Impact of technological treatment of feed ingredients on feed efficiency in farm animals

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Summary

- Competition for ingredients → increase in use of by-products, of which quality is affected by processing → more attention for nutritional value required and rewarded in feed efficiency

- Present feed evaluation systems do not adequately include effects of processing and need to be improved at this point (e.g. for LYS)

- Research and implementation of feed processing in the compound feed industry should focus more on underlying mechanisms and consequences for optimal nutrient utilisation
Reasons to focus on feed efficiency

- Optimal use of limited resources to meet the demands of the increasing world population
- Competition between feed, food and fuel/green chemicals
  - Use of byproducts in animal feed
  - Changes in nutrient content of byproducts
  - Large influence of production/biorefinery processes
- Environmental consequences
- Cost efficiency of animal production at farm level
Variation in feed costs of GF pigs (118 kg)
(Agrovision 2010)

Bars represent 20% of pig farms
Effect of processing on SBM and RSM diets
(Hulshof et al., 2013)

SBM and pSBM

RSM and pRSM
Effect of processing on gain:feed ratio

- Processing affected feed utilisation

<table>
<thead>
<tr>
<th></th>
<th>SBM diet</th>
<th>pSBM diet</th>
<th>RSM diet</th>
<th>pRSM diet</th>
<th>SEM</th>
<th>P-value processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain:feed</td>
<td>0.52</td>
<td>0.42</td>
<td>0.46</td>
<td>0.39</td>
<td>0.030</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Related to decreased content and digestibility of amino acids
Processing of feed ingredients (1)

- To obtain primary products for human consumption, feed ingredient as residue
  - Oil seed meal: SBM, RSM, SSM
  - Cereal by-products: bran, middlings, gluten meal (D)DGS
- Number of processes involved, in general optimised for primary product
- Additionally: decrease of anti-nutritional factors, e.g. TIA, glucosinolates, etc.
Oilseeds crushing

1. Seeds/Beans
2. Cleaning/Drying
3. Sorting/Dehulling
4. Heating/Pressing
5. Solvent Extraction
   - Wet cake
     - Desolvent Toasting
       - Drying Cooling
       - Meals
   - Miscella
     - Removing solvent by distillation
       - Extracted Crude Oil
       - Pressed Crude Oil
       - to refining
     - Filtration
     - Degumming
Rapeseed biorefinery

Diagram:
- Industrial defatted rapeseed meal
  - Hydro-alcoholic extraction
    - Centrifugation
    - 4 times
  - Pre-extracted meal
    - Basic extraction
      - Centrifugation
      - Protein extract
        - Adjustment at pH 4.5
          - Centrifugation
    - Soluble extract
      - Residual meal
  - Soluble proteins
    - Dialysis
      - Freeze-drying
      - Albumins
  - Isoelectric precipitated proteins
    - Dialysis
      - Freeze-drying
      - Globulins (more or less denatured)
## Processing of rapeseed (Li et al., 2002)

<table>
<thead>
<tr>
<th></th>
<th>Prepressed RS Meal</th>
<th>High T pressed RS cake</th>
<th>Low T pressed RS cake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cfat</td>
<td>32</td>
<td>62</td>
<td>100</td>
</tr>
<tr>
<td>CP</td>
<td>389</td>
<td>409</td>
<td>361</td>
</tr>
<tr>
<td>Lys</td>
<td>23.8</td>
<td>17.9</td>
<td>21.0</td>
</tr>
<tr>
<td>Ileal digestibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>55.1</td>
<td>54.0</td>
<td>65.4</td>
</tr>
<tr>
<td>Lys</td>
<td>62.4</td>
<td>40.6</td>
<td>69.7</td>
</tr>
</tbody>
</table>

Extraction at 115/65°C, pressing at 130°C or 80°C, respectively

- Overall relatively low ileal digestibility
- Differences due to processing and variety
### Nutrients in rape seed products, g/kg DM (Kracht et al., 2002)

<table>
<thead>
<tr>
<th></th>
<th>RS</th>
<th>RSM</th>
<th>RSM dehulled</th>
<th>RScake</th>
<th>RScake dehulled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cfat</td>
<td>495</td>
<td>21</td>
<td>21</td>
<td>120</td>
<td>128</td>
</tr>
<tr>
<td>CP</td>
<td>190</td>
<td>396</td>
<td>424</td>
<td>321</td>
<td>363</td>
</tr>
<tr>
<td>CF</td>
<td>65</td>
<td>117</td>
<td>72</td>
<td>102</td>
<td>61</td>
</tr>
<tr>
<td>Lys</td>
<td>10.5</td>
<td>19.0</td>
<td>22.0</td>
<td>18.6</td>
<td>20.3</td>
</tr>
</tbody>
</table>

**Digestibility**

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OM piglets</td>
<td>68</td>
<td>78</td>
<td>59</td>
<td>74</td>
</tr>
<tr>
<td>OM GF-pigs</td>
<td>69</td>
<td>79</td>
<td>74</td>
<td>84</td>
</tr>
<tr>
<td>AID CP</td>
<td>75</td>
<td>78</td>
<td>68</td>
<td>74</td>
</tr>
<tr>
<td>AID Lys</td>
<td>81.0</td>
<td>83.9</td>
<td>75.4</td>
<td>85.8</td>
</tr>
</tbody>
</table>

- Effects of dehulling: in cake > meal, in piglet > GF pig
Reactive and total LYS in individual canola samples (Spragg and Mailer, 2008)

\[ y = 0.011x + 19.88 \]
\[ R^2 = 0.067 \]

\[ y = 0.042x + 16.03 \]
\[ R^2 = 0.836 \]
Reactive vs CP or total LYS in canola meal (Spragg and Mailer, 1988)

Reactive (intact lysine) is not predicted by CP or LYS
Dutch feed ingredients: reactive/total lysine

Van der Poel and Bikker, 2012, unpublished.
<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>total, g/kg</th>
<th>reactive, g/kg</th>
<th>RL/TL, %</th>
<th>ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize DDGS</td>
<td>16</td>
<td>3.1-8.8</td>
<td>2.4-6.8</td>
<td>55-86</td>
<td>1,2</td>
</tr>
<tr>
<td>Wheat DDGS</td>
<td>10</td>
<td>2.7-11.7</td>
<td>1.6-10.0</td>
<td>60-86</td>
<td>3</td>
</tr>
<tr>
<td>Soy bean meal</td>
<td>3</td>
<td>32-36</td>
<td>24-32</td>
<td>90-100</td>
<td>2,4</td>
</tr>
<tr>
<td>Fishmeal</td>
<td>5</td>
<td>42-58</td>
<td>26-39</td>
<td>74-89</td>
<td>2</td>
</tr>
<tr>
<td>Wheat</td>
<td>1</td>
<td>3.5</td>
<td>3.1</td>
<td>91</td>
<td>4</td>
</tr>
<tr>
<td>Maize, dried</td>
<td>1</td>
<td>3.2</td>
<td>2.3</td>
<td>70</td>
<td>4</td>
</tr>
<tr>
<td>Lucerne mix</td>
<td>1</td>
<td>19.4</td>
<td>12.5</td>
<td>64</td>
<td>4</td>
</tr>
<tr>
<td>MBM</td>
<td>1</td>
<td>89.2</td>
<td>88</td>
<td>94</td>
<td>4</td>
</tr>
<tr>
<td>SMP</td>
<td>1</td>
<td>28.7</td>
<td>17.7</td>
<td>62</td>
<td>4</td>
</tr>
</tbody>
</table>

1 Pahm et al. (2008), 2 Boucher et al. (2009), 3 Cozannet et al. (2010), 4 Rutherford et al. (1997)

Ileal digestibility of total LYS 9-82%
Intermediate summary

- The major byproducts used in animal feed have undergone intensive feed processing.
- Processes are optimised for production of the primary product, e.g. oil, starch, ethanol.
- Large variation in nutritional quality of the byproducts for animal feed affects feed efficiency.

Challenge:
- Producers: nutritional value
- Feed industry: variation (criteria?)
Bioavailability of amino acids: lysine

- Maillard reaction (e.g. Rutherford, 2010)

\[
\text{Lysine} + \text{Glucose} \rightarrow \text{Schiff base} \rightarrow \text{Advanced Maillard products} \rightarrow \text{Deoxyketosyllysine}
\]
Fate of lysine during processing and analysis
Methods to determine undamaged lysine (chemically reactive lysine)

- Based on reaction products, e.g.
  - in milk: fructosyllysine $\rightarrow$ furosine / lysine / pyridosine

- Based on unreacted $\varepsilon$-amino group, e.g.
  - FDNB (also $\alpha$-amino group)
  - homoarginine method
Bioavailable lysine in heated peas

Fig. 7. Relationship between lysine digestibility (□—□), availability (■—■) and utilization (▲—▲) in raw field peas (Pisum sativum cultivar Dundale) and field peas heated for 15 min at 110°, 135°, 150° or 165° using a forced-air dehydrator.
Lysine digestibility in (heated) casein

<table>
<thead>
<tr>
<th></th>
<th>Heated SMP</th>
<th>EHC (1)</th>
<th>EHC (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrected lysine dep., g/d</td>
<td>10.7</td>
<td>5.4</td>
<td>9.1</td>
</tr>
<tr>
<td>Corrected lysine dep., g/d</td>
<td>9.1</td>
<td>5.4</td>
<td>9.1</td>
</tr>
<tr>
<td>Corrected PD, g/d</td>
<td>133</td>
<td>87</td>
<td>115</td>
</tr>
<tr>
<td>Corrected BWG, g/d</td>
<td>660</td>
<td>569</td>
<td>677</td>
</tr>
</tbody>
</table>

(1) Based on digestibility total lysine  
(2) Based on digestibility reactive lysine

Digestibility of reactive lysine $\rightarrow$ better prediction of PD  
(Rutherfurd et al.. 1997)
## Diet optimisation

RL barley 72%, wheat 83%, maize 82%, RSM 78%

| Ingredients       | basis | reactive | max / min | | max |
|-------------------|-------|----------|-----------|-------|
| barley            | 30.0  | 20.0     |           |       |
| maize             | 20.0  | 20.0     |           |       |
| wheat             | 16.8  | 31.9     |           |       |
| SBM               | 15.0  | 15.0     |           |       |
| RSM               | 8.0   | 3.3      |           |       |
| molasses          | 4.0   | 4.0      |           |       |
| fat / oil         | 2.8   | 2.0      |           |       |
| L-Lysine-HCl      | 0.32  | 0.45     | !!        |
| RE                | 172.8 | 165.5    |           |
| dv lys/EW         | 8.3   | 8.7      |           |
| dv RL/EW          | 7.8   | 8.3      |           |
| costs, €          | 26.29 | 26.72    |           |
Effects on other amino acids

- Van Barneveld et al. (1994)
  - Limited decrease in AA at $T > 150^\circ C$ compared to LYS

- Rutherfurd and Moughan (1997)
  - Milk: lower AA dig. $\geq 10$ min $121^\circ C$ (mild)
  - Peas: lower AA dig. $\geq 150^\circ C$ (drastic)

- Pahm et al. (2008), drying of DDG+CDS
  - Increased variation in other AA content

- Boucher et al. (2009) $150^\circ C$, 90 min
  - 0-10% loss of total AA, more for ARG, TRP
Effect of ingredient processing on protein quality

- Heat treatment may reduce total and reactive lysine content and their ileal digestibility
- ID reactive lysine rather than ID total lysine is a better indicator of bioavailable lysine
- Variation in RL may contribute to variation in animal performance and feed utilisation
- Effects on other AA is lees but not negligible
- **Processing affects protein nutritional value, but effects are not adequately reflected in present feed evaluation → additional characteristics need to be included**
Processing in the compound feed industry

- Grinding, mixing, conditioning, pelleting
- Aggregation of feed mash in larger units (i.e. pellets)
  - Reduce segregation
  - Sanitation, hygiene
  - Weight/volume (bulk density)
  - Nutritional value

Focus: handling properties and cost of production

Nutritional benefits?

Further opportunities: ingredient and/or feed processing for nutrient utilisation?
Benefits of processing

- Grinding, smaller particle size → higher feed efficiency
  - Results KSU in meal
  - GF pigs and sows
  - Farms: 75% > 800 μm

- Pelleting: upto 8% improved feed efficiency (Stark, 2012)
  - Particle size reduction
  - Feed spillage
  - Gelatinisation of starch, denaturation of CP
Effect of intensive feed technology  
(Bruininx, pers. comm. 2013)

<table>
<thead>
<tr>
<th>processing</th>
<th>Pellet</th>
<th>HTST Extrusion</th>
<th>SEM</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pens</td>
<td>28</td>
<td>28</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Body weight at start (kg)</td>
<td>25.7</td>
<td>26.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Body weight at end (kg)</td>
<td>115.7</td>
<td>115.5</td>
<td>0.84</td>
<td>Ns</td>
</tr>
<tr>
<td>ADG (g/day)</td>
<td>862</td>
<td>873</td>
<td>14.0</td>
<td>Ns</td>
</tr>
<tr>
<td>ADFI (kg/day)</td>
<td>2.12(^a)</td>
<td>2.05(^b)</td>
<td>0.049</td>
<td>*</td>
</tr>
<tr>
<td>FCR (kg/kg)</td>
<td>2.46(^a)</td>
<td>2.35(^b)</td>
<td>0.029</td>
<td>**</td>
</tr>
</tbody>
</table>
Technological processing may reduce specific endogenous losses

Wheat + Sunflower meal diet

- Lys
- CP

End. Ileal AA loss (g/kg DMI)

Specific End. Ileal CP loss (g/kg DMI)

Technological treatment

(Lahaye et al. 2004)
Effect of extrusion of pig diets on ileal and faecal nutrient digestibility
(Raedts and Van der Poel, 2008, unpublished)

+4.4% ileal CP dig. (34 of 42 exps.)
+3.6% fecal cfat dig. (9 of 11 exps.)
+4.0% ileal starch dig. (13 of 17 exps.)
+1.6% fecal starch dig. (5 of 7 exps.)

- Extrusion improves mean nutrient digestibility
- But effects vary and depend on processing conditions and diet composition
Processing individual ingredients

- Particle size reduction of cereals and legume seeds improves digestibility, but optimum depends on type of cereal / legume (and age of pig)
- Pelleting and expanding may improve digestibility, effect depends on ingredient, process conditions (and studies!)

Required

- Scope for improvement by treatment of individual ingredients compared to complete diets?
- Better understanding of processing: heat, shear and moisture and interaction with ingredient characteristics
Summary

- Competition for ingredients → increase in use of by-products, of which quality is affected by processing → more attention for nutritional value required and rewarded in feed efficiency

- Present feed evaluation systems do not adequately include effects of processing and need to be improved at this point (e.g. for LYS)

- Research and implementation of feed processing in the compound feed industry should focus more on underlying mechanisms and consequences for optimal nutrient utilisation
Thank you for your kind attention