Preserving health status of farm animals: what is expected from feed and nutrition

- A broad topic -

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Preserving health status of farm animals: what is expected from feed and nutrition
- A focus on pig nutrition -

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Preserving health status: a major issue for livestock production

- HEALTH
  - ECONOMY: Productivity, Efficiency
  - ENVIRONMENT: Manure production, Pathogen excretion
  - ANIMAL WELFARE: Public perception
  - PUBLIC HEALTH: Food safety
Preserving health status: a major issue for livestock production

Intensive farming
- antibiotic and medication use

Alternative farming
- Environment less controlled
- Fewer medications
Feed and health are interconnected

1/ a good health status contributes to maintain feed efficiency, growth rate and to limit feed cost

Ex. Chronic respiratory disease in pig:
- feed conversion ratio + 0.3
- duration of growing phase + 7-28 d

Source: http://www.thepigsite.com/pighealth/article/33/the-costs-of-disease/

major importance of feed costs ~60% of production cost
Feed and health are interconnected

1/ a good health status contributes to maintain feed efficiency, growth rate and to limit feed cost

2/ Feed and nutrition : a significant role in health maintenance
How does feed interact with animal health?

- Ingestion
- Digestion (microflora)
- Metabolism
- Physiology

NUTRITION

Performance Health
2a/ Feed can be responsible of health disturbances

Ex. Contamination by undesirable and toxic components

- bacteria, virus, fongi
- contaminants : toxins, mycotoxins

⇒ Feed safety issue

⇒ Not in the scope of this lecture
Mycotoxins have multiple effects
Example in pigs

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>AFB1</th>
<th>OTA</th>
<th>DON</th>
<th>T-2</th>
<th>FB1</th>
<th>ZEA</th>
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<tr>
<td>Anorexia</td>
<td>+</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Growth</td>
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<td>+</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Liver damage</td>
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<td>+</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Kidney damage</td>
<td>+++</td>
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<tr>
<td>Immunomodulation</td>
<td>+++</td>
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</tbody>
</table>

Alteration of intestinal functions:
- nutrient absorption,
- pathogen translocation and inflammation...

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Mycotoxins have multiple effects

Example in pigs

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<td>+++</td>
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<tr>
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<td>+</td>
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<td>+++</td>
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<td></td>
<td>+</td>
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<td></td>
</tr>
<tr>
<td>Abortion</td>
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<td>+</td>
<td>++</td>
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</tr>
<tr>
<td>Infertility</td>
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<td></td>
<td>+++</td>
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<tr>
<td>Vulvovaginitis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>Pulmonary oedema</td>
<td></td>
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<td></td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>Immunomodulation</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td></td>
<td></td>
<td>+++</td>
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aminer: Vaccine efficacy
2b/ Feed supplies ingredients that support an optimal « functioning » of the organism

- Tissue and organ development and functioning
- Animal ability to cope with various challenges and infections

- Gut physiology including microflora
- Immune capacity and body defenses
- Muscle and bone development
- ...
Outlines

• Feeding level: impact of **restricted feeding** on health

• Feed ingredients: **role of fibers** on digestive functioning and « gut health »

• The roles of **nutrients** on animal health: the example of amino acids
Outlines

• Feeding level: impact of *restricted feeding* on health
• Feed ingredients: *role of fibers* on digestive functioning and « gut health »
• The roles of *nutrients* on animal health: the exemple of amino acids
Feeding strategies for post-weaning pigs (when removing antibiotics growth promoters)

- **Liquid feeding**
  - adapted to the immature digestive system
  - improved ADG and feed efficiency compared to dry feed
  - positive effect on intestinal villi

- **Restricted feeding**
  - less substrates for microbial fermentation
  - reduced incidence of diarrhea
  - growth retardation but possible compensatory growth (> feed efficiency)

- **Low protein diets**
  - microbial fermentation and production of toxic compounds (NH₃)
  - growth retardation but compensatory growth (crystalline amino acids)

*Kil and Stein (2010)*
The effects of restricted feeding on health has been studied for many species.

- **Weaning**
  - 50% AL
  - ↓ Diarrheas
  - ↓ fecal excretion of *E.coli*
  - ↓ Growth rate
  - No positive impact on health
  - *Ad libitum* by Pastorelli et al. 2012

- **Weaning and growing period**
  - 60-80% AL*
  - ↓ Mortality
  - ↓ Morbidity
  - *Ad libitum* by Gidenne et al. 2012

- **LPS injection**
  - 50-75% AL
  - ↓ hyperthermia
  - ↓ inflammatory response
  - *Ad libitum* by Matsuzaki et al. 2001
Effects of restricted feeding in growing pigs housed in poor sanitary conditions

Le Floc’h et al 2014

- Health was challenged for 5 weeks at the beginning of the growing phase: model of poor hygiene (adapted from Le Floc’h et al 2010)
  - Poor hygiene: no cleaning → inflammation
  - Good hygiene: cleaning and disinfection
- 2 feeding levels: Ad Libitum feeding (AL) vs Feed restricted (FR = 60% AL)
- 4 experimental treatments: 2 hygiene x 2 feeding levels (n=80)
Effects of restricted feeding in growing pigs housed in poor sanitary conditions

- Poor hygiene reduced growth rate and nutrient digestibility, and induced an inflammatory response that was not modified by feed restriction

- **No positive effect of feed restriction**
Effects of restricted feeding in growing pigs housed in poor sanitary conditions

- Poor hygiene reduced growth rate and nutrient digestibility, and induced an inflammatory response: these responses were not modified by feed restriction

  ➔ No positive effect of feed restriction

- Feed efficiency was improved in previously feed restricted pigs irrespective of hygiene conditions

- Both feed restriction and hygiene modified the profile of the faecal microbiota
Effects of restricted feeding in growing pigs housed in poor sanitary conditions

- Separation of the 4 experimental groups on the total 16S microbial communities

- Among the 18 most discriminating phylotypes: feed restriction favours bacteria that may reduce the local and systemic inflammation (Clostridium butyricum, Lactobacillus animalis, Bifidobacterium choerinum ...)

Le Floc’h et al 2014

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Effect of restricted feeding on pig co-infected with respiratory pathogens

Feed-restricted pigs: shorter hyperthermia and a positive mean weight gain over the 3 first days following H1N1 infection as compared to AL pigs (weight)

Feed restriction was applied 1 wk before H1N1 inoculation
The effects of restricted feeding on health has been studied for many species

... with contrasted effects

- Could be a relevant strategy to limit gut disorders in young animals: adaptation of digestive capacity (limits overfeeding)
- Reduced growth rate could be compensated by gain in feed efficiency
- Feed restriction should be transitory and not too drastic
Outlines

• Feeding level: impact of restricted feeding on health

• Feed ingredients: role of fibers on digestive functioning and « gut health »

• The roles of nutrients on animal health: the example of amino acids
Diversity of fibers for diverse effects

Fibers

- plant structural and non structural dietary carbohydrate
- resistant to hydrolysis by digestive enzymes
- hydrolyzed and fermented by the microorganisms

Physicochemical properties

- depend on polysaccharides
- viscosity, adsorption capacity, hydration ...

Adapted from Le Gall & Montagne 2012, Lindberg 2014
Fibers exert positive effects on digestive tract

**On gut mucosa**
- Anti inflammatory molecules
- Cell proliferation (trophic effect)
- ...

**On gut microbiota**
- Fermentation: VFA production, acidification of gut content, anti inflammatory molecules
- Proliferation: microflora diversity, exclusion of pathogenic bacteria
- ...

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Fibers favour diversity of microflora

Diversity

Postweaning days

Konstantinov et al. 2003; 2004, 2006; Lallès et al, 2004
Dietary fibers increase bacterial proliferation and fermentation

**Proliferation**

Relationship between pH and [VFA] in the colon digesta of piglets

![Graph showing microbial proliferation across different gut segments with different fiber types.](Jensen_1999)

![Graph depicting the relationship between pH and total organic acids in piglet colon digesta.](Högberg_2006)
Dietary fibers reduced fermentation of proteins

Weaning at 28 d of age
Fiber source: beet pulp/inuline/lactulose (50/7.5/20 g/kg)

**Feces characteristics (10 d postweaning)**

<table>
<thead>
<tr>
<th>Feces content</th>
<th>Diet</th>
<th>Control</th>
<th>+ fiber</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (g/kg)</td>
<td></td>
<td>331</td>
<td>300</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>NH₄ (mmol/L)</td>
<td></td>
<td>78</td>
<td>64</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>VFA (mmol/L)</td>
<td></td>
<td>118</td>
<td>120</td>
<td>ns</td>
</tr>
<tr>
<td>% acetate</td>
<td></td>
<td>65</td>
<td>66</td>
<td>ns</td>
</tr>
<tr>
<td>% propionate</td>
<td></td>
<td>18</td>
<td>18</td>
<td>ns</td>
</tr>
<tr>
<td>% butyrate</td>
<td></td>
<td>8.1</td>
<td>8.2</td>
<td>ns</td>
</tr>
<tr>
<td>Branched VFA</td>
<td></td>
<td>6.0</td>
<td>5.1</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Awati et al., 2003
Effect of dietary fibers on growth and health of weanling piglets housed in low hygiene conditions

- **Experimental design:**
  - 48 piglets weaned at 28 d of age
  - Piglets housed in poor hygiene conditions (n=24) or good hygiene conditions (n=24)
  - **Period 1:** Phase I (2 wks) control Phase I diet (highly digestible: 12% TDF) vs high fiber diet (beet pulp + soybean hulls: 17% TDF)
  - **Period 2:** Phase 2 (3 wks) Control Phase 2 diet vs high fiber diet (14 vs 31% TDF)
Effects of dietary fibers on growth and health of weanling piglets housed in low hygiene conditions

**Short term effects** of fibers after weaning
- Pig growth: digestibility and feed intake (satiety) and energy dilution
- Diarheas in poor hygiene environment

**Long term effects** of fibers after weaning
- No detrimental impact on growth
- Straight chain VFA and Branched chain VFA: « positive » effect
- Microbial diversity (feces): « positive » effect
Impact of fibers on digestive functionning and health of weaning piglet

5-6 % CF : effects on « gut health »

Palmer et Hulland, 1965
Armstrong et Cline, 1976
Bertschinger et al, 1978
Larsen, 1981
Skoeries et al, 1982
Bolduan et al, 1988
Göransson et al 1995
Aumaitre 1995
Kim et al 2005
Mateos et al 2006
Bach-Knudsen et al 2008
Wellock et al 2008

Rivera et al, 1978
Piel et al, 2005

English, 1981
Ball et Aherne, 1982
Etheridge et al, 1984
Hopwood et al, 2002
Montagne et al 2004
Montagne et al 2012
Outlines

• Feeding level: impact of restricted feeding on health

• Feed ingredients: role of fibers on digestive functioning and « gut health »

• The roles of nutrients on animal health: the exemple of amino acids
Metabolic disturbances caused by immune system activation

Hormones
- cortisol
- insulin
- IGF-I

Cytokines
- TNF-α
- IL-6
- IL-1β
- INF-γ

† protein synthesis
† protein breakdown
† protein synthesis
† energy production
proliferation activation
† feed intake

Changes in AA partitioning !!!

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AA and health

• Incorporation into specific proteins
  Mucins, immunoglobulins, APP ...

• AA are nutrients for the liver and immune cells
  • neoglucogenesis
  • cell proliferation
• AA are precursors for the synthesis of active molecules
  • cytotoxic compounds
  • antioxidant compounds
AA and health: nutritional consequences

- AA are essential for body defenses
  - AA dietary supply may contribute to support body defenses and immune capacity
- AA are less available for performance (growth ...)
  - AA dietary supply may contribute to support performance when health status is not optimum
Effect of a chronic lung inflammation on TRP metabolism

Lung inflammation induced by IV CFA* injection

**plasma TRP concentrations**
(fasted state)

- Control pair fed
- Inflammation

Days after challenge

<table>
<thead>
<tr>
<th>µM</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
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<tbody>
<tr>
<td></td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

**Inflammation** ➔ **plasma[TRP]**

**TRP disappearance from plasma**

- Catabolism
- Incorporation into TRP rich-proteins ➔ APP ➔ [Haptoglobin]

* CFA : complete Freund’s adjuvant

Melchior et al 2004
Effect of a chronic lung inflammation on TRP metabolism

Lung inflammation induced by IV CFA injection

Plasma TRP concentrations (fasted state)

**Tissue sampling**

TRP catabolism through the IDO* pathway

* IDO indoleamine 2,3 dioxygenase
TRP supply alleviates the effect of lung inflammation

Lung inflammation induced by IV CFA injection

**Plasma Trp concentrations (fasted state)**

- Inflammation/Trp +
- Control pair fed/Trp -
- Inflammation/Trp -

**Plasma haptoglobin**

- Days after challenge

TRP supply above recommendations maintains TRP plasma concentrations and limits the inflammation

Le Floc’h et al 2008
How TRP could be involved in the control of inflammation

Catabolism of TRP by immune cells

Mellor & Munn, 2003

IFN-γ → KYN → T cell proliferation → control of inflammatory response

Inflammation
How TRP could be involved in the control of inflammation

Catabolism of TRP by immune cells

Mellor & Munn, 2003

Inflammation

Dietary TRP

T cell proliferation

control of inflammatory response
How TRP could be involved in the control of inflammation

Catabolism of TRP by immune cells

Mellor & Munn, 2003

Dietary TRP

Antioxidant properties

Inflammation

control of inflammatory response
Impact of TRP dietary supply on parameters related to health

- TRP above recommendations (0.30 vs 0.18%) oxidative stress induced by diquat* injection in piglets:
  - antioxidant SOD* and GPx* in the liver and plasma MDA*
  - plasma urea
  - did not attenuate the effect of oxidative stress on growth performance

- TRP above recommendations (0.24 vs 0.74%) the impact of weaning stress:
  - salivary cortisol response
  - maintains gut morphology

- TRP supplied intragastrically reduced colitis lesions caused by DSS* in neonatal piglets
  - local inflammatory response
  - healthier pigs (less severe diarrheas)

* Diquat: an herbicide known for inducing oxidative stress; SOD and GPx are antioxidative enzymes and MDA is a biomarker of oxidative stress

* Dextran sodium sulfate

Mao et al 2014
Koopmans et al 2006
Kim et al J 2010
Growth rate of pigs in good and poor hygiene conditions: effect of Trp level

In pigs suffering from inflammation:
- ▶ Trp: no growth restoration

* Inflammation caused by low hygiene of housing

Average daily gain, g/d
10-35 kg

Le Floc’h et al 2010
Growth rate of pigs in good and poor hygiene conditions: effect of Trp level

In pigs suffering from inflammation:
- **Trp**: no growth restoration
- greater impact of low TRP supply on growth rate
  ➔ greater response of growth to additional TRP

*Inflammation caused by low hygiene of housing*
Conclusions (1)

Preserving health of farm animals: What is expected from feed and nutrition?

- strategies for health preservation with less medication
- strategies for limiting the consequences of poor health status on performance
Conclusions (2)

From a research perspective

✓ The interactions between feed and health are numerous, diverse and complex

✓ New knowledge are still necessary
  ➢ Role of digestive microbiota
  ➢ Knowledge on nutrient functions beyond performance
  ➢ ...

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Conclusions (2)

From a research perspective

The next step:
- physiologic response
- changes in the microflora profile
- gene expression ...

Animal health: an integrated response
Conclusions (3)

From on-farm use perspective

☑ Some limitations are still to overcome

☑ When feed formulation and feeding practices could be adapted to preserve both health and performance
  ➢ in a preventive way ➔ identification of sub limiting nutrients
  ➢ in a curative way ➔ problem of low feed intake
  ➢ to support compensatory performance
Conclusions (3)

From on-farm use perspective

✓ **How** feed formulation and feeding practices could be adapted to preserve both health and performance
  ➢ group of individuals (critical phase) vs individual in a group
Conclusions (3)

From on-farm use perspective

✓ What could be expected from Precision Livestock Farming:

- the challenge of (early) detection of health disturbances: *cough and lameness detection* (Berkmans 2014), *changes in feeding behavior* (Maselyne et al 2015), *drinking behavior* (Cornoué et al 2013)

- Feed the group or the individual through precision feeding (Andretta et al 2014)
Conclusions (3)

From on-farm use perspective

✓ Feed should be associated to other management strategies
What is ongoing? An example

An European project dedicated to **production diseases**\* in **intensive pig and poultry production systems**

**Leader**: University of Newcastle (I Kyriazakis)

22 partners - 2014-2018

Production diseases\* : multifactorial diseases in which genetics, environment (housing, nutrition, management) and pathogenic challenge show complex interactions

- To develop our **understanding** of the underlying physiological and metabolic mechanisms in interaction with the genotype (bone health, inflammatory response, digestive disorders) and housing conditions (sows)
- To test **nutritional strategies** to overcome the impact of these diseases
Many thanks to my colleagues:
Ludovic Brossard
Alexandra Chatelet
Florence Garcia-Launay
Lucile Montagne
Isabelle Oswald

Contact: nathalie.lefloch@rennes.inra.fr

http://www6.rennes.inra.fr/pegase_eng/

Any questions?