

# Acidification in monogastric fish: limits and potentials

By Christian Lückstädt

## The impact of acidifiers on the proper digestion of high protein diets.

In monogastric animals, including a wide variety of different fish species (ranging from salmon and trout, tilapia, sea bass to pangasius), the chemical breakdown is next to others achieved in the stomach through acidification. According to Wikipedia 'a monogastric digestive system works as soon as the food enters the mouth. Saliva moistens the food and begins the digestive process. After being swallowed, the food passes from the esophagus into the stomach, where stomach acid and enzymes help to break down the food. Bile salts stored in the gall bladder empty the contents of the stomach into the small intestines where most fats are broken down. The pancreas secretes enzymes and alkali to neutralize the stomach acid.'

The 'stomach acid' working in all monogastric animals is hydrochloric acid, a very strong inorganic acid, which is produced by gastric glands (parietal cells). This acid is able to lower the pH in the stomach to levels between pH 1-3. The hydrochloric acid production at birth is negligible, but it will increase with the age of the animal. The more the acid is produced in the stomach, the lower is the pH.

The present pH is involved in the activation of pepsin, which is a proteolytic enzyme. This is needed in the digestion of protein. Pepsin is secreted as an inactive zymogen, called pepsinogen (inactive in order to not 'digest' the stomach itself when no food is available). Its conversion into the active form is catalysed by the action of the acid. Similar to every enzyme, pepsin has certain optimal conditions in which it works best. The optimal pH for pepsin activity is 2.0. At higher pH levels the activity is severely reduced.

## Monogastric aquaculture species

What are the implications of this for monogastric aquaculture species, which are heavily depending on the high protein inputs and on its proper digestion of these expensive ingredients?

One of the possible answers may come from feed additives. The use of organic acids or acid salts has been studied and reported in numerous publications over the past half-century in animal nutrition (Cole et al., 1968). Supplementing diets with organic acids reduces the pH in the stomach, it stimulates thereby the activation of pepsinogen to pepsin and thus may improve protein digestibility and decrease the rate of gastric emptying. It further improves protein digestion by increasing the rate of proteolysis of large protein molecules (Theobald and Lückstädt, 2011).

The reduction of pH in the feed and stomach largely depends on the buffering capacity of feed ingredients. Animal protein (e.g. fishmeal), extensively used in aquaculture diets, has a 15 fold higher buffering capacity compared to cereals. These effects are especially important in view of the low hydrochloric acid output in young animals, as described before (Freitag, 2007). Most of these data are however stem from monogastric livestock, such as pig. Its investigation in aquaculture diets however has been done only very recently.

Bucking and Wood (2009) looked into the effect of feeding on stomach pH. The authors fed rainbow trout (mean weight 350g) a commercial trout feed with 41% crude protein in a single-meal (2% body weight ration) and monitored the resulting pH in the stomach. Just before feeding the stomach pH was at ~2.7, whereas the pH one hour after feeding went significantly up to pH 4.9. It remained there for at least 8 hours, thereby being far above the optimum for pepsin activity. The chyme was released into the duodenum 8 hours after feeding, at far too high pH-levels. The authors speculated that the buffering capacity of the feed was a major contributor to the increased pH of gastric fluids. It took the fish more than 24 hours to reach the 'low' initial pH of the stomach (Figure 1a and 1b).

The effect of diet buffering capacity on the gastric acidification in juvenile fish was proven as well by Marquez et al. (2011a). They found that fishmeal diets had a 10-fold higher buffering capacity and therefore needed more energy for acid secretion per digestion cycle, than test-diets without animal protein meals.

Figure 1a: Stomach pH in trout before and just after feeding.

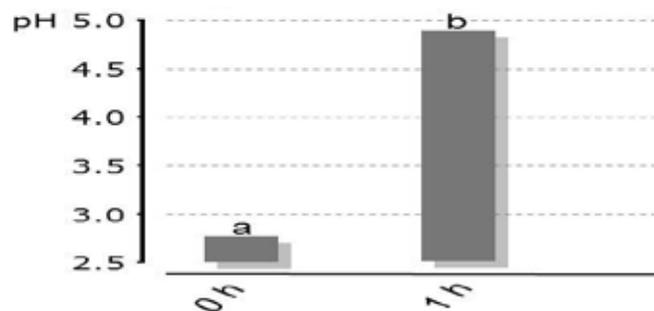
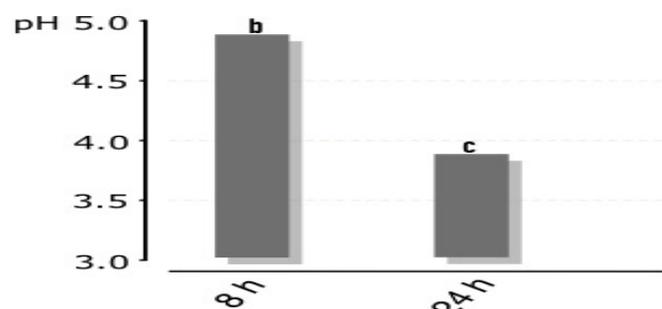


Figure 1b: Stomach pH in trout during digestion.



Figures are adapted from Bucking and Wood (2009).

Similar observations on feeding and gastric pH have been made by Yufera et al. (2011). This Spanish research group fed juvenile gilthead seabream in three different ways: once, twice or continuously and monitored the resulting pH-levels in the stomach. Feeding was done either at 9:00 or at 9:00 and 17:00, or continuously between 9:00 and 21:00. The gastric pH exhibited significant daily rhythms under the three tested feeding regimes (Figure 2). Only in the feeding regime with continuous offer of feed the stomach pH remained for a while in the region of the pepsin optima. This may be a reason for the significant greater weight of the fish from that feeding regime. It could be also explained by higher gastric activity in fish with gastric pH-levels below 4.5, as documented by Marquez et al. (2011b).

A subsequent study from Yufera et al. (2012) took this a step further. This time, the authors looked at the connection between stomach pH and pepsin activity in juvenile marine fish. Fish were again fed either a single-meal, twice or continuously the same diet at the same times as mentioned above. In comparison, fish fed only once again had pH levels in the stomach around 4.5, while the highest pepsin activity was actually reported before the feeding with 30 pepsin activity units per fish. Contrary to that, continuously fed fish reached a minimum pH in the stomach of ~2.5 and had a resulting pepsin activity of almost 280 units per fish in the late afternoon. This clearly demonstrates the impact of low pH on pepsin activation (Figure 3a and 3b).

Figure 2. Stomach pH in sea bream after feeding three different feeding regimes.

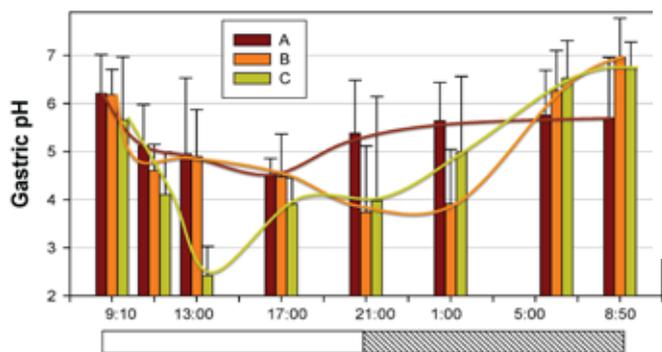


Figure 3a. Stomach pH in differently fed marine fish

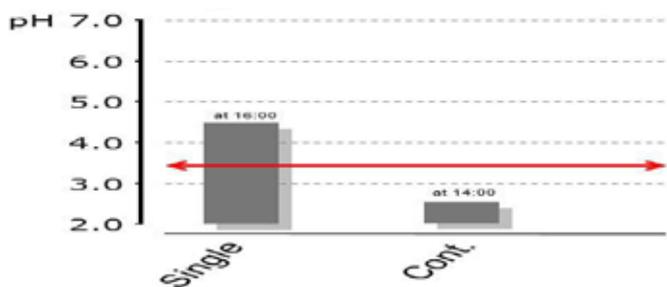
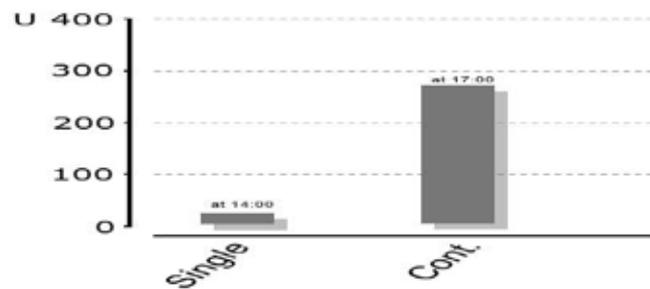


Figure 3b: Resulting pepsin activity in the stomach of marine fish



(Figures 3a & b are adapted from Yufera et al., 2012.)

on protein digestion is often overlooked. A recent meta-analysis for potassium diformate (Aquaform, ADDCON) found significantly improved weight gain and feed efficiency for tilapia in levels which can be already described as 'growth promotion' (Lückstädt, 2012).

These results may not stem only from the surely existing anti-bacterial effects. Since an acidifier, if chosen properly, may have impacts on buffer capacity and/or stomach pH they will also have an impact on the digestion processes in the gastric tract. It may be time to look into this further.



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### What are the implications?

The use of acidifiers is gaining more interest in recent years (Lückstädt, 2008). However, most of the described effects are thought to stem from the anti-bacterial mode of action of organic acids. The impact



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