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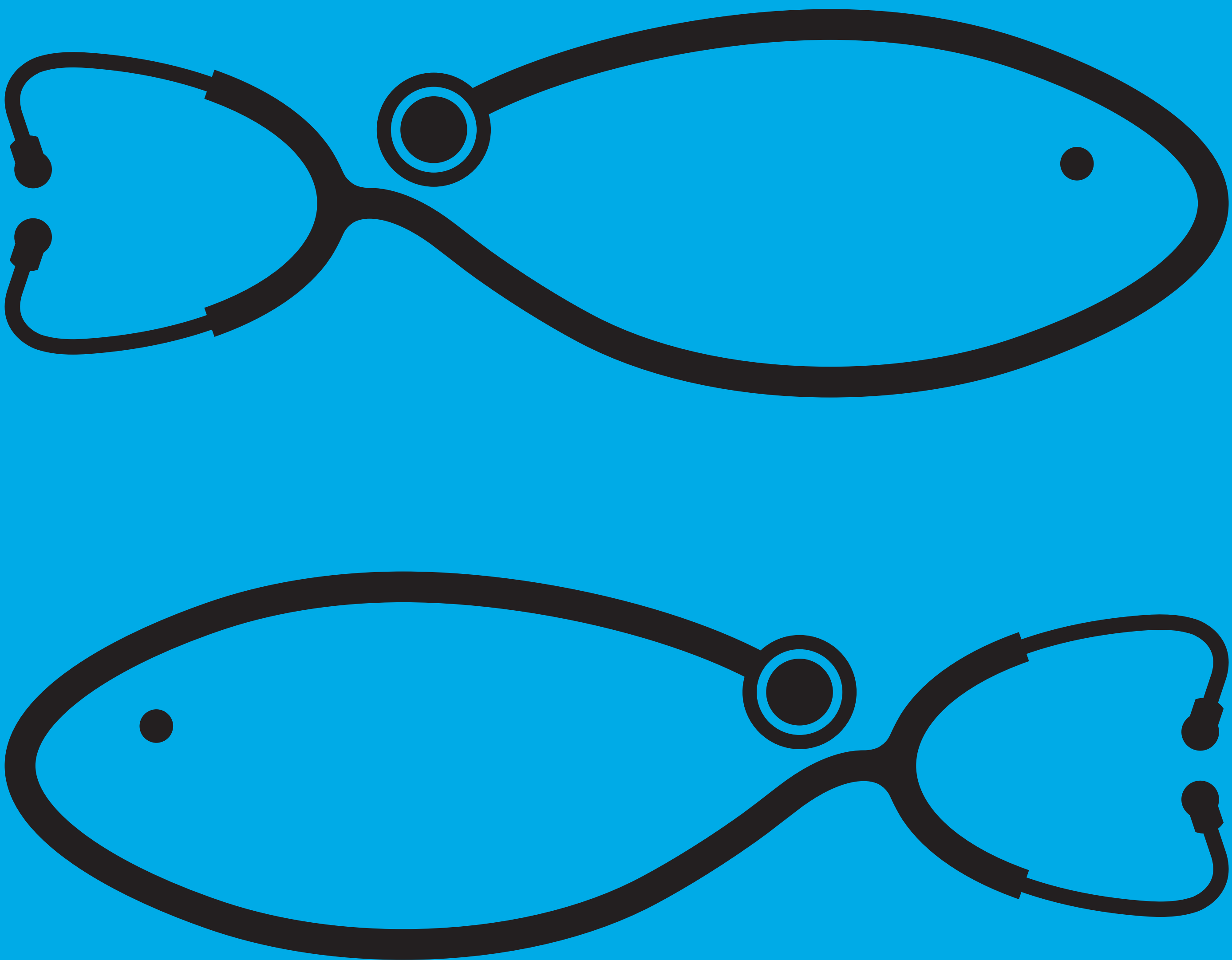
Organic acids and autolyzed yeast reduce the impact of pathogens in fish

Mycotoxin management in livestock production: a model for aquaculture?

Top 5 aquaculture performance indicators



## When was your last gut performance checkup?

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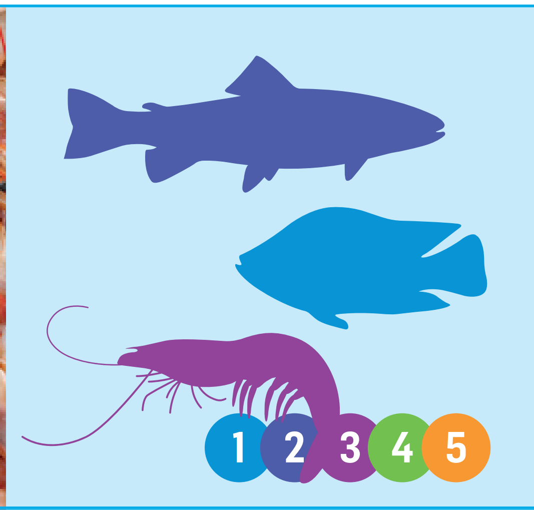


# When was your last gut performance checkup?

**The aquaculture industry is enjoying a period of rapid growth and investment due to the high demand for aquatic protein. Production techniques have intensified and innovation in management techniques are constantly being implemented to maximize output; fish are even being farmed in the desert thanks to innovation!**

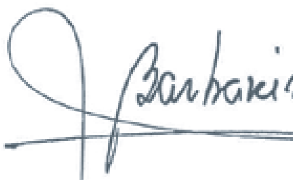
Yet, the aquaculture industry must also stay adaptable to remain naturally ahead. Adopting new technologies alone will not guarantee success. Aquatic species are highly sensitive to a number of external factors that must all be managed throughout the production cycle.

Traditionally, disease management in the aquaculture industry means the administration of antibiotics. However, regulatory guidelines and consumer demand for antibiotic-free fish and shrimp products have changed the market. Thanks to the introduction of natural alternatives, feed additives such as organic acids, phytogenics and probiotics can be used in place of antibiotics to reduce disease challenge. We delve into results with organic acids and yeast in the first article on page 4 of this issue of Science & Solutions.

The use of plant-based protein in aqua feeds is a cost-effective alternative to fishmeal. Producers should be aware that plant-based protein sources are often contaminated by harmful mycotoxins. The aquaculture industry has relatively little knowledge or experience of dealing with these anti-nutritional factors compared with other terrestrial livestock producers. On page 9, Rui Gonçalves highlights five management tips that the aquaculture sector can employ thanks to experience gathered by the livestock sector.

Finally, as in any industry, measuring and monitoring performance is vital. Constant measurement of performance indicators, such as those presented on page 15, will allow the early identification of problems so that the necessary adjustments can be made to ensure maximum profitability. Do you use any or all of these performance indicators in your business? Regardless of which formula you use, talk to your BIOMIN representative about making improvements to your performance.

We hope you enjoy reading this issue of Science & Solutions, keeping you naturally informed.



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# Organic Acids and Autolyzed Yeast Reduce the Impact of Pathogens in Fish


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**Rising demand for aquatic protein is driving the intensification of production, which is increasing the incidence of diseases. High stocking densities and high organic outputs provide optimum conditions for the spread of pathogens including a wide range of microorganisms, viruses, parasites and fungi. Organic acids and autolyzed yeast products can reduce the impact of these pathogens, supporting performance and profitability.**


## IN BRIEF

- Antibiotic use in aqua production is falling due to customer demand, but the threat of economic loss from disease is ever present.
- Alternatives to antibiotics include organic acids, autolyzed yeast and plant extracts.
- Organic acids have antimicrobial properties, which control and prevent disease.
- Autolyzed yeast supports the immune defense systems.
- As shown in trials, Biotronic® Top3 and Levabon® Aquagrow are interesting alternatives to traditional pathogen control medication.

## Bacterial threats

Bacteria can survive very well in aquatic environments, especially when water temperatures rise or when farming systems are unbalanced. But these bacteria can cause significant economic losses. Bacteria from the *Aeromonas*, *Edwardsiella*, *Pseudomonas*, *Streptococcus*, *Vibrio* and *Yersinia* genera can all be pathogenic to aquatic animals.

There are many ways to control bacterial disease outbreaks in aquaculture and one of the most common control methods is to use antibiotics. However, a growing awareness of consumers opposing the use of antibiotics in aquaculture production means that some farmers are now banned from selling aquatic products to export markets. The extensive use of such antimicrobials is linked to the development of antibiotic-resistant bacterial strains and the transfer of resistant genes between different bacterial species. The emergence of pathogenic-resistant bacteria has negative

**Acidifiers can improve gut health, increase nutrient utilization by reducing the pathogen load, and increase disease resistance without compromising growth performance.**

impacts, not only on aquaculture, but also on human health. It also negatively affects consumer perception. Therefore, the demand for more environmentally-friendly alternatives is higher than ever. Anti-microbial substances such as organic acids and plant extracts are now commonly used in the fish farming industry. Additionally, other solutions like yeast cell walls can prevent disease by enhancing the innate immune system of fish whereas vaccines only enhance adaptive (acquired) immunity.

## Organic acids to control pathogens in fish

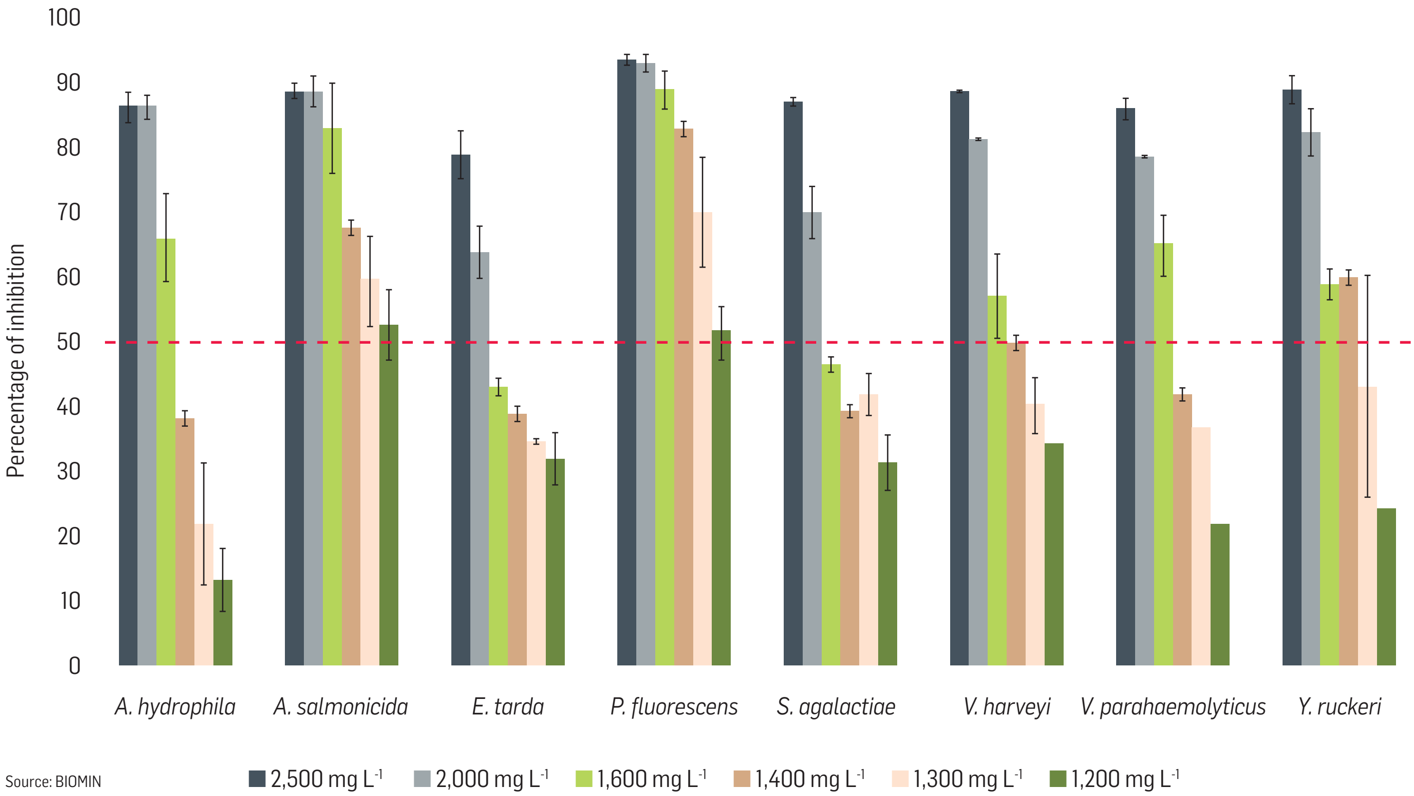
Organic acids, or combinations of acids, are an efficient tool for improving growth performance, gut morphology and pathogen control in aquaculture. Recently researchers have focused on the role of organic acids and their salts to prevent and control diseases with great success. They demonstrated, for example, that dietary supplementation with organic salts, such as propionate and butyrate, improved gut morphology under hypoxia and reduced enteritis symptoms (in high soya bean meal diets) in *O. niloticus* (Tran-Ngoc *et al.*, 2016). Similarly, scientists have demonstrated the very strong anti-microbial effect of organic acids under challenge with *Streptococcus agalactiae* (Ng *et al.*, 2009) and a high potential to exert beneficial effects on growth, nutrient utilization and disease resistance in tilapia.

While the effects of organic acids on pathogenic bacteria are not yet fully clear, it is commonly understood that they can exert either bacteriostatic or bactericidal effects depending on the physiological status of the organism and the physicochemical characteristics of the environment. Undissociated organic acids are lipophilic and can easily bypass the plasma membrane of bacteria. Once inside the cells, where pH levels are usually more neutral than in the outer environment, organic acids dissociate in their anions and protons. Traditionally, it has been assumed that the cytoplasmic pH drop caused by this mechanism is the main toxic efficacy of organic acids. Recently, other toxicity mechanisms have been proposed such as the capability of these acids to interfere with cytoplasmic membrane structure and functionality, as well as interference with nutrient transport, electron transport and macromolecular synthesis inside the cells.

Scientists cultured a number of pathogens in growth medium, with and without the enhanced organic acid Biotronic® Top3 from BIOMIN. The pathogens were chosen based on their ability to cause widespread disease and high economic losses in aquaculture, and included *Aeromonas* spp., *Edwardsiella* sp., *Pseudomonas* sp., *Streptococcus* sp., *Vibrio* spp. and *Yersinia* sp. Researchers observed that Biotronic® Top3 effectively reduced the growth of all pathogens (*Figure 1*).

Biotronic® Top3 was most effective against Gram-negative pathogens, although inhibition of *Streptococcus* was also observed. This is not surprising, since the formulation contains a unique BIOMIN® Permeabilizing Complex, specifically designed to weaken the outer membrane of Gram-negative bacteria.

**Figure 1.**
Growth inhibition of aquatic pathogens by Biotronic® Top3




Source: BIOMIN

**Autolyzed yeast (containing the cell walls and available nutrients) is well known in the aquaculture industry to support immune defense mechanisms.**

## Choosing a science-backed solution

The organic acid market within aquaculture is vast, and choosing the correct solution can be confusing. It is important that products are assessed using both *in vitro* and *in vivo* models. A recent peer-reviewed publication demonstrated how Biotronic® Top3, an enhanced acidifier, can be used to reduce pathogens and improve disease resistance in aquaculture (Menanteau-Ledouble *et al*. 2017).

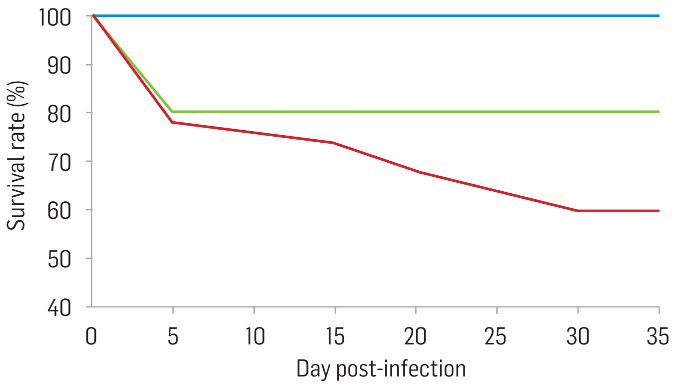
In one *in vivo* study, specific pathogen free (SPF) rainbow trout (*Oncorhynchus mykiss*) were split into two groups, and received either a commercial feed or the same feed supplemented with Biotronic® Top3. After 25 weeks, fish were artificially infected with *Aeromonas salmonicida* by intraperitoneal (IP) injection, immersion and cohabitation. For quality control purposes, fish in both treatments were also 'mock' infected to take into account background mortality. Once the infection had taken its course, the survival rate was calculated (*Figure 2*). In control tanks, mortalities were observed immediately indicating the virulence of the pathogen. In the Biotronic® Top3 treatments, much slower death rates were seen, indicating that the infection could be slowed down. This may benefit fish farmers as they can identify and treat diseases before incurring huge losses. After 35 days of challenge, Biotronic® Top3 supplemented fish showed a considerably higher survival rate (80%), compared to just 60% in control tanks, indicating the protective capabilities of Biotronic® Top3. Furthermore, the rainbow trout that received Biotronic® Top3 had a significantly higher survival rate (70%) than those not receiving the supplement (25%) when challenged via IP injection.

## Autolyzed yeast to enhance marine fish immunity (*Lates calcarifer*)

The immune system is a set of cellular and humoral components used to defend the body against foreign substances, such as microorganisms, toxins or malignant cells. They respond to factors such as endogenous or exogenous components that stimulate the immune system. The fish immune system is divided into innate and adaptive (memory), both further divided into cell mediated defense and humoral factors (soluble substances). Today, it is known that these systems work together in order to destroy invaders or to trigger defense processes. The innate system includes all components present in the body before the appearance of the pathologic agent and acts as the first line of defense with a faster reaction than the specific system. Among these components are the skin as a physical barrier, the complement system, the antimicrobial enzymes, the interleukins, the interferons and the organic defense cells, such as granulocytes, monocytes, macrophages and natural killer cells (Bayne and Gerwick, 2001; Ellis, 1999; Magnadottir *et al*., 2011).

Autolyzed yeast (containing the cell walls and available

**Figure 2.**
Survival curves of fish during pathogen challenge. Data represents the average mortality across three infection routes




Source: BIOMIN

**Figure 3.**
Asian seabass (*Lates calcarifer*)

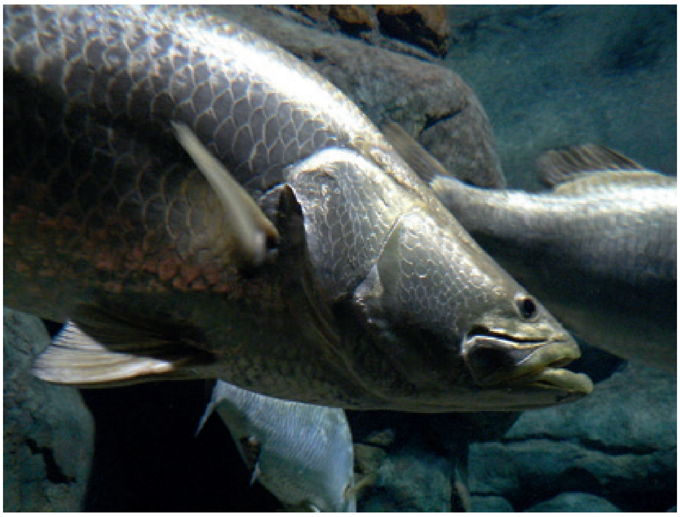


Photo courtesy of David Bal

**Figure 4.**
Survival rate of Seabass (*Lates calcarifer*) after *S. iniae* challenge

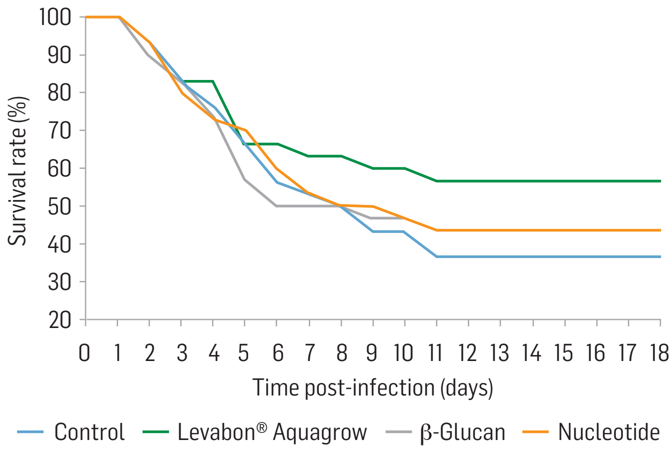



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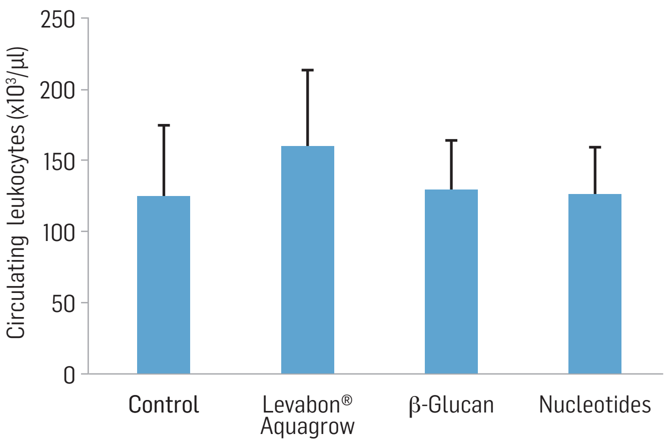
**Figure 5.**
Circulating leukocytes (white blood cells) after eight weeks of feeding experimental diets and prior to pathogen challenge




Source: BIOMIN

nutrients) is well known in the aquaculture industry to support immune defense mechanisms. Autolyzed yeast consists of concentrations of yeast cells that are allowed to die and break up, so that the endogenous enzymes of the yeast break their proteins down into simpler compounds which are then available for animals (e.g. amino acids, peptides, nucleotides). Autolyzed yeast cell walls contain mannan-oligosaccharides (MOS), β1,3 and β1,6 glucan, chitin and nucleotides. β-glucans are glucose-based polysaccharides that have an immune-stimulant effect in aqua species. They activate several immune cells including macrophages, neutrophils, monocytes, natural killer cells and dendritic cells. MOS have three main modes of action: improvement of gastrointestinal health, modulation of the immune system and pathogen absorption.

A study was conducted to evaluate the effect of several immune-stimulants in Asian seabass (*Lates calcarifer*; *Figure 3*). A total of four treatments were tested: a control (commercial feed), the commercial feed supplemented with Levabon® Aquagrow (autolyzed yeast), the commercial feed supplemented with β-glucan, and the commercial feed supplemented with nucleotides. After eight weeks, fish were artificially infected with *Streptococcus iniae* by IP injection at $10^7$ CFU/ml. The results showed that in control tanks, the survival rate was only 37% 11 days post-challenge. The treatment containing the autolyzed yeast Levabon® Aquagrow gave the highest survival rate at 57%. Single immune-stimulants (β-glucan and nucleotides) showed an intermediate survival rate of 43% (*Figure 4*).

Fish fed Levabon® Aquagrow had higher circulating white blood cells (*Figure 5*). Considering the important protective role leukocytes play, it is not surprising that fish with higher


numbers of these immune cells can fight pathogens more effectively, improving survival.

## Conclusion

Disease outbreaks are a persistent threat to the profitability of aquaculture farms. Dietary supplementation with the organic acid blend Biotronic® Top3 can improve survival in trout during a challenge with *Aeromonas salmonicida* but also inhibits the growth of a wider range of Gram-negative and Gram-positive bacteria pathogens. Acidifiers can improve gut health, increase nutrient utilization by reducing the pathogen load, and increase disease resistance without compromising growth performance.

Additionally, several immune-stimulant substances have demonstrated a positive improvement on the survival rate of Asian seabass after a bacterial disease challenge with *Streptococcus iniae*. In this study, the autolyzed yeast Levabon® Aquagrow containing the full blend of immuno-stimulants had better efficacy than the single β-glucan or nucleotide application. For aquaculture producers who want to avoid the sub-therapeutic use of antibiotics, Biotronic® Top3 and the autolyzed yeast Levabon® Aquagrow offer an interesting alternative to traditional pathogen control medication, opening the door to higher profitability.

A version of this article was originally published in International Aquafeed magazine.

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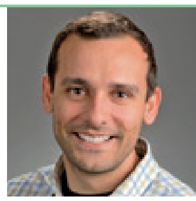
# Mycotoxin Management in Livestock Production: A Model for Aquaculture?



**Rui A. Gonçalves MSc**
Scientist

Future growth and sustainability of the aquaculture industry depend on the sector's ability to identify alternative sources of protein to substitute fishmeal in aquafeeds. Consequently, many new alternatives are available, e.g. insect meal, macroalgae meal or single-cell protein. However, high costs and limited availability are still challenges to overcome. Plant-based meals seem to be one of the most promising and viable solutions, but a common problem is the presence of mycotoxins.

## Mycotoxin occurrence

The first big difference between livestock and aquaculture production is the level of knowledge about mycotoxin occurrence and co-occurrence in the plant feedstuffs used to make the diets. Only recently has interest in mycotoxin contamination in aquafeeds started to grow, so know-how about mycotoxin occurrence in aquafeeds is still being accumulated. In the past, small amounts of plant meals were included in the diets of carnivores and herbivores, which has increased the disregard for mycotoxin threats in aquafeeds. Due to the novelty of the topic, and contrary to the livestock industry, the contamination of aquaculture feedstuffs with mycotoxins is, in general, often neglected. There is a growing awareness of mycotoxin contamination in aquafeeds. However, we are still far from having solid knowledge of the mycotoxin contamination patterns in aquafeeds, and how the type of plant meal used influences it.

## IN BRIEF

- New alternative sources of protein for aquaculture diets are now available, many of them derived from plants.
- Plant-based protein sources are often contaminated with mycotoxins, a relatively unknown and often overlooked anti-nutritional factor in the aquaculture sector.
- Symptoms of mycotoxicosis are less evident in fish and shrimp species compared to terrestrial livestock species.
- Regular testing of feed for mycotoxins will help identify threats and enable the correct mitigation strategy to be employed to keep contamination below sensitivity limits.

## Tip #1: Survey your plant meals for mycotoxins to avoid any possible risk.

### The wrong information may lead to employing the wrong strategies

One of the main misconceptions deeply entrenched across the aquaculture industry is that the majority of mycotoxin issues result from poor storage conditions leading to aflatoxin contamination. It is true that poor storage conditions can lead to the growth of *Aspergillus* spp. and *Penicillium* spp., which can ultimately lead to the production of aflatoxins and ochratoxin A. However, BIOMIN has observed that most of the mycotoxins found in aquaculture finished feeds are from *Fusarium* spp., i.e., resulting from field contamination of the raw materials used to produce aquafeeds. In this case, this mainly concerns deoxynivalenol (DON) and fumonisins. In some cases, aflatoxins continue to represent a challenge, especially in tropical countries and/or when storage conditions are inadequate.

## Tip #2: Correctly identify the mycotoxin(s) in your diet or raw material in order to implement the correct management plan.

### How do I know if my fish/shrimp are being exposed to mycotoxins?

Mycotoxins are structurally very diverse. This characteristic generates a wide range of symptoms in mycotoxin-affected animals, ranging from decreases in production efficiency to increases in mortality. In aquaculture, symptoms are generally unspecific, which makes accurate diagnosis difficult. The diagnosis of mycotoxicoses in farm animals is further complicated for two reasons. First, the synergistic effects of multiple mycotoxins in feeds create a different pattern of symptoms. Second, mycotoxins are responsible for suppressing the immune system, which allows opportunistic pathogens to colonize, prompting the display of secondary symptoms in the host. Sensitivity to mycotoxins varies greatly between species and is dependent on several factors that can modify the expression of toxicity including age, gender, nutritional and health status prior to exposure, and environmental conditions.

The situation is already very complex, but in addition to this we must consider the 138 different fish species and 38 shrimp species (FAO, 2011), with different feeding behaviors (herbivorous, omnivorous and carnivorous) and inhabiting different environments (freshwater, brackish water, marine). This high number of variables tends to dilute scientific output from all aquaculture research, not only in the field of mycotoxins. The low number of experts working with mycotoxins in their research compounds the problem, making it more difficult to have comprehensive diagnoses on the effects of mycotoxins in the main species.

Some reports describe clinical signs for the most common mycotoxins (Anater *et al.*, 2016), however, most of them are generalist parameters and can be attributed to any diverse pathologies or challenges e.g. anti-nutrition factors or lectins in the diet, or environmental changes (bacteria, environmental toxins). Some of the parameters referred to above include reduction in growth performance, alteration of blood parameters (erythrocyte/leucocyte count), changes in blood enzyme levels (Alanine Aminotransferase (ALT), Aspartate Transaminase (AST) or Alkaline Phosphatase (ALP)), alterations to the liver or the suppression of immune parameters.

Two notable exceptions are aflatoxicosis (yellowing of the body surface, (Deng *et al.*, 2010)) and ingestion of fumonisin (alteration of the sphinganine to sphingosine ratio (sa/so)

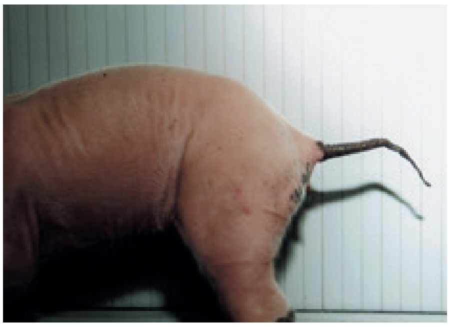
**Figure 1.**

Photographs illustrating classic clinical signs of mycotoxin ingestion in livestock and aquaculture production. Photographs i-iv show easily identifiable mycotoxicoses in poultry and swine. Photographs v and vi show animals fed DON at considerably high doses with no macroscopic signs of disease except anorexia (which could be attributed to other causes in a field situation).

**i.** Leg weakness in poultry caused by DON ingestion.

**ii.** Splay legs in piglets caused by zearalenone ingestion.

**iii.** Oral and dermal lesions in poultry caused by ingestion of T-2 toxin.



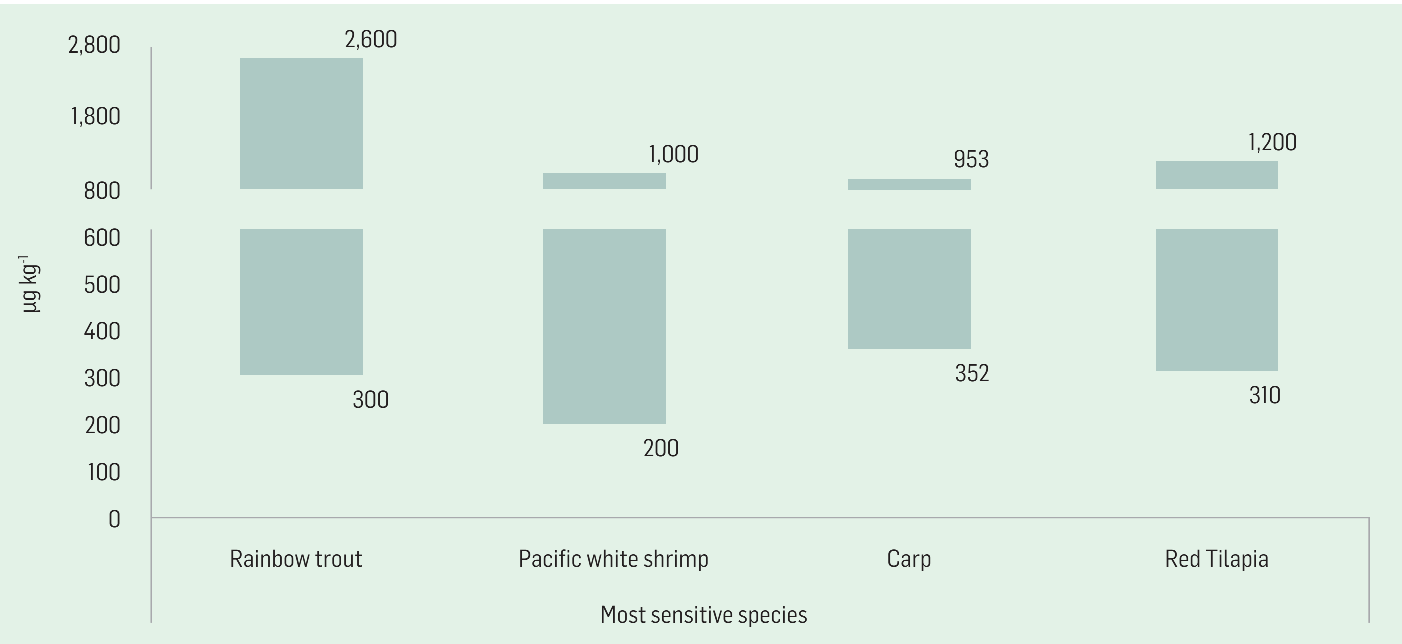
**iv.** Dermal lesions/necrosis in piglets tails caused by DON ingestion.

**v.** Rainbow trout fed non-contaminated (left), 4 ppm DON (middle) and 11 ppm DON (right). None of the treatments, even 11 ppm DON, considered a very high dose for rainbow trout, showed any observable clinical signs.

**vi.** The liver of fish fed 11 ppm DON does not show any macroscopic lesions, and the hepatosomatic index was similar to the control group (Gonçalves *et al.*, 2018).

**Figure 2.**

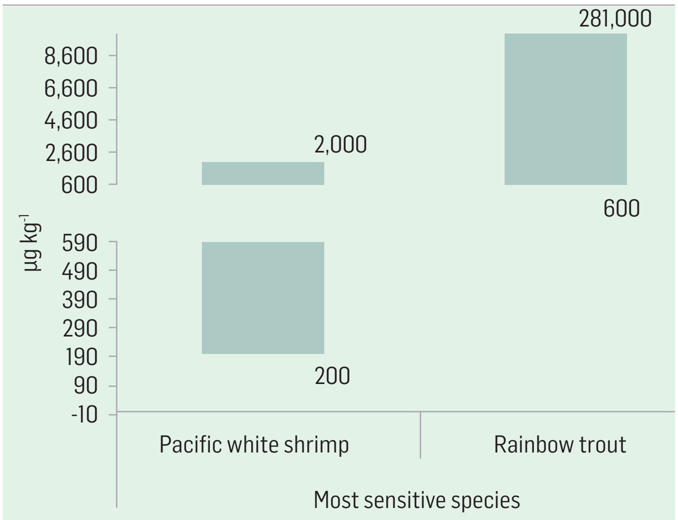
Sensitivity levels to DON of some sensitive species. DON has been studied in several important aquaculture species including rainbow trout, which is the most sensitive species, and white leg shrimp.




Sources: Hooft *et al.*, 2011 (Rainbow Trout (*Oncorhynchus mykiss*)); Tola *et al.*, 2015 (Red tilapia (*Oreochromis niloticus x O. Mossambicus*)); Pietsch *et al.*, 2014 (Carp (*Cyprinus carpio, L*)); Trigo-Stockli *et al.*, 2000 (White leg shrimp (*Litopenaeus vannamei*)).

**Figure 3.**

Sensitivity levels to fumonisins of some sensitive species. Fumonisins have not been extensively studied in aquaculture species, however, the few studies available indicated that white leg shrimps and rainbow trout can be sensitive to fumonisins in feed.




Fumonisins are the sum of $FB_1$ and $FB_2$.

Sources: García-Morales *et al.*, 2013 (White leg shrimp); Meredith *et al.*, 1998 and Riley *et al.*, 2001 (Rainbow trout).

(Tuan *et al.*, 2003)). Only aflatoxicosis can be visually identified so to correctly diagnose a change in the sa/so ratio, blood or haemolymph samples need to be collected and analyzed.

Compared to livestock, there is a lack of any clear, clinical signs of mycotoxin ingestion in aquatic species (*Figure 1i-v*).

## Tip #3: Keep a detailed and up-to-date record of your farm activities

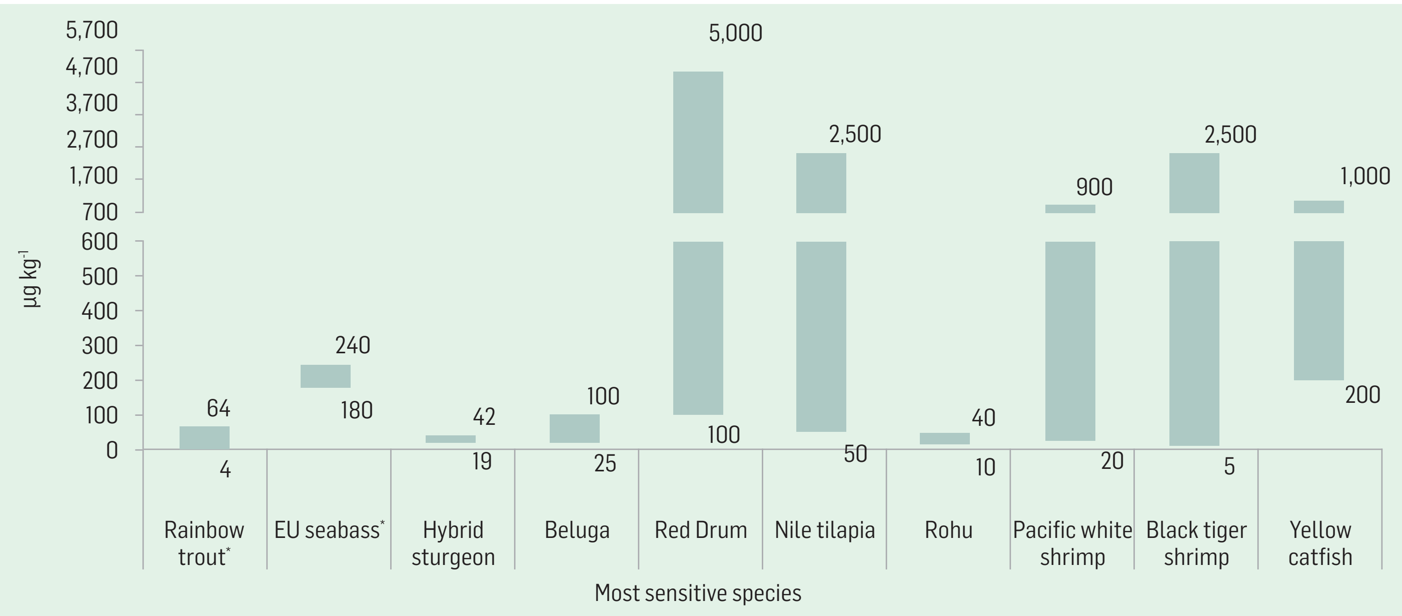
The lack of any clear clinical signs of mycotoxicoses makes it very important to have a rigid mycotoxin management plan and a good record of farm activities. For example, an up-to-date record of environmental parameters (salinity, temperature, N-compounds, oxygen) and feed management (feed intake, identification of feed batches) could be fundamental to identifying the causes of a sudden decrease in feed intake or growth performance or an increase in mortality. While analyzing environmental and feed management parameters, you may also consider mycotoxin contamination depending on the success of your mycotoxin management plan.

## Impact of mycotoxins: Are my contamination levels critical?

In aquaculture, it is common practice to study the impact of anti-nutritional factors (ANFs) present in the plant meals, and try to overcome these limitations. However, mycotoxins are often overlooked as ANFs. It is not yet common practice in academia to evaluate the raw materials used to formulate test diets for the presence of mycotoxins. As a result, when comparing to livestock species, much less is known about the effects of mycotoxins in aquaculture species. The efforts of the aquaculture scientific community are even more diluted when taking into account the much higher number of aquaculture species compared to the number of livestock species. As reported previously, sensitivity to mycotoxins

**Figure 4.**

Sensitivity levels to aflatoxins for some sensitive species. Aflatoxins have been extensively studied in farmed fish and crustacean species due to the toxicity of $AFB_1$. Several species are extremely sensitive to aflatoxins. While aflatoxin contamination is more common in tropical countries, the global trade of raw materials and aquaculture feeds could potentially export the occurrence of mycotoxins to other regions.




Sources: El-Banna *et al.*, 1992, Cagauan *et al.*, 2004, and Selim *et al.*, 2014 (Nile tilapia (*Oreochromis niloticus*)); El-Sayed and Khalil, 2009 (EU Sea Bass (*Dicentrarchus labrax L.*)); Bintvihok *et al.*, 2003, and Boonyaratpalin *et al.*, 2001 (Black tiger shrimp (*Penaeus monodon Fabricius*)); Ostrowski-Meissner *et al.*, 1995 (White leg shrimp); Wang *et al.*, 2016 (Yellow catfish (*Pelteobagrus fulvidraco*)).

**The lack of any clear clinical signs of mycotoxicoses makes it very important to have a rigid mycotoxin management plan**

varies greatly between species and is dependent on several factors which can modify the expression of toxicity including age, gender, nutritional and health status prior to exposure and environmental conditions. However, for some species we can already provide some advice. The figures on pages 12 and 13 show some of the sensitivity levels (minimum and maximum) of DON (*Figure 2*), fumonisins (*Figure 3*), and aflatoxins (*Figure 4*).

## Tip #4: Ensure mycotoxin contamination stays below sensitivity levels.

Most published studies address the effects of single mycotoxin contamination. Thus, it is assumed that values reported in the literature are quite conservative when taking into account that most aquafeeds are contaminated with more than one mycotoxin (Gonçalves *et al.*, 2016, 2017, 2018). The interaction between several mycotoxins might decrease the sensitivity levels reported.

There are still several gaps that need to be addressed in order to understand how to better manage mycotoxin risks in aquaculture. In recent years, the awareness of mycotoxin-related issues within the aquaculture industry has grown significantly. This is driven by increasing scientific evidence of the negative impacts of mycotoxins in aquatic species, and by frequent reports of the prevalence of mycotoxins in many raw materials.

## Aquaculture: raised in a complex environment

One of the first challenges faced in aquaculture production is the environment where the fish lives, breathes, eats and defecates: the water. In aquaculture, fish and shrimp live in close connection with the surrounding environment. Through the ingestion of water, aquatic farmed animals are constantly exposed to pathogens and environmental stress. There are approximately one million bacteria per milliliter of water in coastal areas, and in aquaculture systems, especially in intensive systems, this number will be considerably higher. Most bacteria found in aquatic environments are opportunistic, therefore the slightest unbalance in the animal's immune system will be used by these opportunistic bacteria to become pathogenic.

Due to this complex interaction between the environment and the animal, two main challenges emerge. First, the fact that the animals are in water makes the rapid perception of any macroscopic clinical signs (e.g. skin lesions, lethargy or other common visual control points) very difficult. This is particularly true for animals raised in highly turbid water (i.e. most of the aquaculture in Asia and South America). Second, as soon as an animal has a suppressed immune system or its immune defense is affected (e.g., a skin lesion), opportunistic bacteria rapidly infect. When the farmer realizes that something is wrong, there is a high probability that the animals are already contaminated with *Vibrio* spp. and, depending on the environment, many other bacteria. The question of whether the animals are sick due to the initial bacterial infection or whether they are the target of secondary opportunistic bacterial infections arises.

## Tip #5: Maintain high levels of biosecurity, ensure good feed management, and frequently monitor the health status and behaviour of your animals.

The best way to investigate production problems is to examine biosecurity and feed management. Keep information on environmental parameters (e.g., salinity, temperature, N-compounds, oxygen, rain), and feed management (e.g., feed intake, identification of feed batches, feed ingredients, purchase date, date of first use, and storage temperature and humidity). Take regular samples to assess growth performance. Make sure the samples are properly stored and updated to reduce reaction times to potential problems.

## Mycotoxin management in livestock production: a model for aquaculture?

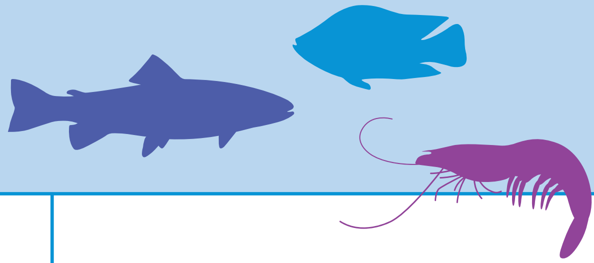
Both production sectors have their own challenges. However, the aquaculture industry may learn from the mycotoxin management plans already in place for livestock. Furthermore, some plant meals used in livestock are also commonly used in aquaculture, so there are benefits in sharing information regarding occurrence and co-occurrence levels.

Regarding sensitivity levels, in aquaculture there is a great disparity of vulnerability between the already studied species. Research should continue to better understand which are the most sensitive species and to which mycotoxins. We also need to understand why some species (e.g. channel catfish) are extremely resistant to some mycotoxins (in this case DON), to help us improve the resistance of other sensitive species.

This article originally appeared in International Aquafeed
References available on request.

# Top 5 Aquaculture Performance Indicators

There are numerous performance indicators used by aquaculture farms to measure the success of a production cycle. Here we take a closer look at the top 5 indicators according to the global BIOMIN aquaculture team.



## 1 Feed conversion ratio (FCR)

Feed is the biggest cost on aquaculture farms, so making sure that fish and shrimp properly utilize feed is a very valuable metric for producers.

The lower the number, the more efficiently the feed is being converted into weight gain. Producers and nutritionists work together to decrease the FCR, therefore getting more output for the same amount of input.

$$\text{FCR} = \frac{\text{feed given (g)}}{\text{animal weight gain (g)}}$$

## 2 Survival rate

Numerous factors affect the survival rate of aquatic species—many of them in the external water environment, which harbors many pathogens. Disease management is a constant priority in aquaculture production, and is carried out with the help of the survival rate metric.

During periods of disease challenge, producers may monitor survival rate over specific periods of time within the production cycle to determine the effectiveness of any treatment given.

$$\text{Survival rate \%} = \frac{\text{number of surviving animals at the end of the production cycle}}{\text{total number of animals at the beginning of the cycle}} \times 100$$

## 3 Body weight gain (BWG)

Fish and shrimp are traded on weight, so the heavier the animals, the more the producer will be paid. Fish and shrimp diets are formulated using the best ingredients to encourage weight gain.

Producers will monitor body weight gain throughout the production cycle by weighing a sample of animals and extrapolating the calculation for the whole population.

$$\text{Body weight gain (g)} = \text{final body weight (g)} - \text{initial body weight (g)}$$

## 4 Average daily gain (ADG)

Further to how much the animals grow, the rate at which the fish and shrimp grow is also crucial to know. Being able to predict when a crop will reach their final weight allows producers to forecast how many crops they can grow in a year, and helps with the purchase of inputs such as feed.

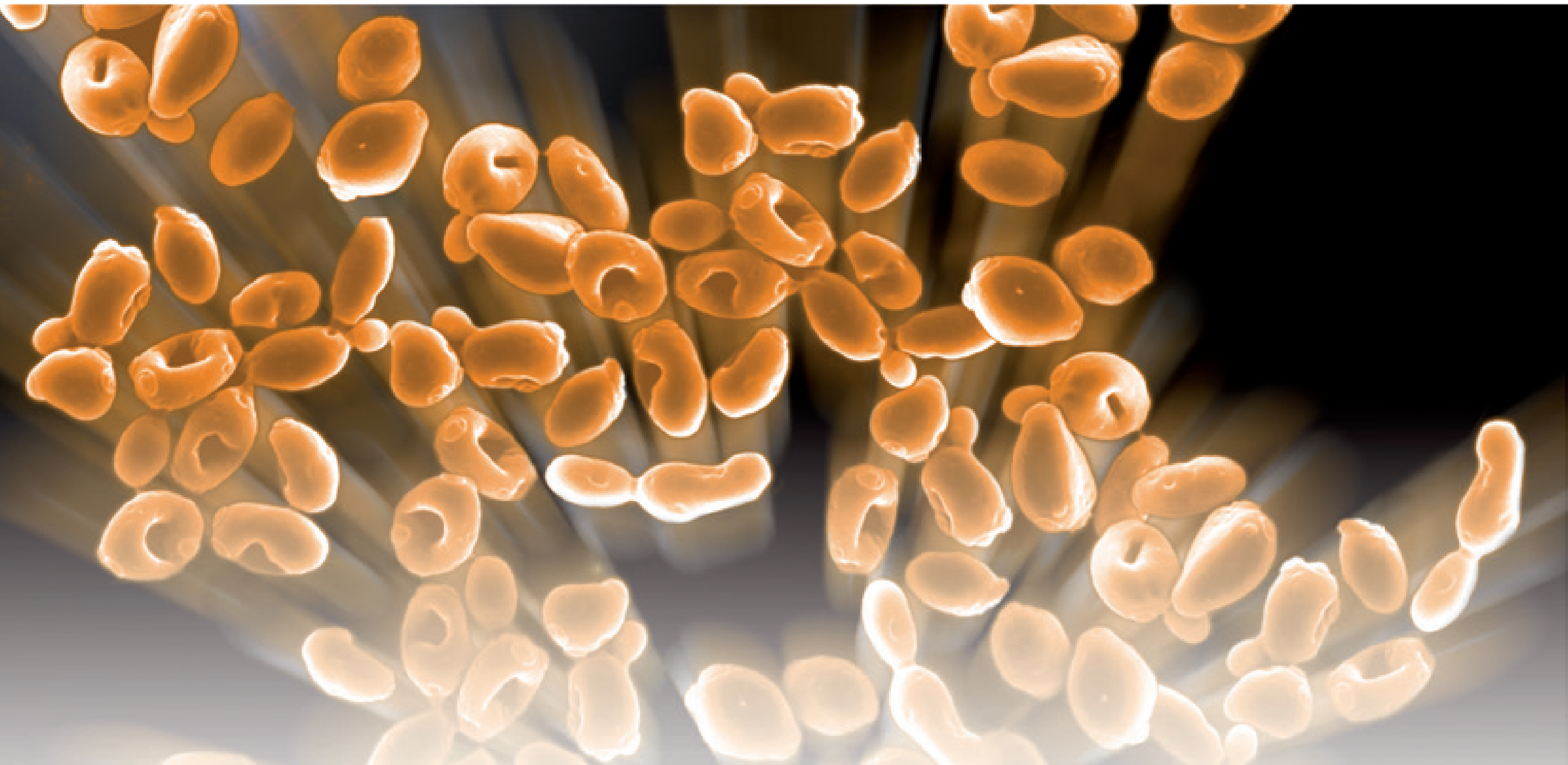
This metric can also be adjusted to calculate weight gain over different lengths of time as required by the production unit, e.g. the weekly growth rate (WGR).

$$\text{Average daily gain (g)} = \frac{\text{body weight gain (g)}}{\text{number of days}}$$

## 5 Yield / hectare

This performance indicator takes into account the stocking density and measures the output per unit of production space. It is typically measured in kg / ha but this varies depending on country and species.

$$\text{Yield / ha} = \frac{\text{total output (kg)}}{\text{total production area (ha)}}$$



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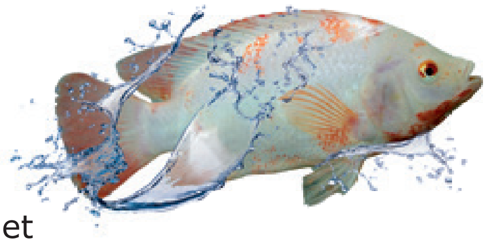

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