Recent Developments in Net Energy Research for Pigs

Jean NOBLET
INRA, UMR SENAH, Saint-Gilles, France
Jean.Noblet@rennes.inra.fr

Introduction (1)

Cost of feed > 50-60% of cost of pig meat production
Energy is the main feed cost
More and more ingredients are available + competition between animal species, with biofuels, with humans, etc.
Feed composition has an obvious impact on animals performance and economical results
Pigs (genetics, sex, BW, health, ...), environmental conditions (T, ...) and production objectives are variable
New challenges and constraints (pollution, ...)
Introduction (2)

- Nutritional values: precise hierarchy ⇒ New concepts?
- Recommendations: variable ⇒ Factorial approach + modeling
- Coherence of nutritional values and nutrient requirements
- Precise animal requirements and feed nutritional values are necessary

What new on (net) energy for swine?

Methods for evaluating energy in pig feeds
Energy utilization

Gross Energy (GE)

\[ \text{dE} \] → Fecal energy

Digestible Energy (DE)

\[ \frac{\text{ME}}{\text{DE}} \] → Urinary and gas energy

Metabolizable Energy (ME)

\[ k \] → Heat increment

Net Energy (NE)

Effect of BW on dE (1) (4 diets)

<table>
<thead>
<tr>
<th>BW, kg</th>
<th>DM intake, g/d</th>
<th>Energy digestibility, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>1250</td>
<td>82.6</td>
</tr>
<tr>
<td>49</td>
<td>1680</td>
<td>83.0</td>
</tr>
<tr>
<td>61</td>
<td>1940</td>
<td>83.6</td>
</tr>
<tr>
<td>72</td>
<td>2015</td>
<td>84.2</td>
</tr>
<tr>
<td>80</td>
<td>2060</td>
<td>84.8</td>
</tr>
<tr>
<td>90</td>
<td>2120</td>
<td>85.3</td>
</tr>
<tr>
<td>35-95</td>
<td>1845</td>
<td>83.6</td>
</tr>
</tbody>
</table>

*Fecal digestibility measurements should be carried out in 60-70 kg BW pigs (/20-100kg)*
Effect of BW on dE (2)

<table>
<thead>
<tr>
<th>BW, kg</th>
<th>45</th>
<th>100</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (7 diets)</td>
<td>83.2</td>
<td>85.5</td>
<td>86.3</td>
</tr>
<tr>
<td>Starch rich diet</td>
<td>90.6</td>
<td>91.6</td>
<td>92.0</td>
</tr>
<tr>
<td>Fiber rich diet</td>
<td>71.6</td>
<td>75.6</td>
<td>78.0</td>
</tr>
</tbody>
</table>

Effect of BW is dependent on feed characteristics

Effect of physiological stage on dE (n=77)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Growing</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW, kg</td>
<td>61</td>
<td>234</td>
</tr>
<tr>
<td>DM intake, g/d</td>
<td>1854</td>
<td>2104</td>
</tr>
<tr>
<td>dE, %</td>
<td>82.1</td>
<td>85.2</td>
</tr>
</tbody>
</table>

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

Le Goff and Noblet, 2001
Effect of physiological stage on dE

<table>
<thead>
<tr>
<th>Trial (n diets)</th>
<th>1 (14)</th>
<th>2 (77)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Growing Adult</td>
<td>Growing Adult</td>
<td></td>
</tr>
<tr>
<td>BW, kg</td>
<td>43 208</td>
<td>61 234</td>
</tr>
<tr>
<td>DM intake, g/d</td>
<td>1373 1485</td>
<td>1854 2104</td>
</tr>
<tr>
<td>dE, %</td>
<td>75.8 84.7</td>
<td>82.1 85.2</td>
</tr>
</tbody>
</table>

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

Effect of technology on dE

<table>
<thead>
<tr>
<th>Technology</th>
<th>Mash</th>
<th>Pellet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat-SBM diets (n=2)</td>
<td>88.6 *</td>
<td>89.2</td>
</tr>
<tr>
<td>Corn-SBM diets (n=3)</td>
<td>88.4 **</td>
<td>90.3</td>
</tr>
<tr>
<td>Corn (n=5)</td>
<td>87 **</td>
<td>90</td>
</tr>
<tr>
<td>Full-fat rapeseed</td>
<td>35 **</td>
<td>83</td>
</tr>
<tr>
<td>Linseed (extrusion)</td>
<td>51 **</td>
<td>84</td>
</tr>
</tbody>
</table>

Technology affects dE; it has to be considered in energy evaluation of feeds for swine.
Effect of technology on DE value of wheat DDGS

![Bar chart showing effect of technology on DE value of wheat DDGS](chart.png)

INRA data, unpublished

Effect of ash content on dE

<table>
<thead>
<tr>
<th>Minerals, %*</th>
<th>1.0</th>
<th>4.0</th>
<th>7.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash, % DM</td>
<td>4.6</td>
<td>7.2</td>
<td>9.8</td>
</tr>
<tr>
<td>dN, %</td>
<td>85.4</td>
<td>82.4</td>
<td>81.7</td>
</tr>
<tr>
<td>dE, %</td>
<td>85.5</td>
<td>83.2</td>
<td>82.4</td>
</tr>
</tbody>
</table>

* Calcium carbonate + dicalcium phosphate

Minerals level should be kept constant in diets for measuring digestibility (difference method)

INRA

J Noblet, unpublished

ASAS 2008 Energy systems

ASAS 2008 6
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 \# 0.4% of DE (related to fermented energy)

- In the adult pig:
  - \( E \) methane \# 2-3 times higher than in growing pigs

Urinary energy should be calculated; methane energy is estimated (or neglected in young pigs)

Methodological aspects of DE and ME measurements

- \( dE \) is affected by
  - BW
  - Technology
  - Ash
  - Gut health
  - Etc.

\[ \text{Conditions should be standardized} \]

- Methods: total collection, markers, in vitro, NIR, prediction equations, etc.
- ME can be estimated from DE values
Utilisation of energy

- Metabolisable energy
  - Retained energy
  - Heat production

Comparative slaughter
Calorimetry

Indirect calorimetry

$O_2, CO_2, N_2 \rightarrow O_2, CO_2, N_2$

Heat production = $f(O_2, CO_2, \ldots)$
Dynamics and components of heat production

Heat, MJ/day

Heat increment

09:00 13:00 17:00 21:00 01:00 05:00 Time, hr

Activity

Feed

Maintenance (FHP; zero activity)

Heat, MJ/day

NE measurements

Net energy = ME - Heat increment

↓

Net energy = ME - (HP - FHP)

↓

Net energy = RE + FHP

\[ k_g = \frac{\text{NE}}{\text{ME}} \]
Methodological aspects of NE measurements

- NE is related to FHP values and amount and composition of energy gain \(\Rightarrow\) 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
- INRA system: 45 kg boars; indirect calorimetry; FHP = 750 kJ/kg BW^{0.60}; n=61 diets; evaluated in heavier pigs and adult sows

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

<table>
<thead>
<tr>
<th></th>
<th>CP</th>
<th>EE</th>
<th>ST</th>
<th>NDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross energy</td>
<td>22.7</td>
<td>38.8</td>
<td>17.4</td>
<td>19.0</td>
</tr>
<tr>
<td>DE growing pig</td>
<td>22.5</td>
<td>31.7</td>
<td>17.2</td>
<td>3.2</td>
</tr>
<tr>
<td>DE adult pig</td>
<td>22.5</td>
<td>31.7</td>
<td>17.2</td>
<td>6.4</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>NDF, %</th>
<th>dE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Adult pig</td>
</tr>
<tr>
<td></td>
<td>-0.90</td>
</tr>
<tr>
<td>20</td>
<td>Growing pig</td>
</tr>
<tr>
<td></td>
<td>-0.64</td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>
Digestibility of energy in the adult pig

NDOMg: Undigestible organic matter in the growing pig
dif DE = DE adult pig – DE growing pig (MJ/kg DM)

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
Metabolic utilization of energy

- $k_g, \% = 74.7 + 0.009 \times \text{Starch} + 0.036 \times \text{EE}$
  - $0.023 \times \text{CP} - 0.026 \times \text{ADF}$
  - In "40 kg" growing boars, 130 g daily protein gain, 2.2
    - $\times$ ME, 22°C, 61 diets
  - Chemical composition: g/kg DM

- The coefficients of the equation are not affected by pig BW (Protein:Fat) and physiological stage (maintenance vs growth)

The same NE system/equation can be used at all stages of pig production

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
Estimation of NE content (MJ/kg DM)

\[
\begin{align*}
\text{NE2} &= 0.0121 \text{ DCP} + 0.0350 \text{ DEE} + 0.0143 \text{ Starch} \\
&\quad + 0.0119 \text{ Sugars} + 0.0086 \text{ DRes} \quad (\text{RSD} = 0.25) \\
\text{NE4} &= 0.703 \text{ DE} + 0.0066 \text{ EE} + 0.0020 \text{ Starch} \\
&\quad - 0.0041 \text{ CP} - 0.0041 \text{ CF} \quad (\text{RSD} = 0.18) \\
\text{NE7} &= 0.730 \text{ ME} + 0.0055 \text{ EE} + 0.0015 \text{ Starch} \\
&\quad - 0.0026 \text{ CP} - 0.0041 \text{ CF} \quad (\text{RSD} = 0.17)
\end{align*}
\]

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

Validation of NE equations (\(n = 41\))

\[Y = X\]
Dietary crude protein and energy utilization in growing pigs

<table>
<thead>
<tr>
<th></th>
<th>Diet 1</th>
<th>Diet 2</th>
<th>Diet 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP, %</td>
<td>11.7</td>
<td>22.6</td>
<td>23.1</td>
</tr>
<tr>
<td>Lysine, g/d</td>
<td>10.2</td>
<td>11.0</td>
<td>27.3</td>
</tr>
<tr>
<td>N gain, g/d</td>
<td>19.8</td>
<td>19.6</td>
<td>30.0</td>
</tr>
<tr>
<td>Heat production*</td>
<td>1.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.42&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.42&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Retained Energy*</td>
<td>1.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.13&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>*MJ/kg<sup>0.60</sup>; adjusted for the same ME intake</sup>

No effect of final use of CP on efficiency

Contribution of nutrients to energy supply (in growing pigs; % of starch)

<table>
<thead>
<tr>
<th></th>
<th>Starch</th>
<th>Fat</th>
<th>Crude protein</th>
<th>Dietary fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross energy</td>
<td>100</td>
<td>221</td>
<td>129</td>
<td>106</td>
</tr>
<tr>
<td>DE</td>
<td>100</td>
<td>174</td>
<td>123</td>
<td>3</td>
</tr>
<tr>
<td>ME</td>
<td>100</td>
<td>177</td>
<td>109</td>
<td>3</td>
</tr>
<tr>
<td>NE</td>
<td>100</td>
<td>195</td>
<td>80</td>
<td>-6</td>
</tr>
</tbody>
</table>
INRA & AFZ feeding tables

Languages: French, English, Spanish, Chinese

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

Six energy values per ingredient

- DE, ME and NE for growing pigs
  (+ piglets)
- DE, ME and NE for adult pigs (pregnant and lactating sows)
- A software will be proposed soon
Comparison of energy systems

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>DE</th>
<th>ME</th>
<th>NE</th>
<th>NE/ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>243</td>
<td>+</td>
<td>252</td>
<td>++</td>
</tr>
<tr>
<td>Corn</td>
<td>103</td>
<td>=</td>
<td>105</td>
<td>+</td>
</tr>
<tr>
<td>Wheat</td>
<td>101</td>
<td>=</td>
<td>102</td>
<td>+</td>
</tr>
<tr>
<td>Pea</td>
<td>101</td>
<td>=</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>68</td>
<td>=</td>
<td>67</td>
<td>-</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>107</td>
<td>-</td>
<td>102</td>
<td>-</td>
</tr>
</tbody>
</table>

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

Hierarchy between feeds is dependent on energy system
Comparison of NE systems
(n = 61 diets; MJ/kg DM)

\[ \text{NE\textsubscript{m}}, \text{MJ/kg DM} \]

\[ \text{CF} \]

\[ \text{Starch} \]

\[ x = 10.50 \]

\[ y = 10.12 \]

Measured NE, MJ/kg DM

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

<table>
<thead>
<tr>
<th></th>
<th>CP, %</th>
<th>Amino acids</th>
<th>Energy intakes, MJ/d*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19.0</td>
<td>+++</td>
<td></td>
</tr>
<tr>
<td>Amino acids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DE</td>
<td>38.9\textsuperscript{a}</td>
<td>&gt;&gt;</td>
<td>37.3\textsuperscript{b}</td>
</tr>
<tr>
<td>ME</td>
<td>37.1\textsuperscript{a}</td>
<td>&gt;</td>
<td>36.1\textsuperscript{b}</td>
</tr>
<tr>
<td>NE</td>
<td>27.6</td>
<td>=</td>
<td>27.5</td>
</tr>
</tbody>
</table>

*Energy intakes 30-100 kg and adjusted for the same BW gain (1080 g/day) and the same body composition at slaughter
Performance of growing pigs according to energy evaluation system (2)

<table>
<thead>
<tr>
<th>Fat addition, %</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed: gain*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MJ ME/kg</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>98</td>
</tr>
<tr>
<td>MJ NE/kg</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

*Adjusted for the same feeding level

Most energy requirements have been established on DE or ME bases with cereals based diets (kg ≥ 75%)

No interaction between stage of growth or feeding level and diet composition on kg ➔ The same equations can be used at all stages

NE requirements can be expressed as NE for growth at all stages

\[ NE = 0.75 \times ME \] or \[ 0.72 \times DE \]
Conclusions (1)

- Energy value (Ed mainly) is dependent on methods/conditions used for its determination
- 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
- The importance of a "reliable" energy system is emphasized when more non conventional ingredients (co-products, etc.) are available

Conclusions (2)

- NE system is better for a satisfactory estimate of "true" energy value of feeds and pigs performance
- Energy value of feeds for pigs is highly dependent on digestibility ➔ Improvement of knowledge
- Effects of technology, enzymes, ....?
- An accurate protein evaluation system is also necessary: "standardized" ileal digestible amino acids
Future?

- To implement available knowledge!
- To be careful in using (digestibility) methods!
- To improve knowledge and technologies on utilization of dietary fiber
- Multi-formulation: feeds vs all animal species
- Resources are limited/demand: To improve the output (meat): input (feed, energy, C, etc.) ratio in connection with social demand

Thanks:
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E-mail: Jean.Noblet@rennes.inra.fr