Practical Application of Enzyme Supplementation in Swine

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Introduction
Application of enzymes to improve nutrients digestibility of plant-based feed ingredients for swine and poultry has now been studies for decades. Initially, the main focus was phytase to break down the phytate molecule and release the attached phosphorus molecules. In the last two decades, enzymes to assist digesting NSP were developed, tested, and commercialized. In the meantime, enzymes to assist digesting starch, protein and fat have been tested as well. A large array of chemical characteristics exists among plant-based feed ingredients, and success of enzyme application will depend on these characteristics. The substrate must match the enzyme and be a limitation for nutrient digestibility or voluntary feed intake. Two diet formulation methods exists to apply enzyme treatments in practice: (1) formulate diets to a regular nutrient content and supplement with an enzyme, while hoping for an improvement in feed efficiency, or (2) formulate diets to a reduced nutrient content and count on an uplift by the enzyme to a regular nutrient content, while reducing feed costs. An overview of considerations and practical application of enzyme supplementation in swine will be presented.

Ingredients
Seeds of plants crops or fractions thereof each contain some of the three main energy categories: carbohydrates [divided into sugars, starch and non-starch polysaccharides (NSP)], protein, and oil (fat). Among the listed feed ingredients, a large array in content of these main energy categories exist, ranging from 10 to 37% NSP, 14 to 63% starch, 9 to 47% protein, and 1 to 5% fat (Table 1).

Table 1. Concentrations of starch (+ sugars), NSP, protein, and fat (% as is) of seven selected feed ingredients (adapted from CVB 1994).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Starch</th>
<th>NSP</th>
<th>Protein</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat middlings</td>
<td>25</td>
<td>37</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Oats</td>
<td>39</td>
<td>31</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Barley</td>
<td>54</td>
<td>18</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>14</td>
<td>17</td>
<td>47</td>
<td>2</td>
</tr>
<tr>
<td>Field peas</td>
<td>47</td>
<td>14</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>Wheat</td>
<td>61</td>
<td>10</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Corn</td>
<td>63</td>
<td>10</td>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>

In least-cost diet formulation, the greatest cost-pressure exists against digestible or available energy (Zijlstra et al. 2001). Overall in swine nutrition, the inverse relationship between NSP content and energy digestibility has been well described for several feed ingredients, for example wheat (Zijlstra et al. 1999) and barley (Fairbairn et al. 1999). Logically, enzymes that degrade fiber and thereby improve energy digestibility or voluntary feed intake will thus have a high
chance to be beneficial economically, whereas phytase to improve phosphorus digestibility may also reduce nutrient excretion and thereby improve sustainability of the swine industry.

Among ingredient, large differences in digestibility of the main macronutrients exist (Figure 1). Among the cereal grains, oats has the lowest digestibility of crude fiber, then barley, wheat, while corn has the highest digestibility of crude fiber. Both peas and soybean meal have a high digestibility of crude fiber. By-products from value-added processing, including wheat middlings from wheat flour milling, generally have a lower nutrient digestibility than the parent cereal. Digestibility of other carbohydrates, including starch, sugars, and the remainder of the fiber fractions was lower for wheat middlings, oats and barley compared to the other four feed ingredients. Protein digestibility followed and similar pattern as digestibility of other carbohydrates with the highest protein digestibility observed for soybean meal. According to the database (CVB 1994), fat digestibility showed a large variation among feed ingredients. Phosphorus digestibility was consistently below 40%, likely due to the phytate contained in plant-based feed ingredients.

![Figure 1. Digestibility of the macronutrient components and phosphorus of seven selected feed ingredients in grower-finisher pigs (adapted from CVB 1994). Other CHO stands for other carbohydrates (starch, sugar, and the remainder of the fiber fractions).](image)

The data set for nutrient digestibility suggest targets ingredients for enzyme supplementation or other technological treatments to improve nutrient digestibility. Using this approach, barley and wheat, and more recently wheat byproducts have gained attention for supplemental enzymes to improve nutrient digestibility, whereas corn and soybean meal only have gained sporadic attention.
**Enzymes in wheat-based diets**

For diets based on either wheat or barley, improvements in energy digestibility, growth performance or voluntary feed intake have been achieved often but not consistently using supplemental enzymes. As indicated in Figure 1, more opportunities exist with wheat and barley to improve digestibility of crude fiber and therefore energy digestibility using supplemental enzymes or other feed processing technologies such as particle size reduction.

Arabinoxylans or xylans are the main NSP in wheat that limit energy digestibility in swine (Zijlstra et al. 1999). Logically, xylanase is an enzyme used for wheat diets to improve energy digestibility. Energy digestibility might also be improved using particle size reduction; by grinding the wheat more finely, the relative surface area of the ground particles increases and nutrient digestibility might be improved. The combination of xylanase supplementation and particle size reduction was studied in wheat-based diets (Mavromichalis et al. 2000). Particle size reduction improved feed efficiency linearly, but xylanase supplementation did not affect feed efficiency or dry matter digestibility. In a accompanying study with finisher pigs, xylanase supplementation tended to improve nutrient digestibility and reduced feed intake while growth performance was maintained (Mavromichalis et al. 2000).

Wheat samples can have a wide range in total xylan content, and this wide range is inversely related to energy digestibility (Zijlstra et al. 1999). The wheat sample that is included is the diet can thus affect the chance of observing a beneficial effect of xylanase supplementation. Indeed, in recent experiments in our laboratory, the beneficial effect of xylanase supplementation and particle size reduction depended on the wheat sample that was included in the test diet (Zijlstra et al. 2004), similar to previous experiments conducted with barley differing in NSP profile (Zijlstra et al. 1998). The latter indicates that feed evaluation and processing decision should be integrated to maximize the beneficial effects of enzyme supplementation or particle size reduction.

Wheat by-products from dry milling for flour production are gaining increasing attention in the swine industry. These by-products are generally available at a reduced cost; however, much research will have to be completed to characterize and improve the nutritional value of the by-products. However, wheat by-product and other by-products imported from overseas may be beneficial to fill the expected gap in availability of feed corn in North America (Wisner and Baumel 2004). Enzyme supplementation may play a key role in maximizing the existing opportunities for inclusion of alternative feed ingredients in swine diets.
Practical application

Two diet formulation methods exists to apply enzyme treatments in practice: (1) formulate diets to a regular nutrient content and supplement with an enzyme, while hoping for an improvement in feed efficiency, or (2) formulate diets to a reduced nutrient content and count on an uplift by the enzyme to a regular nutrient content, while reducing feed costs. In most experiments including the experiment discussed in the proceedings, enzymes are included in the diet as a top dress: diets are formulated to meet the nutrient requirement. A second approach is to include enzymes in the diet to deal with the expected variation in ingredient quality. Hopefully in the future, rapid screening of ingredient samples will allow to match the substrate with the enzyme and allow the enzyme dose to be adjusted depending on the substrate content in the ingredient or complete diet.

For commercial swine production, a predictable growth performance is an important component of financial viability. With least-cost diet formulation, the greatest cost pressure is against available or digestible energy content of diets (Zijlstra et al. 2001).

Knowledge to the expected improvement of energy content of feed ingredients is key for the following practical approach. This approach is valid for enzymes providing an increase in energy digestibility and thus digestible energy content. The formulated diet energy content is reduced by the amount of “uplift” expected by the supplemental enzyme, other nutrients are maintained at the previous level, and if needed, energy to lysine ratio is adjusted properly. Due to the reduced energy content, diet cost is reduced and financial room is available to include a supplemental enzyme into the diet. The uplift ensures that the expected dietary energy content is achieved and that swine growth performance and carcass characteristics can be maintained.

Summary

Feed ingredients have a range in content of energy-providing macronutrients. Especially digestibility of the crude fiber fraction has a large range in nutrient digestibility among feed ingredients. The range in fiber digestibility is directly related and inversely related to a range in digestibility of energy, the most expensive nutrient contained in swine diets. Supplemental enzymes may be beneficial to improve energy digestibility. Specific substrates and thus enzymes are beneficial for wheat and barley, but multi-enzyme cocktail were beneficial for diets based on corn and soybean meal as well. By taking the expected uplift in energy digestibility and thus energy content into consideration during least-cost diet formulation can the diet cost be reduced and should supplemental enzymes allow a cost benefit, depending on the price of the enzyme.