1

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Protein and energy evaluation of pig feeds, carcass measurement

Recent advances and use in tools

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2

Presentation of INRA and UMR PEGASE

3

Introduction (1)

- Cost of feed > 50-70% of cost of pig meat production + important fluctuations over time
- More and more ingredients are available + competition between animal species, with biofuels, with humans, etc.
- Feed characteristics can be highly modified (technology, additives, etc.)
- Nutritional values: precise hierarchy
- Impact of feed characteristics (nutrient, ingredient, etc.) on welfare, health, environment, etc. → "Non-nutritional" value of feeds
- Different evaluation methods

4

Introduction (2)

- Recommendations : variable ⇨ Factorial approach+ modeling
- Coherence of nutritional values and nutrient requirements
- Precise animal requirements and feed nutritional values are necessary
- Use of tools (Evapig and InraPorc) to integrate knowledge

5

Main topics:

- Energy value of pig feeds
- Protein value of pig feeds
- Feeding tables and EvaPig
- New perspectives in feed evaluation
- Carcass measurement
- Use in InraPorc

6

Energy value of pig feeds

7

Energy utilization

Gross Energy (GE) ← Feed composition

dE → Fecal energy ← Dietary fiber Production stage

Digestible Energy (DE)

ME/DE → Urinary and gas energy ← Proteins

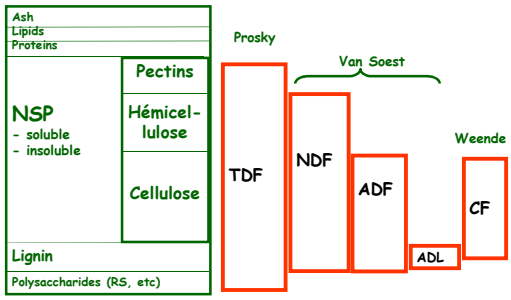
Metabolizable Energy (ME)

k → Heat increment ← Production stage

Net Energy (NE)

8

Definition and analysis of DF



9

Digestibility of DF in growing pigs

	Trial 1	Trial 2
Number of diets	114	70
Pigs BW, kg	43	62
Digestibility (%) of		
NDF	47	57
NDF – ADF	54	66
ADF	37	38
	Noblet and Perez, 1993	*Le Goff and Noblet, 2001*

10

Digestive utilization (%) of dietary fiber in the growing pig

	NSP	NDF
Wheat straw	16	15
Wheat bran	46	40
Sugarbeet pulp	69	60
Soybean hulls	79	68

Chabeauti et al., 1991

11

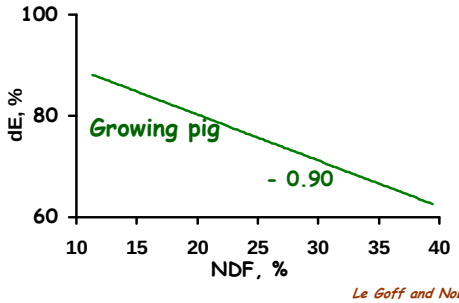
Variability of digestibility of NSP (%) in growing pigs (45 kg BW)

Wheat straw	16	Lignin ++; cellulose +
Wheat bran	46	Lignin +; cellulose +
Sugar-beet pulp	69	Pectin ++; lignin -
Soybean hulls	79	Pectin ++; lignin -

Chabeauti et al., 1991

12

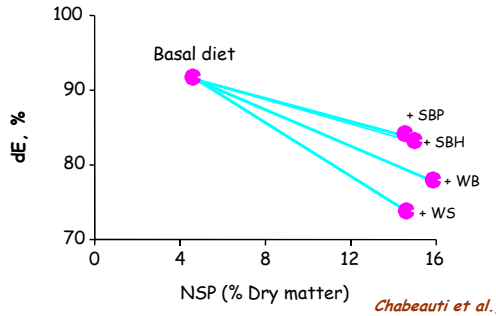
Digestibility of energy in growing pigs (n=77)



Le Goff and Noblet, 2001

13

Change in energy digestibility due to DF addition: effect of DF origin



Chabeauti et al., 1991

14

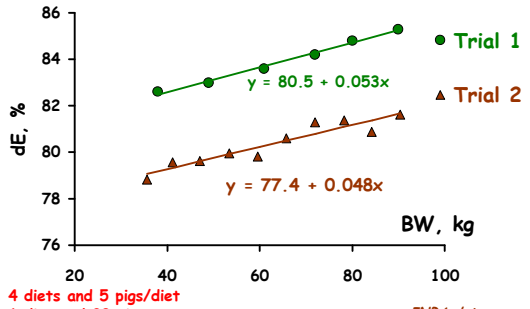
Contribution of nutrients to energy supply in growing pigs (kJ/g) (77 diets)

	CP	EE	ST	NDF
Gross energy	22.7	38.8	17.4	19.0
DE growing pig	22.5	31.7	17.2	3.2

Le Goff and Noblet, 2001

15

BW and energy digestibility in growing pigs



Trial 1: 4 diets and 5 pigs/diet
Trial 2: 1 diet and 20 pigs

INRA data

16

Effect of BW on dE

BW, kg	45	100	150
Mean (7 diets)	83.2	85.5	86.3
Starch rich diet	90.6	91.6	92.0
Fiber rich diet	71.6	75.6	78.0

Noblet and Shi, 1993

Effect of BW is dependent on feed characteristics

17

Effect of physiological stage on dE (n=77)

Stage	Growing	Adult
BW, kg	61	234
DM intake, g/d	1854	2104
dE, %	82.1	85.2

The difference between young and adult pigs should be considered in energy evaluation systems

Le Goff and Noblet, 2001

18

Digestive utilization (%) of dietary fiber (NSP) in pigs

	Growing pig		Adult pig
Wheat bran	46	+	54
Corn bran	36	++	82
Sugarbeet pulp	89	-	92

Noblet and Bach-knudsen, 1997

19

Effect of body weight on transit of digesta in pigs

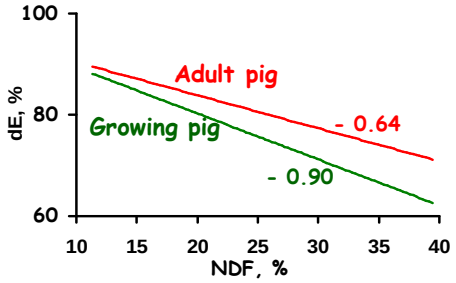
• Body weight, kg	40	80	250
• T_0, hr	19.4	26.0	62.3
• MRT, hrs	33.1	37.3	81.0

T_0: first appearance of marker; MRT: mean retention time

Le Goff et al., 2002

20

Digestibility of energy in growing and adult pigs (n=77)



Le Goff and Noblet, 2001

21

Contribution of nutrients to energy supply in pigs (kJ/g) (77 diets)

	CP	EE	ST	NDF
Gross energy	22.7	38.8	17.4	19.0
DE growing pig	22.5	31.7	17.2	3.2
DE adult pig	22.5	31.7	17.2	6.4

Fat affects energy concentration
Dietary fiber is a major factor of variation of DE
Two energy values for adult and growing pigs

Le Goff and Noblet, 2001

22

Digestibility of energy in growing and adult pigs

	Growing	Adult	Δ, %dEg
Wheat	87.6	89.2	+1.8
Corn	87.9	91.4	+4.0
Soybean meal	85.2	90.4	+6.2
Wheat bran	56.7	62.7	+10.4
Corn gluten feed	65.6	76.4	+16.5
Soybean hulls	51.4	70.3	+36.8

INRA & AFZ feeding tables

23

Effect of technology on dE

Technology	Mash		Pellet
Wheat-SBM diets (n=2)	88.6	*	89.2
Corn-SBM diets (n=3)	88.4	**	90.3
Corn (n=5)	87	**	90
Full-fat rapeseed	35	**	83
Linseed (extrusion)	51	**	84

Technology affects dE; it has to be considered in energy evaluation of feeds for swine

INRA data

24

Urinary and gas energy

- In the growing pig:
  - E urines, MJ/kg DM=0.19+0.031xN urines (g/kg DM)
    (N urines = 50% digestible N)
  - E methane: related to fermented energy (<0,5% of DE)
  - ME/DE is about constant in complete and balanced feeds (#96%) and varies between 91% (Soybean meal) and 100% (fat) for ingredients

DM: feed dry matter intake

Le Goff and Noblet, 2001; Noblet et al., 2004

25

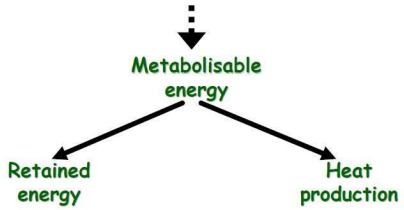
Methodological aspects of DE and ME measurements

- dE is affected by
  - BW
  - Technology
  - Gut health
  - etc.

  ⇨Conditions should be standardized
- Methods: total collection, markers, in vitro, NIR, prediction equations, etc.
- ME can be estimated from DE values

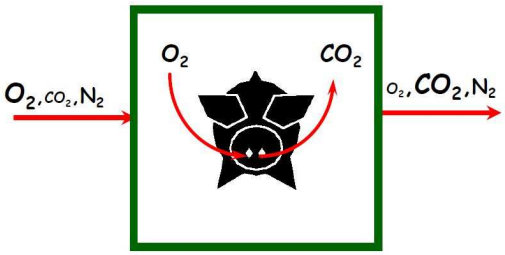
26

Utilization of energy



27

Indirect calorimetry



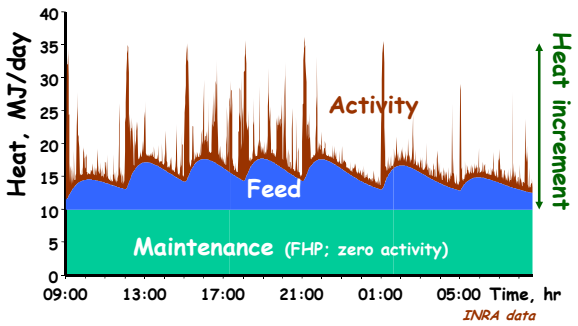
Heat production = f(O2, CO2, ….)

28

Respiratory chambers for calorimetry method

29

Dynamics and components of heat production



30

NE calculation: calorimetry method

Net energy = ME - Heat increment

Net energy = ME - (HP - FHP)

Net energy = ME - HP + FHP

RE

k = NE/ME

31

Methodological aspects of NE measurements

- NE is related to FHP values and amount and composition of energy gain → genotype, BW, sex, feeding level, diet balance (AAs), environment conditions, behavior, etc. have to be standardized for measuring NE values
- NE values measured or calculated under different conditions are not comparable
- Validation of a NE system is necessary

32

INRA Net Energy system (pig)

- Animal model: 45 kg boars
- ME intake # 2.3 MJ ME/kg $BW^{0.60}$
- Method: indirect calorimetry (+ digestibility)
- FHP = 750 kJ/kg $BW^{0.60}$
- n=61 diets
- Regression methods → Equations NE = f(…)
- Evaluated in heavier and adult pigs
- Validated: calorimetry and growth trials

33

Efficiencies of utilization of ME of nutrients (k_g, %)

Crude protein	58
Crude fat	90
Starch	82
Dietary fiber	58

- Comparable (relatively) in the growing pig and in the adult sow (at maintenance)
- No effect of BW/composition of BW gain on efficiencies
- Values confirmed in recent trials and with different methodologies

Noblet et al., 1993; 1994

34

Estimation of NE content (MJ/kg DM)

NE2 = 0.0121 DCP + 0.0350 DEE + 0.0143 Starch + 0.0119 Sugars + 0.0086 DRes (RSD = 0.25)

NE4 = 0.703 DE + 0.0066 EE + 0.0020 Starch - 0.0041 CP - 0.0041 CF (RSD = 0.18)

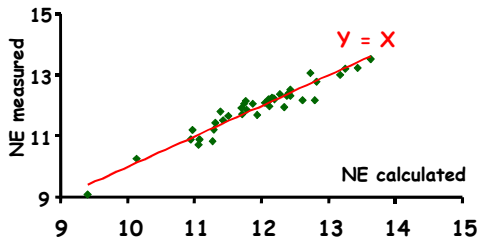
NE7 = 0.730 ME + 0.0055 EE + 0.0015 Starch - 0.0026 CP - 0.0041 CF (RSD = 0.17)

Equations
- can be used at all stages of pig production
- applicable to compound feeds and ingredients
- have been validated
- to be compared to other NE "equations"

Noblet et al., 1994

35

Validation of NE equations (n = 41)



INRA data

36

Six energy values per ingredient

- DE, ME and NE for growing pigs (+ piglets)
- DE, ME and NE for adult pigs (pregnant and lactating sows)

37

Comparison of energy systems (pig)*

	DE		ME		NE	NE/ME
Ingredients						
Fat	243	+	252	++	300	90
Corn	103	=	105	+	112	80
Pea	101	=	100	-	98	73
Wheat bran	68	=	67	-	63	71
Soybean meal	107	-	102	--	82	60

** As % of the energy value of a compound feed (wheat: 67%, soybean meal: 16%, fat: 2.5%, wheat bran: 5%, peas: 5%, …)*

INRA&AFZ feeding tables

38

Performance of growing pigs according to energy evaluation system (1)

	Growing			Finishing		
CP, %	Normal		Low	Normal		Low
Amino acids	+		++	+		++
Energy, MJ/BW gain						
DE	31.1	*	30.2	44.3	*	43.3
ME	29.9	*	29.2	42.7	*	42.0
NE	22.2		22.0	32.1		32.1

INRA data, unpublished

39

Performance of growing pigs according to energy evaluation system (2)

Fat added, %	0	1.75	3.50	5.25	Stat
Feed : gain					
MJ DE/kg	100.0	99.2	98.5	98.4	**
MJ ME/kg	100.0	99.2	98.6	98.6	**
MJ NE/kg	100.0	99.7	99.6	99.6	NS

Wu et al., 2007

40

Energy evaluation of pig feeds: conclusions (1)

- Energy digestibility: increases with BW: values at 60-70 kg are representative of the G-F period
- Energy digestibility: higher in mature than in G-F pigs => 2 energy values: adult vs G-F pigs
- The superiority of mature pigs depends on feed (botanical) origin and feed composition

41

Energy evaluation of pig feeds: conclusions (2)

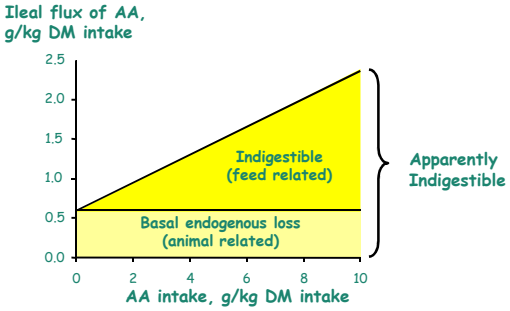
- The ME should be evaluated according to a standardized N retention
- The hierarchy between feeds is dependent on energy system: DE/ME systems (vs NE systems)
  - overestimate protein- and DF-rich feeds
  - underestimate starch- and fat-rich feeds
- A NE system is characterized by its NE prediction equation(s)

42

Protein value of pig feeds

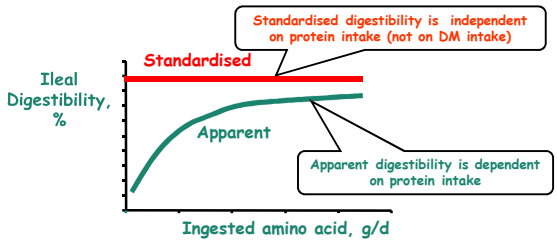
43

Partition of ileal amino acid flux in the growing pig



44

Apparent and standardised ileal digestibility of amino acids



Apparent digestibility = (AA feed - AA digesta)/AA feed

Standardised digestibility = (AA feed -(AA digesta - Basal AA loss))/ AA feed

45

Measurement of basal endogenous loss

- **Protein-free method** (data for AFZ tables)
  - no protein but fiber, energy, vitamins
  - high variability, underestimation, AA deficiency
  - more precise on short duration (7 j) and with AA blood perfusion
- **Protein diet totally digestible (casein + wheat gluten)**
  - Diet with protein source totally digestible before ileum end
  - Real basal measure ?
- **Linear regression**
  - Decreasing CP content in diets (4 diets successively)
  - Basal loss = extrapolation to linear regression to no CP content
  - Confirmation of protein-free but heavy to practice

46

Basal endogenous loss (g/kg DM)

Méthodes	Protéiprive		Caséine/ Gluten de blé		Régression		EHC		Protéiprive et perfusion d'AA
	Moy.	ET	Moy.	ET	Moy.	ET	Moy.	ET	Moy.
n	*16*		*11*		*3*		*2*		*1*
Protéines	10.53	3.07	12.60	4.02	11.96	3.27	17.15	0.41	12.70
N	1.68	0.49	2.02	0.64	1.91	0.52	2.75	0.06	2.03
NAA	1.29	0.39	1.47	0.41	1.22	0.29	2.16	0.03	1.50
NnAA	0.46	0.18	0.55	0.32	0.69	0.23	0.58	0.04	0.53
Acides aminés essentiels									
Arg	0.40	0.08	0.36	0.12	0.45	0.02	0.46	0.04	0.42
His	0.16	0.02	0.21	0.08	0.19	0.03	0.34	001	0.21
Lys	0.36	0.10	0.44	0.17	0.68	0.09	0.51	0.07	0.56
Phe	0.31	0.07	0.36	0.21	0.26	0.03	0.41	0.03	0.74
Leu	0.44	0.10	0.54	0.17	0.41	0.10	0.70	0.02	0.69
Ile	0.29	0.08	0.51	0.16	0.29	0.03	0.58	0.07	0.42
Val	0.41	009	0.74	0.37	0.41	004	0.69	0.02	0.63
Met	0.10	0.03	0.12	0.03	0.11	0.03	-	-	0.21
Thr	0.51	0.08	0.72	0.20	0.51	0.02	0.87	0.10	0.82
Trp	0.13	0.01	0.15	0.02	-	-	-	-	-

Jansmann et al., 2002

47

Standardised digestible amino acids (SID AA)

- **SID values: independent from the feed CP content**
- **SID amino acid contents of ingredients are additive**
- **SID values are supposed**
  - to be identical at all stages of pig production
  - to be little effected by technology (???; lack of infos)
- **Internationally accepted concept** (Stein et al., 2007); => most data bases with this concept => they are comparable (at least relative values)

48

Lysine content of ingredients

	Total	SID
Diet	100	100
Ingredients		
Maize	29	26
Wheat	36	33
Wheat bran	68	53
Soybean meal	340	353
AA mixture**	4580	5180

** As % of the lysine content of a diet containing wheat (67%), soybean meal (16%), fat (2.5%), wheat bran (5%), peas (5%), HCl-lysine (0.10%), methionine (0.05%), threonine (0.05%), ..*

*** 50% HCl-lysine, 25% threonine, 25% methionine*

INRA&AFZ feeding tables

49

Threonine content of ingredients

	Total	SID
Diet	100	100
Ingredients		
Maize	49	47
Wheat	52	50
Wheat bran	75	57
Soybean meal	294	304
Mixture of AA**	4015	4680

** As % of the lysine content of a diet containing wheat (67%), soybean meal (16%), fat (2.5%), wheat bran (5%), peas (5%), HCl-lysine (0.10%), methionine (0.05%), threonine (0.05%), ..*

*** 50% HCl-lysine, 25% threonine, 25% methionine*

50

Diets formulation (protein and AA)

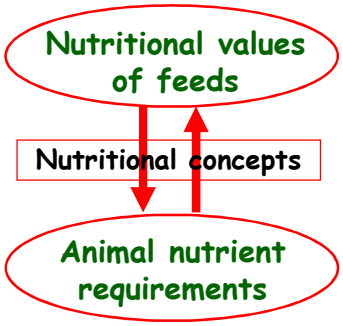
- Below maximum protein levels (/stage)
- Above minimum ratios between SID Lysine and NE (/stage)
- Above minimum ratios between SID AA and SID Lysine
  - Threonine: 65
  - Sulfur AA: 60
  - Tryptophan: 20
  - Valine: 70

51

Feeding tables and softwares

52

Nutritional system/data base



53

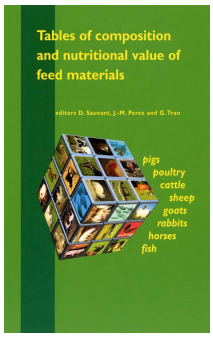
Feeding tables

Plus "hundreds" of non academic/"home made"/etc. tables

54

INRA & AFZ feeding tables

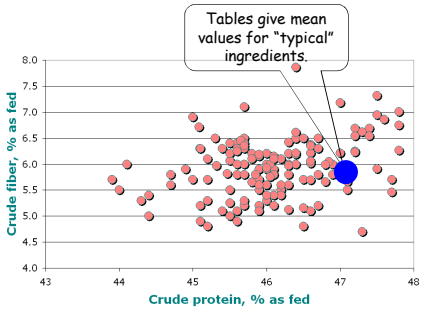
Languages: French, English, Spanish, Chinese



More info at:
http://www.zootechnie.fr/tables/index.htm

55

Feeding Tables?



Soybean meal 48

56

The EvaPig software

INRA

AJINOMOTO EUROLYSINE S.A.S.

57

Objectives of EvaPig®

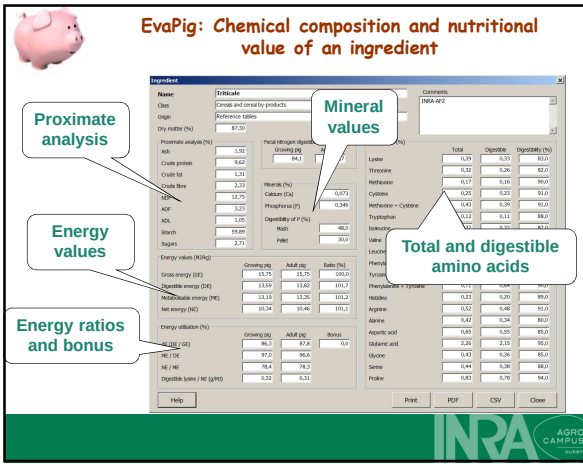
- EvaPig® : calculator of energy, amino acids and phosphorus values of ingredients and diets for pigs according to their actual composition and on bases of "INRA" concepts.
- EvaPig®: database with 120 reference ingredients (mostly derived from the INRA-AFZ Tables).
- EvaPig® : creates new ingredients and generates their nutritional value
- EvaPig®: creates and calculates nutritive values of diets
- Charts are generated (education).
- Multi-language (14)

58

59

60

EvaPig: Chemical composition and nutritional value of an ingredient



61

Calculations in Tables and Evapig

62

Ingredient creation based on a reference ingredient

- **Creating a new ingredient using a reference ingredient is the recommended method.**
- Combine the values of the reference ingredient with coefficients that are applied to the differences in chemical composition between the new ingredient and the reference ingredient (equations with generic or ingredient-specific coefficients)
- **Formula:**

YNew = YRef + a x (XNew – XRef) + b x (ZNew – ZRef) + …

where Y is the predicted value and X, Z etc. are the predictors, Ref = reference ingredient and New = new ingredient

63

Steps of energy values calculation

- GE = f(protein, fat, ash)
- Ed = f(fiber) (fiber = CF, ADF and/or NDF)
- DE = GE x Ed
- DEadult=f(DEg, Edg, ash)
- ME/DE = f(protein, DE)
- ME = DE x ME/DE
- NE/ME = f(protein, fat, starch, ME)
- NE = ME x NE/ME

Equations and coefficients on Evapig website

64

Diets creation from a list of ingredient

- **Diets are usually created in EvaPig® using a list of ingredients.**
- **The chemical and nutritional values are calculated as the weighed contributions of the ingredients, taking into account their incorporation rates and dry matter values.**

65

Ingredients and diets created using chemical composition

- New ingredients and diets can be created using only their chemical composition
  ➔all the calculations based on generic equations
- Less precise (does not take into account ingredient-specific effects such as anti-nutritional factors or the structure of cell walls)

➔ it should be used only when it is not possible to base the calculations on known ingredient values.

66

Steps of energy values calculation

- GE = f(protein, fat, ash, fiber, sugars, starch)
  - GE value can also be provided and it will be used instead of GE calculated from chemical characteristics
  - EvaPig® uses several equations to predict gross energy. The equation used depends on the available chemical values.

Equations and coefficients on Evapig website

67

Steps of energy values calculation

- GE = f(protein, fat, ash, fiber, sugars, starch)
- Ingredient Ed = f(fiber); ash should not be used
- Diet Ed = f(fiber, ash, in vitro digestible organic matter)
- DE = GE x Ed
- DEa=f(DEg, Edg, ash, protein)
- Energy lost from urine = f(protein)
- Energy lost as methane = f(ash, protein, fat, starch, sugars)
- ME = f(DE, Energy urine, Energy methane)
- NE = f(DE, protein, fat, starch, fiber)

Equations and coefficients on Evapig website

68

New perspectives in feed evaluation for pigs

69

New challenges/perspectives

- Feed and nutrient availability; impact of technology (thermo-mechanical treatments, enzymes, acidifiers, etc.)?
- Ethical and rapid, cheap, accurate, … methods for feed evaluation: in vitro, NIRS, etc.
- Non nutritional values:
  - Feed and health of pigs?
  - Feed and welfare of pigs?
  - Feed and environment protection?
  - Feed and products quality?
  - Feed and "ethics"?
  - Etc.

Dietary fiber

70

Conclusions (1)

- At least two energy values should be used for pig feeds: piglet + growing + finishing *vs* adult pig
- Hierarchy between feeds and least cost formulation results depend on energy system; NE is preferable
- The importance of a "reliable" energy system is emphasized when more non conventional ingredients (by-products, etc.) are available
- Technologies affect the energy availability: knowledge is required

71

Conclusions (2)

- Protein value should be evaluated according to SID amino acids
- SID values would be less dependent on technology, pig physiological stage, etc. than energy
- Updating nutritional values is necessary: new (by-) products, competition, etc.
- New tools are available for evaluating feeds precisely, rapidly, ethically, etc.
- New challenges: evaluation methods, non nutritional criteria for feeds, etc.

72

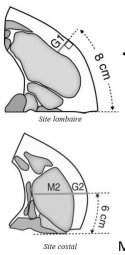
Carcass measurements

Lean meat content (1)

73

Danish Crown slaughter plant

Photo: www.eupigclass.org



In France

Measurement of the thickness of fat and muscle using the *Capter Gras Maigre* : CGM (hot carcass)

↓

CGM equation

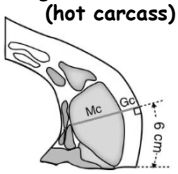
Taux de **M**uscle des **P**ièces
MP = 62,19 – 0,729 G2 (mm) + 0,144 M2 (mm)
RMSEP = 2.03

G Daumas, Ifip

Lean meat content (2)

74

Measurement of the thickness of fat and muscle using the ultra-meter (hot carcass)



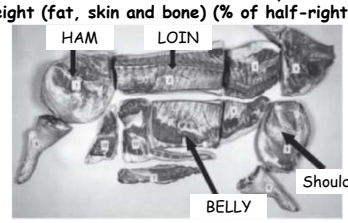
- Between 2nd and 3rd rib
- Image analysis software gives underskin (with « couenne ») fat thickness (GC, mm) and thickness of muscle longissimus dorsalis (MC, mm)

TMP = 62,68 – 0,921 Gc + 0,204 Mc

Lean meat content (3) by dissection

75

- Old method (TVM): 4 pieces dissected and muscle weight determined as the difference between piece weights and non-muscle weight (fat, skin and bone) (% of half-right cold carcasse)



- New one: Normalized dutch dissection

TMPdhn = 25,08 – 1,23 (%backfat) + 0,87 (%loin) + 0,73 (%ham)
(% of weight of half-right cold carcass)

Backfat thickness

76

- Ultrasound measurement
- Average of measurement at three positions
  - Shoulder
  - Midback
  - Loin sites

Each side of or on the mid-dorsal line

77

The empty digestive tract, kidneys, liver, heart and lungs, spleen, diaphragm, leaf fat, head, tail and feet were weighed and combined as a single compartment (VHFT). Empty BW (EBW) was calculated as the sum of blood, VHFT and hot carcass weight. The left half carcass was divided in primal cuts according to the Dutch normalized procedure (Institut Technique du Porc, 1990). The subcutaneous adipose tissue was separated from the loin (backfat, B). The loin (without backfat), shoulder, belly and ham were combined as a single compartment (C). The VHFT, B and C compartments were weighed, frozen, ground separately, minced using a 1-mm grid and homogenized. Two samples of each compartment were taken for further chemical analysis.

Chemical analyses

The DM, ash, crude protein, starch and crude fibre content in the diet and the DM, ash, lipids and crude protein content in the four body samples (blood, VHFT, B and C) were measured.

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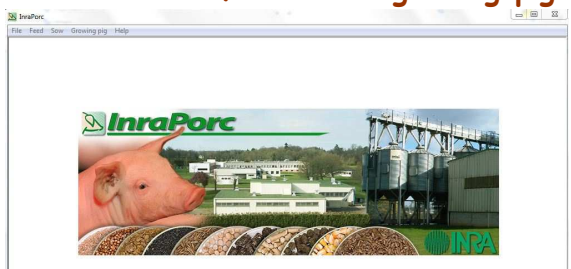
78

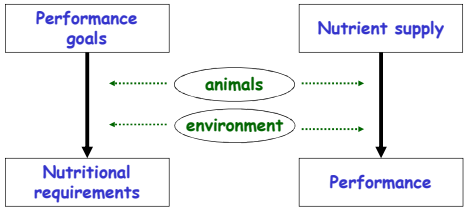
a decision support tool for the nutrition of sows and growing pigs



79

Feeding strategies

Factorial calculation **Modeling**



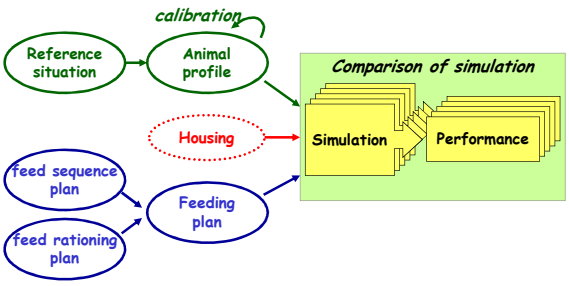
80

The objectives of InraPorc project

- **Development of a decision support tool**
  - Integrate current knowledge of energy and amino acid utilization by sows and growing pigs
    - net energy
    - digestible amino acids
  - Predict the response of the animal to nutrient supply
    - weight gain – feed efficiency – body composition
    - identify the limiting factors in the diet
  - Improve the definition of nutritional requirements
    - performance objectives
    - account for the dynamic change in requirements

81

Concepts behind the "sow" and "growing pig" simulators



82

General outline of the tool

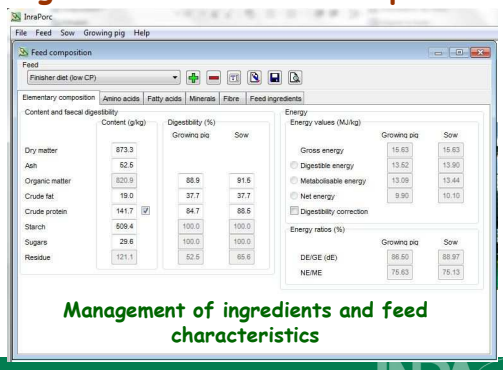
➔ **Feed**
- ➔composition of raw materials (feed ingredients)
- ➔composition of feeds

➔**Sow**
- ➔factorial calculation of requirements
- ➔simulation

➔**Growing pigs**
- ➔simulation of performance

83

Ingredients and feed composition



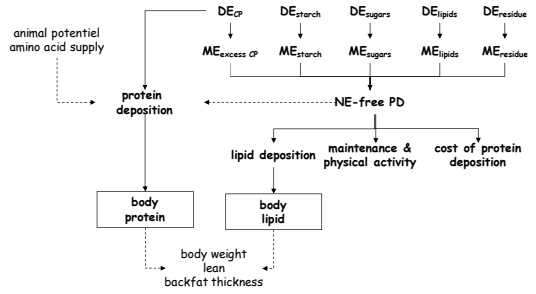
Management of ingredients and feed characteristics

84

Description of the growing pig model

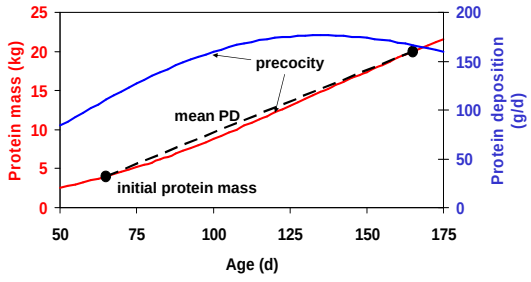
85

Repartitioning of energy



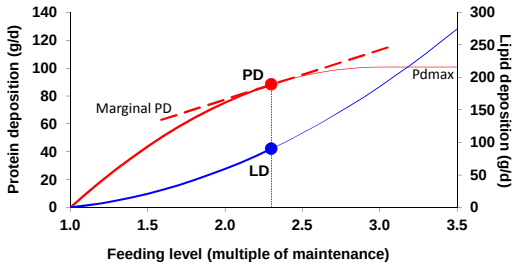
86

Potential PD is described by a Gompertz function



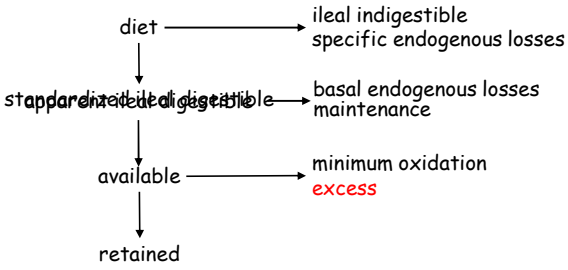
87

Response of protein (PD) and lipid (LD) deposition to energy supply



88

Amino acid utilization



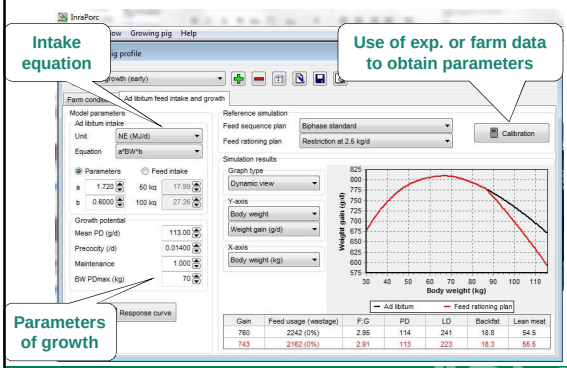
89

Amino acid utilization

	ideal protein	integuments	maintenance: minimum turnover	maintenance: basal endogenous	growth: body composition	growth: maximum efficiency
	%	mg/kgBW$^{0.75}$/d	mg/kgBW$^{0.75}$/d	g/kg DMI	%	%
Lysine	100	4.5	23.9	0.313	6.96	**72**
Methionine	30	1.0	7.0	0.087	1.88	**64**
Cystine	30	4.7	4.7	0.140	1.03	**37**
Threonine	65	3.3	13.8	0.330	3.70	**61**
Tryptophan	18	0.9	3.5	0.117	0.95	**57**
Isoleucine	60	2.5	12.4	0.257	3.46	**60**
Leucine	100	5.3	27.1	0.427	7.17	**76**
Valine	70	3.8	16.4	0.357	4.67	**71**
Phenylalanine	50	3.0	13.7	0.273	3.78	**82**
Tyrosine	45	1.9	9.0	0.223	2.86	**67**
Histidine	32	1.3	10.2	0.130	2.79	**93**
Arginine	42	0.0	0.0	0.280	6.26	**154**

90

Characterize animals



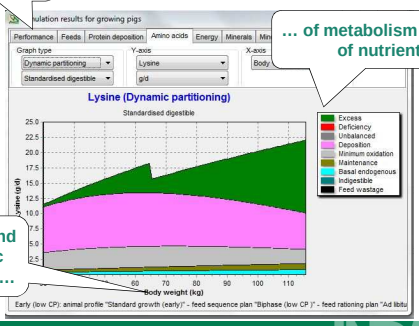
91

Simulation

Analysis of performance

... of metabolism and use of nutrients

Understand dynamic evolution…

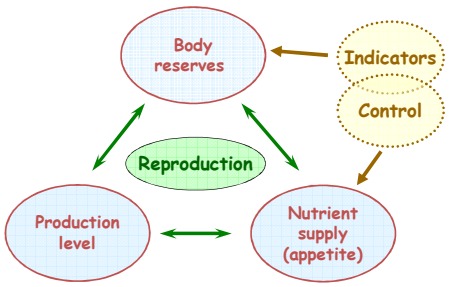


92

Description of the sow model

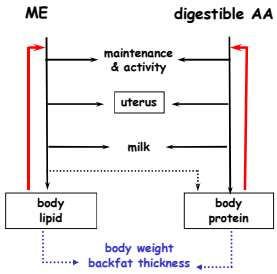
93

Feeding strategies for sows



94

General scheme of nutrient utilization



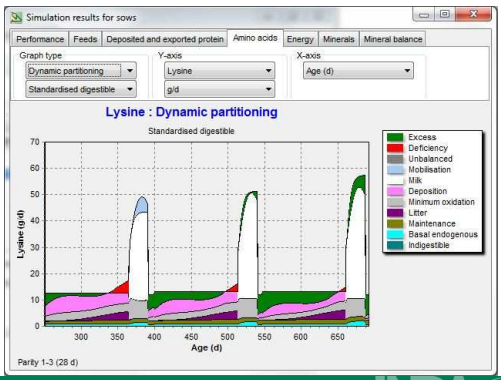
95

Factors affecting the energy utilization

- **Gestation**
  - **Maintenance:** body weight, temperature, activity
  - **Uterine growth:** litter size
  - **Body reserves:** lipid, protein repartitioning = f (stage, parity, breed)
- **Lactation**
  - **Maintenance:** body weight
  - **Milk production:** parity, stage
  - **Body reserves:** lipids, protein mobilization = f (appetite, milk production)

96

Simulation



97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InraPorc est un modèle et un outil d'analyse des performances et d'évaluation des stratégies alimentaires pour des porcs en croissance et des truies.
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98

Thanks