Blood products as sustainable ingredients in livestock nutrition: protein source and alternative to antibiotics

*Keynote Lecture*

*dr. Isabelle Kalmar, DVM, MSc LAS, PhD*
Veterinary R&D, Veos group, BE
The Concept of Sustainable Livestock Production

- widespread concept
- covering a broad array of issues that vary in: urgency, severity, uncertainty of consequences, temporal and spatial dimensions
The Concept of Sustainable Livestock Production

- Sustainability is defined by a multitude of elusive descriptions literally: “the capability of maintaining something in existence”

<table>
<thead>
<tr>
<th>&quot;sustainability&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is meeting the needs of the present generation without compromising the ability of future generations to meet their own needs (1987, WCED)</td>
</tr>
</tbody>
</table>

> 100 definitions by the mid-1990’s (definitional chaos)

something that improves the quality of human life within the carrying capacity of the supporting eco-systems (Milne et al., 2006)

<table>
<thead>
<tr>
<th>“unsustainable” implies a direct or indirect potential to impede the ecosystem functions that support human life, human health and species viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(after Marshall and Toffel, 2005)</td>
</tr>
</tbody>
</table>
The 4 or 3 levels of issues that are considered in the understanding of the term sustainability:

1. **Endanger survival of humans**
2. **Reduce basic health indicators**
3. **Cause species extinction** or violate human rights
4. **Inconsistent with other values**

(after Marshall and Toffel, 2005)
Sustainable Production One Health Concept

- Inextricable Link
  - animal health
  - animal welfare
  - public health
  - environmental health

Strives to a balance in
- economic goals
- social goals
- ecologic goals
⇒ on the long run
Feed-related variables of sustainable livestock production

**INPUT**

FEED
- GHG-emission
- Deforestation
- Depletion
...

**UTILISATION**

optimize efficiency

**OUTPUT**

Productivity
- Welfare
N-emission
- P-emission

Min Up-stream Eco footprint
- choice of ingredients (type & source)
- feed amount

Min Down-stream
- balanced nutrients
- bio-availability
Feed-related variables of sustainable livestock production

**INPUT**
- FEED
  - GHG-emission
  - Deforestation
  - Depletion
- Antibiotics Use

**UTILISATION**
- Support Gut Health
- Optimize efficiency

**OUTPUT**
- Productivity
- Welfare
- N-emission
- P-emission
- Antibiotics-R

Min Up-stream Eco footprint
- choice of ingredients (type & source)
- feed amount

Min Down-stream
- balanced nutrients
- bio-availability
1. Sourcing & Production of ingredients
   ⇔ Sustainability of Up-stream actions

2. Used as feed ingredients
   ⇔ Nutrient Utilisation \((\text{productivity})\)
   ⇔ Gut Health \((\text{animal health/welfare, antibiotics use, productivity})\)

3. Sustainability of down-stream effects
   ⇔ N-emission
   ⇔ P-emission
   ⇔ Antibiotics resistance

Min Input - Max Productivity & Welfare - Min Emission \((P, N, \text{AB-R})\)
Sustainability of blood products

1. Sourcing & Production of ingredients

⇒ Sustainability of Up-stream actions

1. Blood collected at slaughterhouses (anti-coagulant added, refrigerated)
2. Transported
3. Centrifuged → Hb / Plasma
4. Dried

Source: EU animal by-products

EU labor laws
⇒ guarantees on human rights aspects

EU animal welfare and production laws
⇒ guarantees on animal welfare aspects (production and slaughter practices)
⇒ guarantees on environmental issues
Sustainability of ingredients - Type & Source

Soybean meal used to be a by-product in the production of soy oil for human consumption.

**Ingredient**
Soybean meal

**Type**
not purpose-grown until demands outgrew availability

**Source**
vary in sustainability
Sustainability of ingredients - Type & Source

Fish meal used to be a by-product but demand rose above availability ⇒ sustainability ↓

Ingredient
Soybean meal

Type
not purpose-grown until demands outgrew availability

Source
varies in sustainability
1. Sourcing & Production of ingredients

⇒ Sustainability of Up-stream actions

1. Blood collected at slaughterhouses (anti-coagulant added, refrigerated)
2. Transported
3. Centrifuged → Hb / Plasma
4. Dried

Source: EU animal by-products

EU labor laws
⇒ guarantees on human rights aspects

EU animal welfare and production laws
⇒ guarantees on animal welfare aspects (production and slaughter practices)
⇒ guarantees on environmental issues

Type: Not purpose-grown
Not purpose-bred

Exception
“Designer-pigs”
(cfr Hyper-immune eggs)

⇒ Cat-3 EGG products
1. **Sourcing & Production of ingredients**

   ⇔ **Sustainability of Up-stream actions**

   1. Blood collected at slaughterhouses (anti-coagulant added, refrigerated)
   2. Transported
   3. Centrifuged → Hb / Plasma
   4. Dried

**Source & Processing :** C-Footprint

**Up-stream**

→ Allocation based on economic value
  1. Animal husbandry
  2. Slaughtering process

**Down-stream**

→ Transport of blood (diesel)
→ Processing

**Type: Not purpose-grown**
Not purpose-bred

**Exception**
“Designer-pigs” (cfr Hyper-immune eggs)

⇔ Cat-3 EGG products
The sum of all greenhouse gas emissions in the production chain:

- **Animal Production**
  - Feed, transport, manure management

- **Slaughter**
  - Electricity, gas

- **Transport**
  - Diesel

- **Wastewater Management**
  - Electricity

- **Centrifugation**
  - Electricity

- **Spray-Drying**
  - Electricity, gas

Partly allocated* to blood (meat > blood; plasma > Hb)

* Determined by value & mass

Allocated to blood (plasma > Hb)

Specific Allocation Plasma, Hb
The sum of all greenhouse gas emissions in the production chain.

**Spray-dried Hb (porcine)**
870 kg CO₂ eq. / ton

**Spray-dried plasma (porcine)**
3200 kg CO₂ eq. / ton

Carbon footprint of spray-dried Hb (left) and plasma (right) (Ponsioen and Blonk, 2011)
The sum of all greenhouse gas emissions in the production chain

- **Spray-dried Hb (porcine)**: 870 kg CO₂ eq. / ton
  - Protein source in aqua/mink feed
  - Alternative for fish meal

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>C-footprint (kg CO₂/kg)</th>
<th>C-footprint (kg CO₂/kg CP)</th>
<th>landuse change (kg CO₂/kg CP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb powder (92% CP)</td>
<td>0.87</td>
<td>0.95</td>
<td>0.13</td>
</tr>
<tr>
<td>Fish meal (64% CP)</td>
<td>1.1 – 2.3</td>
<td>1.7 – 3.6</td>
<td>0</td>
</tr>
</tbody>
</table>

(Ponsioen and Blonk, 2011)

Carbon footprint per kg protein is 44% to 74% lower in dried Hb compared to fish meal
The sum of all greenhouse gas emissions in the production chain

Spray-dried plasma (porcine)
3200 kg CO₂ eq. / ton

Piglet feed (poultry feed)
- Protein source
- Gut health (bio-active ingredient)

(Ponsioen and Blonk, 2011)
Sustainability of blood products

1. Sourcing & Production of ingredients
   - Sustainability of Up-stream actions

2. Used as feed ingredients
   - Nutrient Utilisation (productivity)
   - Gut Health (animal health/welfare, antibiotics use, productivity)

3. Sustainability of down-stream effects
   - N-emission
   - P-emission
   - Antibiotics resistance

Min Input - Max Productivity & Welfare - Min Emission (P, N, AB-R)
# Sustainability of Blood Products

<table>
<thead>
<tr>
<th>Protein Source</th>
<th>Utilisation</th>
<th>Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>ingredient</td>
<td>bioavailability</td>
<td>N-emission</td>
</tr>
<tr>
<td></td>
<td>anab/katab</td>
<td>P-emission</td>
</tr>
</tbody>
</table>

## Vegetal - Animal Protein Sources

- Amino acid profile: diet ↔ requirements
- Bioavailable AA-profile
- Factors that “come-along” with the protein
  - ANF’s
  - Phosphorous (phytate-P)
  - Bio-security issues
## Sustainability of blood products - AA profile

### 2. Nutrient Utilisation

Balancing amino acid profile = combining complementary ingredients

#### NRC requirements (ad libitum fed, 90% DM)

<table>
<thead>
<tr>
<th>%CP</th>
<th>Pig 3-5 kg</th>
<th>Pig 5-10 kg</th>
<th>wheat</th>
<th>corn</th>
<th>Hb</th>
<th>SDPP</th>
<th>whole egg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arg</td>
<td>2.3</td>
<td>2.3</td>
<td>5.0</td>
<td>4.9</td>
<td>3.8</td>
<td>5.7</td>
<td>6.6</td>
</tr>
<tr>
<td>His</td>
<td>1.8</td>
<td>1.8</td>
<td>2.4</td>
<td>3.0</td>
<td>6.8</td>
<td>2.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Ilo</td>
<td>3.2</td>
<td>3.1</td>
<td>3.8</td>
<td>3.7</td>
<td>0.6</td>
<td>3.4</td>
<td>5.2</td>
</tr>
<tr>
<td>Leu</td>
<td>5.8</td>
<td>5.6</td>
<td>7.2</td>
<td>13.0</td>
<td>13.3</td>
<td>9.6</td>
<td>9.1</td>
</tr>
<tr>
<td>Lys</td>
<td><strong>5.8</strong></td>
<td><strong>5.7</strong></td>
<td><strong>3.0</strong></td>
<td><strong>3.2</strong></td>
<td><strong>9.2</strong></td>
<td><strong>8.1</strong></td>
<td><strong>7.6</strong></td>
</tr>
<tr>
<td>Met</td>
<td>1.5</td>
<td>1.5</td>
<td>1.8</td>
<td>2.2</td>
<td>0.7</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Met + cys</td>
<td>3.3</td>
<td>3.2</td>
<td></td>
<td></td>
<td>1.6</td>
<td>4.4</td>
<td>6.6</td>
</tr>
<tr>
<td>Phe</td>
<td>3.5</td>
<td>3.4</td>
<td>5.0</td>
<td>5.1</td>
<td>7.0</td>
<td>5.7</td>
<td>5.2</td>
</tr>
<tr>
<td>Phe + tyr</td>
<td>5.4</td>
<td>5.3</td>
<td></td>
<td></td>
<td>9.4</td>
<td>10.7</td>
<td>9.9</td>
</tr>
<tr>
<td>Thr</td>
<td>3.8</td>
<td>3.6</td>
<td>3.2</td>
<td>3.7</td>
<td>4.0</td>
<td>6.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Try</td>
<td>1.0</td>
<td>1.0</td>
<td>1.4</td>
<td>0.8</td>
<td>1.5</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Val</td>
<td>4.0</td>
<td>3.9</td>
<td>4.7</td>
<td>4.9</td>
<td>9.1</td>
<td>6.0</td>
<td>6.3</td>
</tr>
</tbody>
</table>

1st limiting AA: Lys  
2nd limiting AA: Thr

Met
2. Nutrient Utilisation

Balancing amino acid profile = Balancing bio-available amino acids
Minimizing N and P emission

National Swine Nutrition guide (US Pork COE, 2010)

<table>
<thead>
<tr>
<th></th>
<th>CP%</th>
<th>Lys%</th>
<th>SID%</th>
<th>Met%</th>
<th>SID%</th>
<th>Lys&lt;sub&gt;SID&lt;/sub&gt;%</th>
<th>P%</th>
<th>P&lt;sub&gt;ad&lt;/sub&gt;%</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDPP</td>
<td>78.0</td>
<td>6.84</td>
<td>91</td>
<td>0.75</td>
<td>92</td>
<td>6.2</td>
<td>1.48(80)</td>
<td></td>
</tr>
<tr>
<td>Egg (dried)</td>
<td>47.0</td>
<td>3.09</td>
<td>81</td>
<td>1.48</td>
<td>90</td>
<td>2.5</td>
<td>0.67 (&lt;50)</td>
<td></td>
</tr>
<tr>
<td>Fish meal</td>
<td>62.9</td>
<td>4.81</td>
<td>95</td>
<td>1.77</td>
<td>94</td>
<td>4.6</td>
<td>3.04 (77)</td>
<td></td>
</tr>
<tr>
<td>(MBM)</td>
<td>(52.8)</td>
<td>(2.76)</td>
<td>(80)</td>
<td>(0.72)</td>
<td>(83)</td>
<td>(2.2)</td>
<td>(4.63; 75)</td>
<td></td>
</tr>
<tr>
<td>SBM</td>
<td>44.0</td>
<td>2.83</td>
<td>89</td>
<td>0.61</td>
<td>91</td>
<td>2.5</td>
<td>0.65 (20)</td>
<td></td>
</tr>
<tr>
<td>SBPC</td>
<td>64.0</td>
<td>4.20</td>
<td>95</td>
<td>0.90</td>
<td>94</td>
<td>4.0</td>
<td>0.81 (&lt;33)</td>
<td></td>
</tr>
<tr>
<td>Wheat bran</td>
<td>15.7</td>
<td>0.64</td>
<td>71</td>
<td>0.25</td>
<td>79</td>
<td>&lt; 0.5</td>
<td>1.20 (50*)</td>
<td></td>
</tr>
</tbody>
</table>

CVB, 2004

P = 0.65; P<sub>ad</sub> = 39
P = 2.56; P<sub>ad</sub> = 77
## 2. Nutrient Utilisation

Balancing amino acid profile = Balancing bio-available amino acids
Minimizing N and P emission

National Swine Nutrition guide (US Pork COE, 2010)

<table>
<thead>
<tr>
<th></th>
<th>CP (%)</th>
<th>%Lys</th>
<th>%SID</th>
<th>%Met</th>
<th>%SID</th>
<th>Lys&lt;sub&gt;SID&lt;/sub&gt; (%)</th>
<th>P-em. (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDPP</td>
<td>78.0</td>
<td>6.84</td>
<td>91</td>
<td>0.75</td>
<td>92</td>
<td>6.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Egg</td>
<td>47.0</td>
<td>3.09</td>
<td>81</td>
<td>1.48</td>
<td>90</td>
<td>2.5</td>
<td>&gt; 3.3</td>
</tr>
<tr>
<td>Fish meal</td>
<td>62.9</td>
<td>4.81</td>
<td>95</td>
<td>1.77</td>
<td>94</td>
<td>4.6</td>
<td>7.0</td>
</tr>
<tr>
<td>(MBM)</td>
<td>(52.8)</td>
<td>(2.76)</td>
<td>(80)</td>
<td>(0.72)</td>
<td>(83)</td>
<td>(2.2)</td>
<td>(11.6)</td>
</tr>
<tr>
<td>SBM</td>
<td>44.0</td>
<td>2.83</td>
<td>89</td>
<td>0.61</td>
<td>91</td>
<td>2.5</td>
<td>5.2</td>
</tr>
<tr>
<td>SBPC</td>
<td>64.0</td>
<td>4.20</td>
<td>95</td>
<td>0.90</td>
<td>94</td>
<td>4.0</td>
<td>&gt; 5.4</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>15.7</td>
<td>0.64</td>
<td>71</td>
<td>0.25</td>
<td>79</td>
<td>&lt; 0.5</td>
<td>6.0*</td>
</tr>
</tbody>
</table>

CVB, 2004

P-emission = 4.0
P-emission = 5.9
2. Nutrient Utilisation

Balancing amino acid profile = Balancing bio-available amino acids
Minimizing N and P emission

National Swine Nutrition guide (US Pork COE, 2010)

<table>
<thead>
<tr>
<th></th>
<th>CP (%)</th>
<th>%Lys</th>
<th>%SID</th>
<th>%Met</th>
<th>%SID</th>
<th>Lys_{SID} (%)</th>
<th>aD P / P-em. (mg/g Lys_{SID})</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDPP</td>
<td>78.0</td>
<td>6.84</td>
<td>91</td>
<td>0.75</td>
<td>92</td>
<td>6.2</td>
<td>190 / 48</td>
</tr>
<tr>
<td>Egg</td>
<td>47.0</td>
<td>3.09</td>
<td>81</td>
<td>1.48</td>
<td>90</td>
<td>2.5</td>
<td>&lt;136 / &gt;132</td>
</tr>
<tr>
<td>Fish meal</td>
<td>62.9</td>
<td>4.81</td>
<td>95</td>
<td>1.77</td>
<td>94</td>
<td>4.5</td>
<td>518 / 158</td>
</tr>
<tr>
<td>(MBM)</td>
<td>(52.8)</td>
<td>(2.76)</td>
<td>(80)</td>
<td>(0.72)</td>
<td>(83)</td>
<td>(2.2)</td>
<td>(1577 / 527)</td>
</tr>
<tr>
<td>SBM</td>
<td>44.0</td>
<td>2.83</td>
<td>89</td>
<td>0.61</td>
<td>91</td>
<td>2.5</td>
<td>52 / 208</td>
</tr>
<tr>
<td>SBPC</td>
<td>64.0</td>
<td>4.20</td>
<td>95</td>
<td>0.90</td>
<td>94</td>
<td>4.0</td>
<td>&lt;67 / &gt;135</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>15.7</td>
<td>0.64</td>
<td>71</td>
<td>0.25</td>
<td>79</td>
<td>&lt;0.5</td>
<td>1200 / 1200</td>
</tr>
</tbody>
</table>
### Sustainability of blood products - AA profile

#### 2. Nutrient Utilisation

Balancing amino acid profile = Balancing bio-available amino acids
Minimizing N and P emission

<table>
<thead>
<tr>
<th>National Swine Nutrition guide (US Pork COE, 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDPP</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Depends on the source: e.g. US vs EU**

- **Different anti-coagulants used** (US phosphate-based; EU e.g. Na-citrate)
- **EU regulations for waste water management**
  (e.g. 2 ppm P, 15 ppm N)
- **US Pork COE**: $1.48\% \text{P}_{\text{tot}}$ / **EU-SDPP**: $< 0.2\% \text{P}_{\text{tot}}$ (if citrate is used)
- $\downarrow$ Bioavailable P and $\downarrow$ Unavailable P in SDPP if citrate is used
1. Sourcing & Production of ingredients
   - Sustainability of Up-stream actions

2. Used as feed ingredients
   - Nutrient Utilisation (productivity)
   - Gut Health (animal health/welfare, antibiotics use, productivity)

3. Sustainability of down-stream effects
   - N-emission
   - P-emission
   - Antibiotics resistance

Min Input - Max Productivity & Welfare - Min Emission (P, N, AB-R)
3. Improving Gut Health

รูปแบบ→ ▲ productivity and animal welfare(30,342),(390,402)

▲ need for antibiotics and antibiotics-resistance

**AB are over-used** → Regulations on AB-reduction are needed

But: deprivation of AB compromises productivity and welfare

Clinical disease → ▼ Animal Welfare; ▼ productivity

Sub-clinical disease → ▼ productivity

<table>
<thead>
<tr>
<th>Therapeutic AB: Yes</th>
<th>Prophylactic AB: No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth-promoting AB: No</td>
<td></td>
</tr>
</tbody>
</table>

**Need for sustainable alternatives**

*e.g.* Reducing infection pressure (on-farm biosecurity)

*e.g.* Improving gut health (bio-active ingredients)
3. Improving Gut Health

- ↑ productivity and animal welfare
- ↓ need for antibiotics and antibiotics-resistance

**Plasma**

- animal-based, sustainable protein source (dig Lys ↑)
- low content of ANF (e.g. no phytate)

- bio-active glycoproteins
  - IgG (substitute for sIgA from sow milk)
    - offers passive mucosal immunity to the gut
  - Growth factors (substitute for milk-borne GF)
    - promotes maturation and integrity of the intestinal lining
  - Non-Ig “binders” (e.g. lectins)

**Use:** Piglet feed (milk replacers, creep feed, post-weaning diets)

[ Poultry feed (productivity ↑; necrotic enteritis ↓) ]
3. Improving Gut Health: plasma

**In Literature**

- Improves (early) post-weaning performance of piglets
- Reduces clinical disease / diarrhea in challenge trials
- Effects on ADFI, ADG, G:F are more pronounced in challenge trials
- IgG and other glycoproteins diminish pathogen adhesion
- Improves intestinal barrier (e.g. tight junctions)
- Can increase brush-border enzyme activity / villus height
- Reduces immune activation (influx immune cells, ...)

**In Practice**

- **↑ ADFI**
- Beneficial amino acid profile
- Highly digestible protein source

**Most importantly, feed intake ↑**
Dietary IgG improves gut health

1. Ingestion

Oral infection

2. Virus replication
   a. Attachment
   b. Entry
   c. Replication
   d. Spread
   e. Egress

3. Fecal shedding

Virus receptor

Enterocytes

Epithelial lining of the gut

Syncytium (plaque)

Cell culture

e.g. Vero cells

Dietary IgG improves gut health

E.g. upon viral challenge...

Veos ©
SDPP provides mucosal immunity
dietary IgG replaces maternal sIgA

1. ingestion

2. virus replication
   a. attachment
   b. entry
   c. replication
   d. spread
   e. egress

Oral infection

intestinal lumen

Virus receptor

Enterocytes

Epithelial lining of the gut

No attachment

e.g. Vero cells

Cell culture

Dietary IgG improves gut health

SDPP provides mucosal immunity
dietary IgG replaces maternal sIgA

Veos ©

Dietary IgG improves gut health

SDPP provides mucosal immunity
dietary IgG replaces maternal sIgA

Veos ©

Dietary IgG improves gut health

SDPP provides mucosal immunity
dietary IgG replaces maternal sIgA
PIGLET
- separation from the sow
- moving
- mixing litters
- new environment
- dry feed

PIGLET’s INTESTINE
- withdrawal milk-borne GF
- withdrawal maternal sIgA (gut mucosal immunity)
- not adapted to the feed

Changes in Intestinal Mucosa
- Impaired Functionality (absorptive and digestive capacity ↓)
- Impaired Integrity (vulnerability ↑)

ANOREXIA

e.g. use of SDPP in post-weaning diets
Multi-factorial etiology

- Post-weaning anorexia
- Impaired digestion & absorption
- Increased vulnerability to pathogens
  - loss of intestinal integrity
  - withdrawal of maternal sIgA
  - availability of undigested food
- Infection pressure

Concerns
- Weight dip
- Diarrhea
- Mortality

Solutions (targets: environment, piglets, feed or drinking water)

- Hygiene
- Cleaning & Disinfection
- All-in All-out
- Antibiotics
  - Palatability pre-starter
- SDPP
- Organic Acids
- Zinc Oxide
- “Acceptance”
- Weaning age
Conclusion: Blood products as sustainable ingredients

1. Sourcing & Production of ingredients
   - Sustainability of Up-stream actions

2. Used as feed ingredients
   - Nutrient Utilisation (productivity)
   - Gut Health (animal health/welfare, antibiotics use, productivity)

3. Sustainability of down-stream effects
   - N-emission
   - P-emission
   - Antibiotics resistance

Min Input - Max Productivity & Welfare - Min Emission (P, N, AB-R)
Blood products as sustainable ingredients in livestock nutrition: protein source and alternative to antibiotics