable	Predictor[1]	Equation type	Intercept	Slope	Linear coefficient	Exp[3]	P-value	R^2	RMSE[3]	Proportion of random error associated with	
										Genotype	Sexual condition
Fat in 4 primal cuts[4]	BW	Linear	-2.659	0.043			<0.0001	0.982	0.496	0.989	0.937
	H_lat_fat			0.207			<0.0001				
	Sh_sub_fat			0.095			<0.0001				

MSPE	Slope Error	Bias Error	Random Error
0.14411	0.00008	0.00479	0.98792
2.94013	0.09701	0.03461	0.93701

Chapter 6. Results III

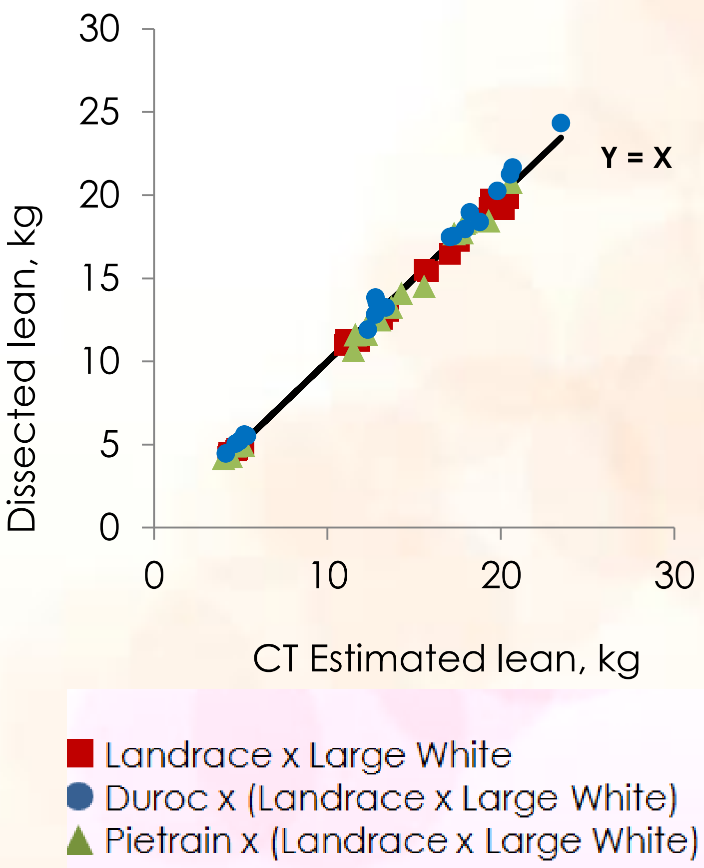
Prediction of fat using CT predictors

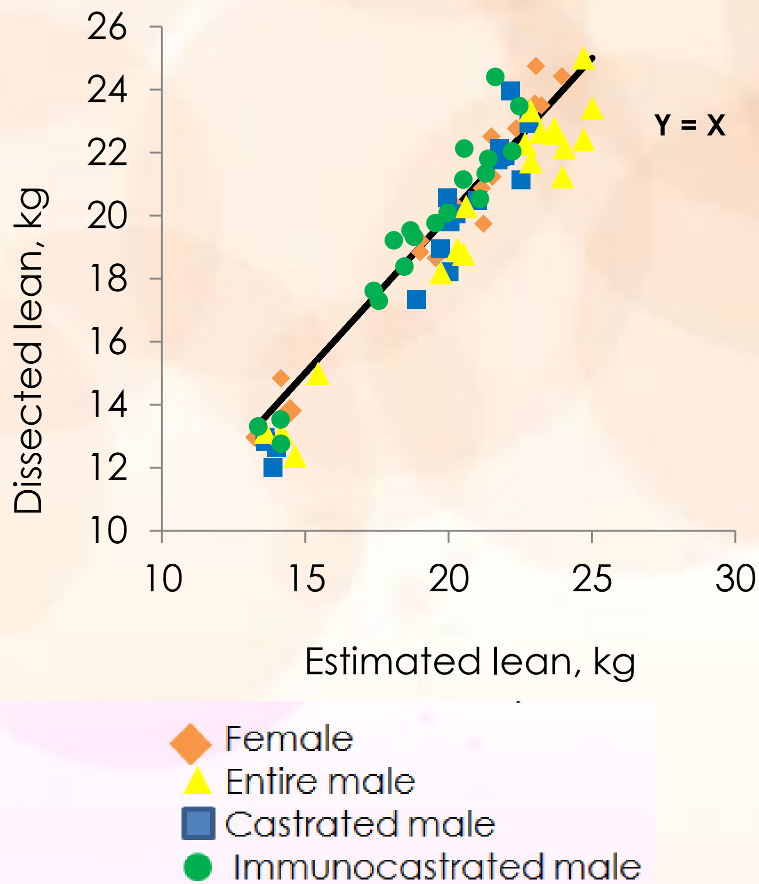




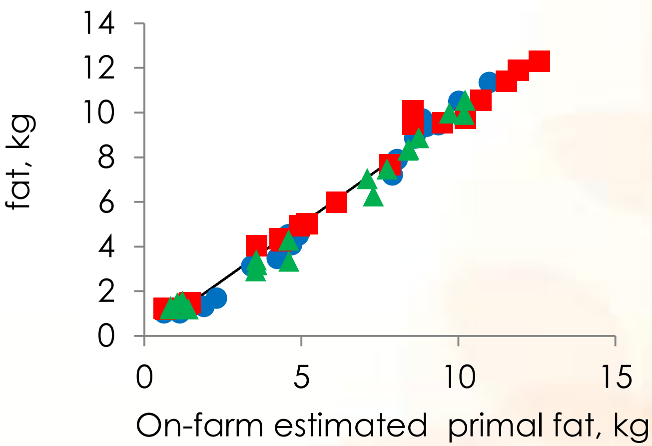
Chapter 6. Results III

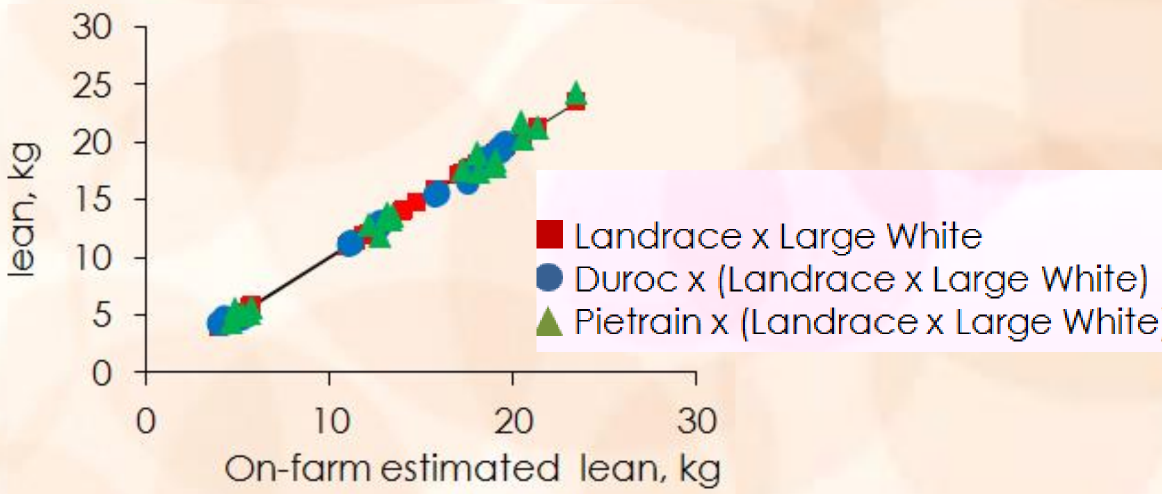
Prediction of lean using CT predictors

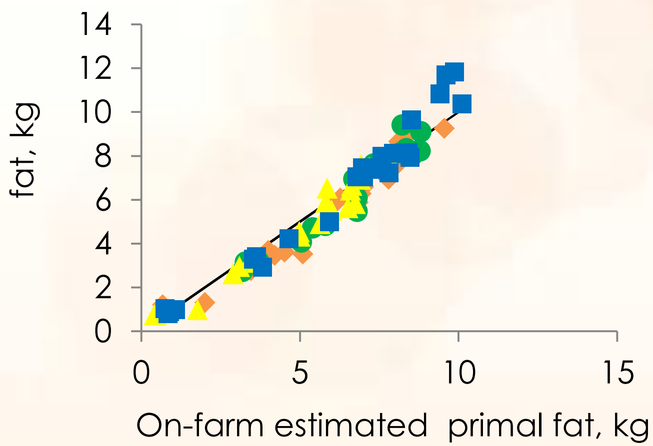


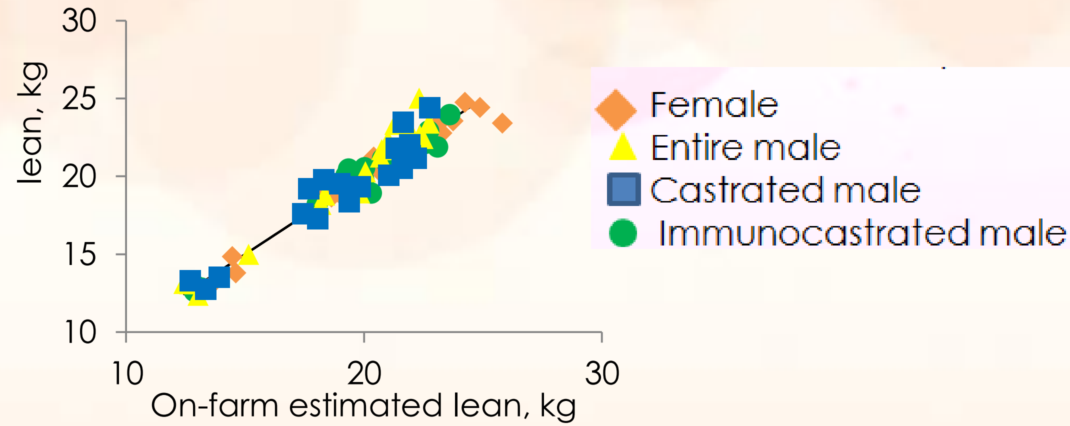


Prediction of fat and lean using on-farm predictors









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Chapter 6. Results III & discussion

The **BW is always used as a predictor** and it explains a high % of the variability.

For the prediction of the amount of lean, different parameters from the **ham** (especially the weight and the subcutaneous fat) presented a **good correlation** (Daza *et al.*, 2010, Jia *et al.*, 2010).

Generally, the **CT prediction equation** presented **less error** than the potential on-farm predictions → Use of volume

However, it has been proved the goodness of the potential on-farm predictors and they should be test in real conditions.

Chapter 7

Results IV

The content of this chapter is submitted to Animal

Chapter 7. Results IV

Growth of total fat and lean and the primal cuts in relation to estimated mature weight in pigs of different sexual conditions, assessed using computed tomography

Anna Carabús[1], Roberto D. Sainz[2], James W. Oltjen[2], Marina Gispert[1] and Maria Font-i-Furnols[1]

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[2]*Department of Animal Science, University of California, Davis, CA 95616, USA*

This chapter deals with:

- *Body composition*
- *Allometric growth*
- *Estimation of the mature body weight*

Chapter 7. Results IV

Volume of fat and lean, of different SEX and TBW, from histograms

Volume (dm^3)	TBW	CM	FE	IM	EM
Lean	30	21.48	20.92	21.66	22.6
	70	43.503^{b}	44.72^{ab}	47.66^{a}	48.13^{a}
	100	56.93^{c}	62.25^{b}	62.43^{ab}	65.71^{a}
	120	65.73^{c}	71.41^{b}	69.43^{b}	75.98^{a}
Fat	30	4.68	4.74	3.52	3.69
	70	16.52^{a}	14.42^{ab}	11.75^{b}	12.49^{ab}
	100	28.96^{a}	24.81^{ab}	23.65^{bc}	20.44^{c}
	120	38.31^{a}	31.89^{b}	33.38^{b}	25.39^{c}

P<0.05

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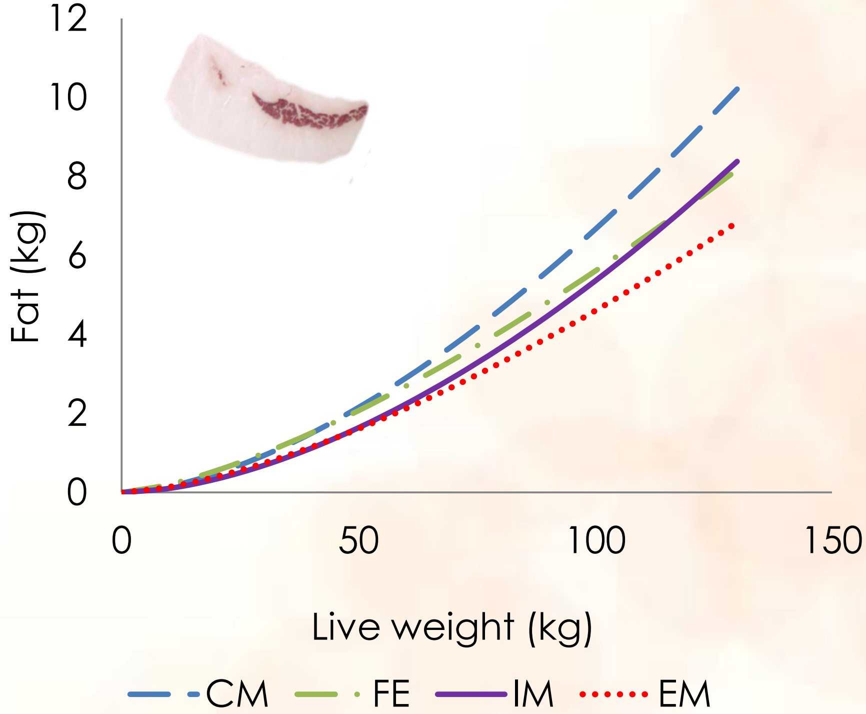
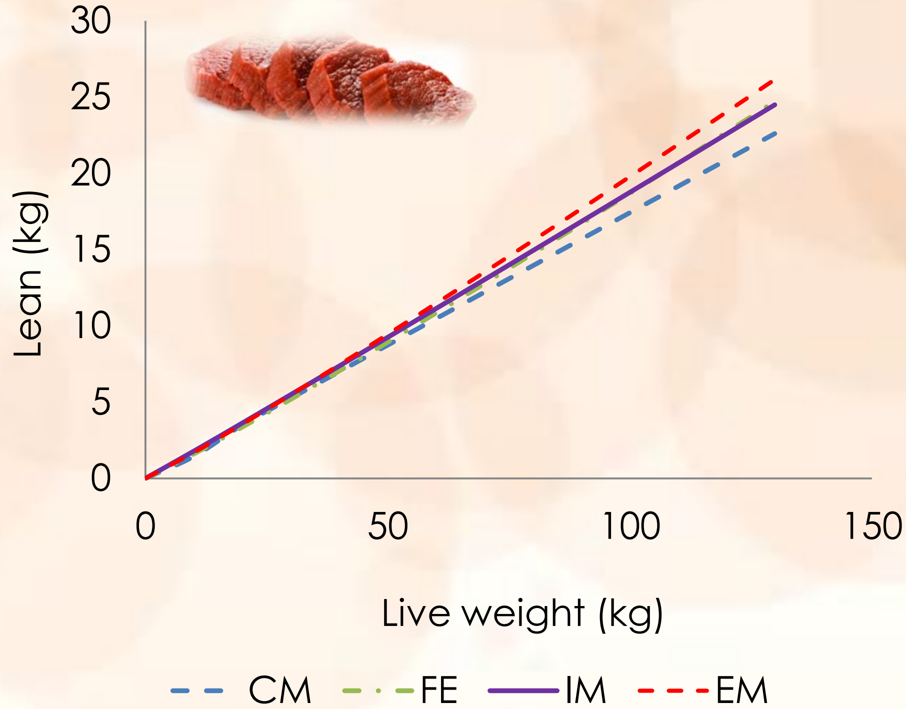
Chapter 7. Results IV





Allometric growth of fat and lean

Chapter 7. Results IV

The MBW of each group of pigs was obtained using the Gompertz equation (Gompertz, 1825):

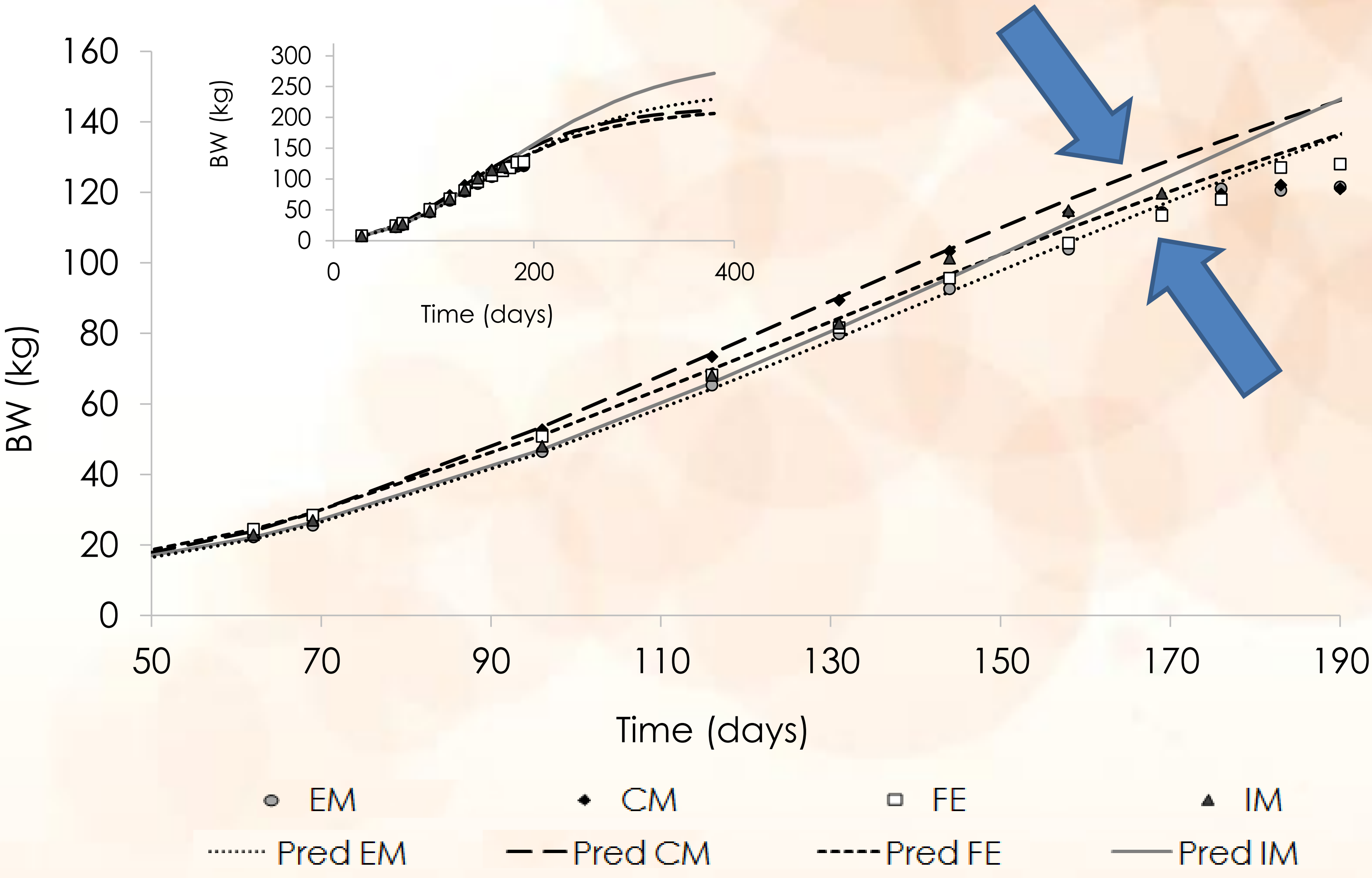
$$Y\ (t) = a.\ e^{(-be)\wedge(kt)}$$

where ***Y* is the BW**, ***t* is the time** period generally expressed in days or weeks (expressed in days in the present study), ***a*** is an asymptote equivalent to **MBW**, ***b*** sets the displacement along the **x** axis, *k* sets the growth rate (*y* scaling) and **e** is Euler's number.

SEX	a	b	k
CM	219.15[b]	5.04[a]	0.013[a]
FE	215.66[b]	4.64[b]	0.012[ab]
IM	302.96[a]	4.86[ab]	0.010[b]
EM	247.07[ab]	4.83[ab]	0.011[b]

P<0.05

Chapter 7. Results IV



Chapter 7. Results IV & discussion

The **Gompertz curve** fit the data very well from 0 to 150 days for all SEX, but seemed to **overestimate** live weights after that point, especially for IM → lack of observed weights above 120 kg.

The predicted MBW for IM was also conditioned by the fact that this group of animals presented **two clear behaviors**, being similar to EM from birth to the second injection of the vaccine and more comparable to CM from that point to the final weight.

Chapter 7. Results IV & discussion

In general, **EM** was the **leanest** and **CM** the **fattest**.

Ham and **shoulder** presented results close to the unity, meaning that their **development is similar to BW**.

The **loin** and the **belly** showed *b values* higher than 1, indicating that they have a "**late deposition**". This is in accordance with the fat b value (b>1) (Kouba and Bonneau, 2009), and it has sense because the belly is the fattest cut.

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Chapter 8

Results V

The content of this chapter is submitted to the Agriculture Systems Journal

Chapter 8. Results V

Keys to select a prediction model for carcass composition from computed tomography images

Anna Carabús, Marina Gispert and Maria Font-i-Furnols

[1]*Department of Product Quality, IRTA, Finca Camps i Armet, 17121 Monells, Catalonia, Spain*

This chapter deals with:

•Comparison of prediction equations

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Chapter 8. Results V

Individual equations vs. Global equations

Chapter 4 vs. Chapter 6

$$MSE = ECT + ET + ED$$

Error due to central tendency

Error due to regression

Error due to random error

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Chapter 8. Results V

Decomposition of the mean square predicted error, comparing the two predictions, taking into account all the genotypes together.

Estimated parameter (kg)	**Individual equations approach**				**Global equation approach**			
	Font-i-Furnols *et al.*, (2015)				**Carabús *et al.*, (2015)**			
	MSPE	**ECT**	**ER**	**ED**	**MSPE**	**ECT**	**ER**	**ED**
Lean	0.382	0.000	0.001	0.999	0.410	0.000	0.001	0.999
Fat	0.148	0.002	0.017	0.981	0.156	0.000	0.001	0.999

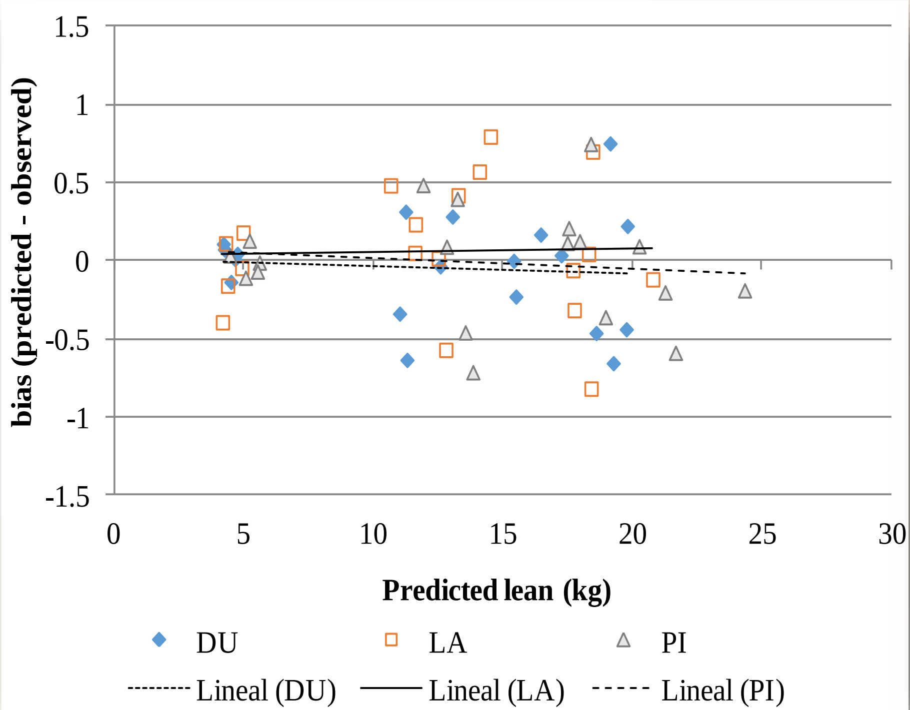
Chapter 8. Results V

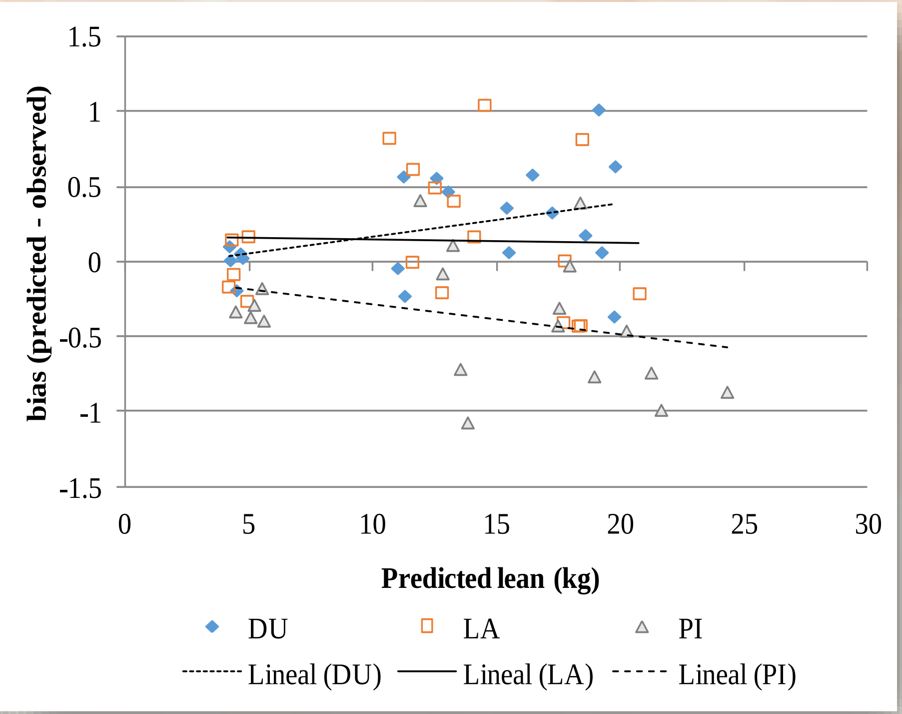
Decomposition of the mean square predicted error, comparing the two predictions, taking into account the genotypes individually.

Estimated parameter (kg)		Individual equations approach Font-i-Furnols *et al.*, (2015)				Global equation approach Carabús *et al.*, (2015)			
	GEN	**MSPE**	**ECT**	**ER**	**ED**	**MSPE**	**ECT**	**ER**	**ED**
Lean	DU	0.125	0.018	0.001	0.981	0.173	0.296	0.132	0.572
	LA	0.181	0.020	0.009	0.971	0.224	0.087	0.002	0.911
	PI	0.132	0.002	0.004	0.994	0.313	0.428	0.034	0.538
Fat	DU	0.078	0.024	0.028	0.948	0.089	0.026	0.048	0.926
	LA	0.051	0.004	0.012	0.984	0.082	0.008	0.027	0.966
	PI	0.071	0.010	0.046	0.945	0.087	0.064	0.011	0.925

Chapter 8. Results V

Residuals of the estimation of the lean obtained by **individual equations** approach (Font-i-Furnols *et al.*, 2015) (left) and **global equation** approach (Carabús *et al.*, 2015) (right).





Chapter 8. Results V & discussion

Prediction equations and their comparison

Both equations presented good results

The global equation permits to apply it for a bigger number of animals, thus is preferable to use it when the population is mixed.

When a higher level of accuracy is need, such as the case of a breeding company, it is preferable to use individual equations developed for each genotype but, in this case, it is also recommended to use a big sample, in order to have high confidence in the results.

Chapter 9

General discussion

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Chapter 9. General discussion

Animals from experiment 1 and 2 are not comparable due to they were raised in different conditions and that is why the discussion has been focus on GEN or SEX individually.

CT has demonstrated to be a useful device for the industry, because the volumes of the tissues are excellent predictors of carcass and cuts composition. However, if the use of the device is limited, a portable device can optimize its price and make it affordable for the industry (such as Scotland or France do).

Chapter 9. General discussion

CT and potential on-farm predictors have shown good results. However, it would be convenient to test the potential on-farm predictors and compare the resolution / predictors obtained from the CT and the US. If working, valuable information can be easily shared to the industry.

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Chapter 10
Conclusions

Chapter 10. Conclusions

1. Image analysis technologies have proved applications in the livestock field. Predictions show higher precision for CT and MRI devices than DXA, VIA and US. The election of the device depends on several aspects such as purposes, availability, need of precision and accuracy, cost, required labour and possibility to be used on farm.

2. There is a very good relationship between cross-sectional CT images obtained in live pigs. This information can be useful for breeding, optimizing management and, for example, in nutritional studies. Consequently, CT images can be used to predict accurately carcass and cuts composition from live pigs, being this information useful in breeding and nutritional studies among others.

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Chapter 10. Conclusions

3. Prediction equations of carcass and cuts composition derived from live pigs by using on-farm measurements as predictors can be useful for genetic improvement, feeding programs and management for pigs of different genotypes and sexual conditions.

4. There are clear differences in the body composition between genotypes and sexes, particularly when pigs are close to the commercial weight but also at early weight. This reflects the real importance of genetic traits and sexual condition, which can be used to produce the desired product.

Chapter 10. Conclusions

5. Although some differences in pigs from different genotypes or sexual conditions exist, in all the cases the fat growth rate, relative to the live weight and to the weight of the main pieces, was higher (allometric coefficient > 1) than the lean and the bone growth rates. This indicates that fat is the last tissue to be deposited in the body and, by controlling the slaughter weight (within genotype and sex), it is possible to control the fat deposition.

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Chapter 10. Conclusions

6. The growth rate for fat in carcass and cuts was faster in Landrace x Large White than in the other genotypes. Regarding sexual conditions, fat deposition was proportionately most rapid in immunocastrated and castrated males and least rapid in entire male and female, and lean deposition behaved inversely. Thus, although immunocastrated males behave as entire males until the second vaccine administration, immunocastrated and castrated males have a very similar performance regarding the speed of deposition of fat.

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Chapter 10. Conclusions

7. Different crossbreeds are suitable for different markets. For the fresh meat market, where low fat product and great lean areas are required, Pietrain x (Landrace x Large White) and females would be the most adequate. Contrarily, for the cured ham production, that requires high level of fat (subcutaneous and intramuscular), the Landrace x Large White and Duroc x (Landrace x Large White) crossbreed and castrated males would be the best candidates.

8. Prediction of body composition from images of live pigs can be obtained precisely using different types of equations. However, linear and allometric models using CT tissue volumes as predictors, or linear models using CT tissue volumes plus additional physical measurements at specific anatomical positions of the body, are more robust than quadratic models.

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Chapter 10. Conclusions

9. The global equation, obtained from and for animals of different genotypes and sexes, permits generalization of the predictions to a larger number of animals, thus it is preferable to use it when the population is mixed or when the parameter estimated does not need high level of accuracy for a specific line. When this is needed, such as in the case of breeding companies, it is preferable to use genotype specific prediction equations.

10. Computed tomography can be notably useful for the meat industry because the carcass quality parameters can be known at early weights of the live animals and models can be applied to know the carcass characteristics at slaughter. As a result, the use of this information can provide economic benefits for all of the stakeholders involved in the meat chain.

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Gràcies !!