The role of phosphorus in the nutrition of Salmonid fish

Minerals are essential, also for fish. However, fish can obtain most of the minerals (calcium, sodium, potassium) directly from the water to cover its requirements. Phosphorus, however, is one of the essential minerals that has to be supplied via the diet. Phosphorus (together with calcium) is a structural component for bones, teeth and scales. In addition, it plays a role in several metabolic processes. Reduced growth rate, reduced feed efficiency and bone deformities are the most common signs of (digestible) phosphorus deficiency.

Phosphorus metabolism and requirements
Dietary phosphorus (P) requirements do vary widely between 0.3% and 0.9% for different fish species (Lall, 2002). There are some indications that fish with scales have a higher P requirement than scale-less fish. In addition, the range of phosphorus requirements for salmonids is also quite wide being 0.5% to 0.8% of the diet (NRC, 1993). For rainbow trout, the P requirements are according to Sugiura et al (2000) 0.66% and 0.55% for 200 g and 400 g fish respectively. Rodehutscord (1996) advised a range of digestible P content for rainbow trout of 2.4 to 5.9 g/kg in the diet.

Requirements are normally expressed as net requirements or expressed in amounts of digestible/available P. Therefore, the total P content of salmonid diets will be higher, depending on the P digestibility of the feed materials used (Figure 1).

Table 1: P levels and apparent P digestibility coefficients (ADC) for rainbow trout for some selected feed materials

<table>
<thead>
<tr>
<th>Feed material</th>
<th>Total P (%)</th>
<th>ADC-P (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring meal</td>
<td>2.2</td>
<td>45 – 52</td>
</tr>
<tr>
<td>Menhaden meal</td>
<td>3.5</td>
<td>36</td>
</tr>
<tr>
<td>Poultry meal</td>
<td>2.2</td>
<td>48 – 62</td>
</tr>
<tr>
<td>Meat and bone meal</td>
<td>5.6</td>
<td>27</td>
</tr>
<tr>
<td>Blood meal</td>
<td>0.7</td>
<td>&gt;95</td>
</tr>
<tr>
<td>Feather meal</td>
<td>0.75 – 1.26</td>
<td>62 – 79</td>
</tr>
<tr>
<td>Wheat gluten</td>
<td>0.2</td>
<td>75</td>
</tr>
<tr>
<td>Wheat middlings</td>
<td>1.3</td>
<td>55</td>
</tr>
<tr>
<td>Corn gluten</td>
<td>0.5</td>
<td>8.5</td>
</tr>
</tbody>
</table>


Figure 1: Phosphorus metabolism, Haddock (Roy et al., 2004)

Phosphorus sources
Feed materials (fish meals, animal meals and plant feed materials) are the main P sources in diets for salmonids. The P availability (or better digestibility) of these sources, however, does differ. In general vegetal feed materials (soya, cereals, etc) do have a low P digestibility because of the fact that most of the P is bound to phytic acid rendering it unavailable for fish. Fishmeals do vary both in view of total P content and digestible P content, depending mainly on the origin and the processing of the fishmeal, high levels of fish bones lowers the P digestibility (Table 1).

This is Tessenderlo Group’s 3rd Feed Ingredients newsletter. In this issue, we pay particular attention to the importance of phosphorus in fish nutrition and inform you about the results of our latest trial on the P digestibility for rainbow trout of several of our feed phosphates. We would also like to draw your attention to our website because a lot of useful information on Tessenderlo Group’s feed phosphates and other feed ingredients can be found here.

All your comments concerning this newsletter are most welcome to us at animalnutrition@tessenderlo.com
The phosphorus digestibility of some selected inorganic feed phosphates for Rainbow trout

In 2004 Tessenderlo Group performed an experiment into the phosphorus digestibility of different feed phosphates using rainbow trout (Oncorhynchus mykiss). This trial was carried out in cooperation with Plymouth University, Fish Nutrition Unit (UK).

Materials and methods

456 rainbow trout (80 g) were used at a stocking rate of 38 fish per tank, two tanks per trial feed, in a controlled re-circulation system with water temperature at 15°C and a photoperiod of 14 h light and 10 h darkness.

Feeds were formulated to contain digestible phosphorus (P) levels below requirements at a level of 5 g/kg, using purified reference diets (Table 1). The P content of the casein appeared to be higher than anticipated. Therefore, the level of digestible P arrived at a (calculated) level of 6.3 g/kg.

Calcium (Ca) levels were balanced at 1%. Yttrium oxide was used as an indigestible marker for the calculation of the P digestibility.

In the trial 6 diets were used, next to the negative control, diets including Aliphos Dical 18 (DCP18), Windmill Dicalphos (DCP20), Aliphos Modical 21.8 (MDCP), Aliphos Monocal 22.7 (MCP) and Windmill Monamphos (MAP).

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The results of this trial with rainbow trout showed that there are appreciable differences in P digestibility from different inorganic feed phosphates. With Windmill Monamphos reaching a value of 86% digestible P, followed by Aliphos Monocal 22.9 and Aliphos Modical 21.8 with digestibility values of both 56%. Aliphos Dical 18 and Windmill Dicalphos showed the lowest digestibilities, 17% and 31% respectively. The results in this trial are in accordance with other findings in previous trials, divalent inorganic P sources having the lower P digestibility values and elevated coefficients for monovalent inorganic feed phosphates, clearly affected by the increase in solubility of the different feed phosphates.

Conclusion

If feed for salmonids has to be supplemented with an inorganic P source preferably it should contain both a high level of total and digestible P. Because of the fact that fish are capable to absorb Ca from the water, Ca free or phosphates with an adverse Ca/P ratio are preferred. Windmill Monamphos does contain the highest level of P of the commercial available feed phosphates and it shows a very high P digestibility reaching 86% in this trial. In addition, Windmill Monamphos does not contain Ca. Therefore, Windmill Monamphos is the product of choice for the production of feed for Salmonid fish.

The assumed P-digestibility levels of the different feed phosphates: Aliphos Dical 18 70%, Windmill Dicalphos 65%, Aliphos Monocal 22.7 90%, Aliphos Modical 21.8 80% and Windmill Monamphos 95%. For Casein the P-digestibility was assumed to be 90%.
**Phosphates in fish feeds**

If feeds for salmonids are produced using high levels of fishmeal, no (or only limited) additional supply of P via the use of inorganic feed phosphates is necessary. However, producers are increasingly using plant feed materials having both a low total and digestible P content. In these feeds, an additional supply of inorganic feed phosphates is certainly necessary. Fish feeds are very concentrated both in energy level and in protein content; therefore, a highly concentrated inorganic P source would be the product of choice (Table 2).

**Table 2: Tessenderlo Group inorganic feed phosphates.**

<table>
<thead>
<tr>
<th>Phosphate</th>
<th>P %</th>
<th>Ca %</th>
<th>Mg %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP</td>
<td>22.9</td>
<td>16.65</td>
<td></td>
</tr>
<tr>
<td>MDCP</td>
<td>21.9</td>
<td>20.5</td>
<td></td>
</tr>
<tr>
<td>DCP2H2O</td>
<td>18.2</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>DCP0H2O</td>
<td>20.2</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>MAP</td>
<td>26</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>MgP</td>
<td>14</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Inorganic feed phosphates contain both a high level of total and digestible P. The digestibility of the different inorganic feed phosphates is, however, not the same. It seems that the digestibility greatly depends on the solubility of the products. The P digestibility (availability) of feed can be measured using different indirect parameters like growth rate and bone parameters (i.e. % P, % bone ash). The direct measurement of the apparent absorption of dietary P from the intestinal tract (apparent digestibility) is, however, the preferred method because it simply measures the difference between ingested and excreted P.

**The role of calcium in fish feeds**

Calcium (Ca) is absorbed from the surrounding water by the gills, therefore, it is difficult to control the total intake of calcium in requirement or digestibility studies. Since fish is indeed capable to absorb sufficient amounts of Ca from the surrounding water, normally no additional Ca has to be supplied via the feed. However, Ca is present in almost all feed ingredients. Therefore, attention should be paid to the Ca/P ratio in the feed. A too wide ratio can affect the P digestibility of the feed by formation of indigestible Ca phosphates in the intestinal tract, because of the increase in pH in the intestinal tract after the stomach. Therefore, if an additional supply of P is needed, Ca-free feed phosphates or eventually feed phosphates with a Ca/P ratio of below 1 are preferred.

**Conclusion**

If feed for salmonids has to be supplemented with an inorganic feed phosphate preferably it should contain both a high level of total and digestible phosphorus. Because of the role of calcium in fish, calcium free or phosphates with an adverse Ca/P ratio are preferred.

**Website of Tessenderlo Group**

We would like to draw your attention to the website of Tessenderlo Group, because a lot of information on feed phosphates and other feed ingredients can be found here: [www.tessenderlo.com](http://www.tessenderlo.com). When you arrive at our home page, go to markets and applications => animal nutrition => feed phosphates. Here you will find general information about feed phosphates but also more detailed product information about the phosphates produced in Belgium (Aliphos), The Netherlands (Windmill) and Italy (Italphos). You will find updated technical specification sheets of all our products (example of Aliphos Dical 18 below) and information of the methods used to determine the P, Ca content, P solubility, undesirable elements and others. We also plan to add MSDS sheets of all our feed phosphates on our website.

Moreover, Tessenderlo developed a CD-ROM, which can be used as a simple tool for implementing the digestible phosphorus system for poultry and pigs. On our website, some information about the digestible phosphorus system is given but if you are interested in this CD-ROM, please contact us at: animalnutrition@tessenderlo.com.

Last but not least, you will find the names, phone numbers and Email addresses of the sales and technical representatives of your region. Do not hesitate to contact us.
Micro-encapsulation: the technology for optimal growth and health of the animals

Current poultry production is based on a very subtle equilibrium between production costs and the sales price of products produced, costs that can vary in a wide range depending on the different management choices. When costs can’t be avoided the main aim of the farmer is to improve animal performance in order to achieve the maximum earning, and the best performance is reached when animals live in a perfect state of health. This target is possible to achieve by following different management techniques (choice of the structure, attention to hygienic practices, etc.) and by nutrition. This last factor most of all is linked with the animal’s metabolism and at the same time is the one that is most easily controlled by the farmer.

Studies carried out over the last decade show how some feed additives are able to enhance zootechnical traits. They have been found to act on the digestive tract reducing microbial problems of feed origin, stimulating pancreatic enzyme secretions and essential oils in particular have been found to increase villi length hence improving absorption (Langhout et al. 1999). The negative aspect of these products is that they are volatile giving problems in handling, can react with other components of feed and it is not easy for them to reach the final parts of the digestive tract where most of pathogens are present. Micro encapsulation has been proven an effective way to solve these problems.

Specialist in micro-encapsulation
Soda Feed Ingredients began in the eighties as a specialist in producing microencapsulated products. They offer nutritionists and the veterinary profession today a comprehensive range of solutions to grow healthy and performing animals with non pharmacologic products, which means no residuals in meat, eggs and milk and consequently a safer food. The technology Soda Feed Ingredients has is the ability to use patented micro encapsulation processes which enable blends of feed ingredients to be presented in various matrices which can release ingredients all along the digestive tract. Other benefits of encapsulating can be to make products safer to handle from a Health and Safety point of view in the premix and feed mill which is also a very important issue to consider when selecting products to handle.

Research
Soda is besides investing day by day in scientific and field research to test and show to the customer the efficiency of its products. One trial has been conducted at Department of Animal Nutrition and Husbandry, Gent University by Dr. Ir. M. Lippens and Dr. Ir. G. Huyghebeert.

The aim was to compare the effects on broiler performances of two additives, RepaXol a premixture of essential oils microencapsulated by complex coacervation and AVIGRO blend of organic acids and essential oils micro encapsulated against a positive and negative control and is currently awaiting publication in a scientific journal. The trial demonstrated that RepaXol out performed all treatments with regard to final body weight and feed efficiency and differences were statistically significant.

In another trial awaiting publication by Hanne Maribo at the Danish Bacon and Meat Council, was also demonstrated an improvement of the feed efficiency in the weaning period of piglet diets when RepaXol was used. Moreover trials have been conducted also in prestigious Universities in the USA. Suprol, a mixture of microencapsulated organic acids and essential oils from RepaXol was tested at the South Dakota State University (Bob Thaler and Brad Rops, J.Anim.Sci., Vol 82, Suppl.I) on growing pigs compared to two groups fed a medicated diet. Results showed pigs fed Suprol were the most efficient group. It was also suggested Suprol improved intestinal integrity and gut environment and therefore was able to utilize more of the nutrients available.

All trial reports are available from SODA Feed Ingredients.