Acidifier concepts in aquafeed

Technical and functional considerations

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Acidifiers are well established in pig and poultry nutrition – especially for young animals (piglets and broiler chicks). The concept of acidifiers has been successfully transferred from agriculture feed to aquaculture feed during the last 10 years.

Dr. Eckel has sold feed additives since 1994. One of our core competencies is the utilization of organic acids and their salts for animal nutrition – either as silage enhancers, as preservatives or as acidifiers. I want to share our experience on some important technical and functional aspects of this transfer.

What are acidifiers?

In general, acidifiers as functional feed additives made from organic acids and their salts. Typically organic acids and their salts are included in the feed at a dosage between 1kg/t (0.1%) and 10 kg/t (1%). Some publications report dosages of up to 20kg/t (2%) – but this might have been just for research purposes. Which organic acids are used as acidifiers? A number of different organic acids and salts can be used as acidifiers. The most common acids an salts are:

- formic acid or calcium formate and potassium formate as their most important salts;
- acetic acid or its sodium salt sodium acetate
- propionic acid or calcium propionate; butyric acid or sodium butyrate
- lactic acid or calcium lactate and – last but not least -
- citric acid with different salts.

Other organic acids and salts used are fumaric acid / fumarates, malic acid / malates, sorbic acid / sorbates. All these organic acids can be distinguished and classified by a number of properties. Very important for the usage as feed acidifiers are differences regarding

- pk_a-value, because it determines the degree of dissociation in different pH -environments;
- solubility, because it determines bioavailability.

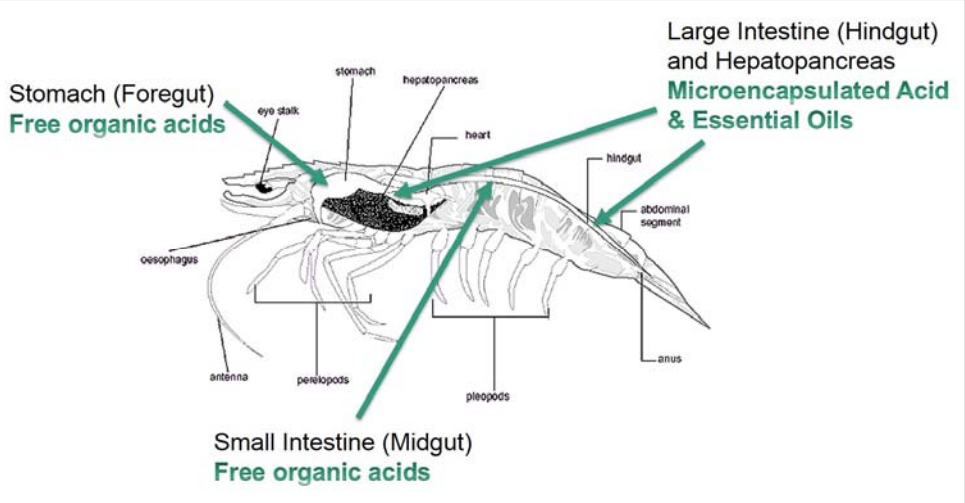
Another important property is the molecular weight, because it determines the number of acid molecules per gram. Finally the nutritional value of organic acid can also be taken into consideration because organic acid salts like propionates are good energy sources.

So, how do acidifiers work?

Acidifiers have several modes of action in the feed and in the animal. The most important modes of action are the antimicrobial effect and the stimulation and activation of digestive enzymes. Other relevant modes of action are an unspecific immune stimulation (e.g. in Shrimp), the chelation of minerals (and enhancing absorption), its nutritional value and its sensoric properties (taste, smell). The antimicrobial action of organic acids is pillared by the ability of organic acids to lower the pH of the feed, to reduce the buffer capacity of feed, to lower the pH-value of the stomach and finally by the ability of organic acids to directly impair

pathogen cells. The direct effect on pathogen cells is closely related to the pH-dependant behavior of the acid molecule. Depending on its natural pK_a value an organic acid binds or releases H^+ ions. If the pH value of the environment is lower that the acid's pK_a value (e.g. in the stomach), the acid will bind the H^+ ions and is said to be undissociated. In the undissociated state the acid molecule are unionized and can therefore easily penetrate the cell walls of pathogen cells. Inside the pathogen cell the pH environment is close to neutral and therefore higher than the pK_a value of the organic acid. Under this circumstances the acid releases (dissociates) its H^+ ion and the acid molecule becomes ionized. Now the ionized acid molecules are trapped in the pathogen cell and start to accumulate. This accumulation will lead to a pH-drop and intracellular damage in the pathogen cell. Or the pathogen has to spend a lot of energy to pump out the ionized acid molecules. As all this depends on a number of factors (pH environment, pK_a value, pathogen cell membrane, and pathogen cell pH-sensitivity) it is easily understandable that the antimicrobial effect of organic acids is not always easy to predict under all conditions. The stimulation of digestive enzymes is the result of a stimulation of physiological feedback mechanisms in the gut. The lowered pH-value of the stomach increases the amount of pepsin in the stomach and the amount of trypsin and lipase released by the pancreas.

Mode of action of acidifiers in fish



Mode of action of acidifiers in shrimp

From feed to feces acidifiers do their work at different stages of the digestive tract. Starting in the feed organic acids have a preservative effect in the feed and after ingestion they reduce the buffer capacity of the feed. Lowered buffer capacity is favorable, because a feed with a high buffer capacity can raise pH value in the stomach which in turn impairs the antimicrobial barrier function of the stomach. This barrier function is supported by a pH-lowering effect of the acidifier. And this pH lowering effects also leads to increased release of proteolytic enzymes in the stomach and in the small intestine. In the small intestine the acidifiers can modulate gut microflora, act as energy source and can enhance absorption of nutrients (e.g. calcium and phosphor) through formation of chelates.

If protected (encapsulated) acidifiers are used, acidifiers can do their job even in more distal parts of the gut. The mode of action depends on the morphological features of the gut. Some aquaculture species might lack a stomach but that does not necessarily mean that they will not benefit from acidic support. But the diversity in fish gut morphology explains the difficulties of transferring acidifier formulas and dosages from one aquaculture application to another. If one takes a look into the large amount of scientific literature about acidifiers in aquafeed he will rediscover a quite confusing pattern of what acidifiers works in which species und what feeding and conditions.

But what can the farmer see in the end?

What are the main effects of acidifiers in aquafeed? As a result of the modes of actions described before, acidifiers in aquafeed have the following effects at farm level:

- Higher growth rates (growth promoter)
- Increased protein digestibility
- Better feed conversion

- Improved immune response
- Reduced mortality

That means that acidifiers in aquafeed contribute to animal performance, farm profit animal health, antibiotic reduction and resource efficiency.

Processing considerations

If acidifiers are be used in aquafeed, one has to take into consideration some technical aspects. On the one hand the organic acids need to reach the animal's intestine. Therefore leaching from the feed particle into the surrounding water must be avoided. The solubility of the acidifier in the feed must not be too high. To achieve this, it is recommended that acidifiers are mixed into the feed manufacturing before the pelleting step. On the other hand the organic acids must be bioavailable inside the animal. Hence, particle size should fit to species requirements and size. And although leaching must be avoided, the acidifier must be soluble in the animals gut to be effective. Finally, the feed manufacturing process has to guarantee a homogenous mixture of the acidifier in the diet.

In the feed manufacturing process the choice of acidifier can also make a difference. Acidic ingredients like free organic acids cause problems in the feed mill. Free organic acids can lead to corrosive damage of machinery. They can cause chemical burns to workers. And they can lead to unforeseeable chemical reactions with other feed ingredients. All this risk can be avoided if one uses acidifiers that are made from natural salts of organic acids (most common are calcium, potassium, sodium salts).

Classic acidifiers consist of a single type of organic acid or a combination of two. In order to further improve the concept of acidifiers Dr. Eckel has developed so-called next generation acidifiers (NGA). The most important features of NGA are

- A combination or at least 3 organic acids.
  For example formic acid + citric acid + lactic acid
- Usage of calcium salts of the organic acids that are highly bioavailable and have high nutritional value
- Microencapsulation of a part of the organic acids
- Microencapsulation in combination with essential oils

The encapsulation leads to a slow release of the encapsulated ingredients (organic acids and essential oils) alongside the gastrointestinal tract. The fat capsule material becomes digested by endogenous lipase enzymes. The spectrum of particle sizes ensures that the release happens at all different parts of the gut. The encapsulation of a part of the organic acid is beneficial because it is a method to prevent leaching. This is especially important in animals that do not swallow whole feed particles but masticate their feed (like Shrimp). Furthermore the encapsulation leads to a slow release effect of free organic acids throughout the gut. Finally, when organic acids are released in the most distal part of the gut they can build an antimicrobial barrier against ascending infections. The essential oils are protected by microencapsulation in order to transport them to the target site (small and large intestine). Here they can unfold their antimicrobial potential. Some essential oils have the ability to increase the permeability of the cell wall of pathogenic bacteria. Hence, they have an own antimicrobial effect and they make organic acids more effective. In laboratory tests we compared the antibiotic effect of an essential oil, an organic acid and a combination of both against common food-borne pathogens. It came out, that the combination was way more effective than the single substances. From a technical point of view the encapsulation has some pitfalls. One has to ensure that the encapsulation material is degradable by the target species. Further the particle size of the capsules has to be adapted to the size of the animals. When encapsulated acidifiers are to be added to the pelleting process one has to ensure that the capsules survive the pelleting process.

" ...the diversity in fish gut morphology explains the difficulties of transferring acidifier formulas and dosages from one aquaculture application to another. "

Feeding trials

Although there is a large body of evidence about the effectiveness of acidifiers in aquafeed, Dr. Eckel conducted its own studies and trials to develop and advance our acidifier products. A few of them are described here:

In a laboratory study at Kasetsart Univesity (Bangkok, Thailand) we investigated the immunological effects of our next generation acidifier on antimicrobial genes (AMPs: C-type lectin and penaeidin) of Pacific White Shrimp in different culture periods. It came out that during harvest period, C-type lectin and penaeidin and prophenoloxidase gene expression of treated shrimp were significantly increased. The researchers concluded that the acidifier up-regulated the expression of AMP genes which is seen as extremely positive to cultured shrimp especially when there are challenges from pathogens, bacterial or viral (e.g. Vibrio spp, White spot virus, IMNV, EMS, etc.). This implies a strong health promoting effect from our next generation acidifier.

Indeed, in another feeding trial this health promoting effect could be veri-

fied. In this trial – also conducted at Kasetsart University – different dosages of the acidifier (0% control, 0.3%, 0.6%, 0.9%, 1,2%) had been compared in a 60 days trial. The health related measurement variables (survival rate, total bacteria count in hemolymph at day 60, Vibrio count in hemolymph at day 60) were significantly improved in the 0.3% group compared to the control group. In addition the results indicate a dose-effect relationship from 0.3% to 1.2%. Although there was a trend so increased body weight gain with higher inclusion rates, this was not statistically significant. But the protein digestibility was measured as well and it was significantly improved from 75% up to 84%. But in another tank trial study with Pacific White Shrimp at nursery stage the growth promoting effect was prominent. After 21 days of feeding with a next generation acidifier at 0.3% weight gain was significantly improved from about 0.2g to 0.5g in all three replicates.

In a commercial scale trial with Tilapia (178 tons of fish biomass) the growth promoting effect and the health promoting of next generation acidifiers were observed again: Survival rate in the treatment group was 20% higher than in the control group without acidifier. At the same time feed conversion was improved from 1.17 to 1.08. Similar results were reported to us from a Tilapia nursery farm where the ponds with acidifier in the feed produced bigger fingerlings (size #22) than the control group without acidifier (size #24) in the same amount of time.

Obviously the concept of acidifiers had been successfully transferred from agriculture to aquaculture. Acidifiers have a strong antimicrobial effect, they can enhance protein digestion and they are able stimulate the immune system of Shrimp. The numerous combinations of species, feeding practices and husbandry systems make it difficult to compare the success or failure of different acidifiers under different settings. From our research and development efforts and the feedback from our customers we conclude that next generation acidifiers with microencapsulated organic acids and essential oils have advantages when compared to classic acidifiers because auf their stronger antimicrobial power. At farm level, next generation acidifiers as additives for aquafeed lead to increased growth performance, better feed conversion and reduced mortality and less need for antibiotics. This contributes to the farm's profit and to sustainability of the production.

More information

This article is based on a presentation by Tilman Wilke at the Aquafeed.com conference, Aquafeed Horizons 2015, which took place June 9, 2015 in Cologne, Germany.

Download the presentation (PDF).

Or contact Tilman Wilke, Product developer, Dr. Eckel GmbH, Germany .

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More resources:

Download the FEFANA Booklet on Organic Acids in Animal Nutrition

The booklet describes their functions and market for Organic Acids, the different types of manufacturing processes and how they fit into the EU regulatory framework. Potential synergies with other feed ingredients, sustainability aspects and information on safe handling and transport of organic acids are also provided in this booklet. (PDF)