Aquaculture has grown consistently over the last decade, mainly in developing countries. Global aquaculture production will continue to grow, mainly as a result of improvements in production technology and increased demand for seafood. However, aquaculture faces several important challenges in terms of efficient use of raw materials, health management and environmental impact.

**Challenges in Aquafeeds**

Reliance on scarce and costly raw materials, such as fishmeal, and the optimal use of alternative ingredients constitute one of the main concerns in aquaculture. Consumer awareness about environmental sustainability also encourages producers to improve production performance through implementation of sustainable aquaculture practices. However, the use of less costly protein sources and low-nutrient dense diets most likely will lead to lower protein digestibility, greater amino acid imbalance and greater carbohydrate and fiber content. These can lead to inefficient nutrient use, resulting in increased feed usage and consequently greater production costs. In addition, sub-optimal animal performance leads to greater susceptibility to disease and greater ammonia emissions, which increases the ecological footprint.

Phytogenic feed additives, consisting of herbs, spices, extracts or other plant-derived compounds, have gained considerable attention as one answer to these challenges. Active ingredients such as phenols and flavonoids can exert multiple effects in animals, including improvement of feed conversion ratio (FCR), digestibility, growth rate, reduction of nitrogen excretion and improvement of the gut microbiota and health status.

**Phytogenics and Feed Efficiency**

The replacement of fishmeal by plant protein, whether for economic or sustainability reasons, can decrease feed efficiency and suppress an aquatic animal’s immune system. Plant raw materials are less digestible and have a negative impact on the gastrointestinal tract. The presence of undigested nitrogenous compounds in the intestine favors the formation of ammonia and biogenic amines by intestinal microbiota. These toxic compounds cause an imbalance of intestinal microbiota, resulting in inflammation and accelerated turnover of intestinal tissue, leading to poor performance and disease vulnerability.

Phytogenics stimulate digestive secretions, increase villi length and density and increase mucus production through an increase in the number of goblet cells. Through different strategies, phytogenics can improve feed digestibility, especially for proteins and amino acids, and increase disease resistance.

These effects are illustrated in a trial made with gilthead seabream *Sparus aurata* at the University of Algarve, Portugal. In this trial, fish were fed a low fishmeal diet (14 percent) supplemented with a matrix-encapsulated phytogenic feed additive (Digestarom®) to evaluate its efficacy on feed efficiency, body composition, pepsin activity and nutrient retention. Dietary supplementation with Digestarom® resulted in a significant reduction of FCR from 1.28 to 1.12 (Fig.1) and an improvement of weight gain and specific growth rates (from 1.76 to 1.82 percent/day). Inclusion of the phytogenic product in the diet significantly enhanced protein and fat retention (Fig. 2). There was a

(Continued on page 32)
significant reduction of total nitrogenous losses, clearly associated with lower metabolic losses (Fig. 3) and an increase in pepsin activity (Fig. 4).

In another trial, Digestarom® was tested on Pacific white shrimp Litopenaeus vannamei at the Pearl River Aquaculture Institute, China. In this trial, supplementation of shrimp diets with Digestarom® resulted in an enhanced shrimp weight (+14 percent) and improved feed conversion (-11 percent) (Fig. 5). Beyond the clear positive effects on improving feed efficiency, nutrient sparing could be a powerful solution to limit nitrogen discharge to the environment. Phytogenic feed additives decrease ammonia emissions through improved protein use, reducing the loss of nitrogen to the environment.

**Phytogenics as a Tool for Preventive Health Management**

It is well documented in the literature that phytogenics can have a positive effect on innate immunity factors such as nitric oxide and total complement, which are important indices of the ability of host immune defense mechanisms to manage infections. The active antimicrobial components of phytogenics can act in several ways: they may lyse the bacterial cell wall, block protein and DNA synthesis or inhibit enzyme secretions and interfere with the signaling mechanism of quorum sensing pathways. Pathogenic microorganisms have a major impact on commercial shrimp production. Any measures that support shrimp resistance to pathogenic challenges are urgently required.

In a trial carried out at the Pearl River Aquaculture Institute, the effect of Digestarom® on disease resistance in white shrimp was evaluated. In this trial, after a supplementation period of 56 days with Digestarom®, shrimp were injected with 0.2 mL of *Vibrio para-haemolyticus* at 5 x 10^7/mL. Time of death and quantity were recorded every 4 h. Shrimp fed Digestarom® had increased resistance against *V. para-haemolyticus* in comparison with the control (Fig. 6) and improved immune parameters and resistance to free radicals (Fig. 7). Compared to the control group, mortality of shrimp fed the matrix-encapsulated phytogenic feed additive was maintained at around 20 percent, while mortality rapidly increased in the control group.

**Phytogenics and Fillet Quality**

Another prospective area for the use of phytogenics in aquaculture is improvement of the anti-oxidative status of fish fillets. Fish, more than ever, are appreciated because some have high levels of unsaturated fatty acids, but these can be easily oxidized. Antioxidants are an important factor for limiting oxidation of fatty acids in the flesh after slaughter. Lipid oxidation can cause faint and pale color, low water holding capacity and reduction in nutritional quality of the fillet. Phytogenic products have the ability to scavenge free radicals by single-electron transfer and are thus excellent feed additives to improve fillet quality.

For this purpose, a trial with rainbow trout *Oncorhynchus mykiss* was carried out at a commercial trout farm in Karditsa, Thessaly, Greece. Malondialdehyde (MDA) was chosen as an indicator of oxidation stability and glutathione-S-transferase (GST) was used as an indicator of auto-oxidation. The levels of glutathione peroxidase and MDA were evaluated on the day of slaughtering and after five days of refrigerated storage. Inclusion of Digestarom®

### TABLE 1. Effects of experimental diets on the antioxidative status of trout fillets after refrigerated storage. Values in the same column with a different superscript symbol differ significantly (p<0.05). Source: Biomin trials (2012).

<table>
<thead>
<tr>
<th></th>
<th>MALONDIALDEHYDE (nmol/mg product)</th>
<th>GLUTATHIONE S-TRANSFERASE (nmol/min product)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 0 of storage</td>
<td>Day 5 of storage</td>
</tr>
<tr>
<td>Control</td>
<td>34.1</td>
<td>49.1^a</td>
</tr>
<tr>
<td>Digestarom® P.E.P. MGE</td>
<td>30.2</td>
<td>32.3^b</td>
</tr>
</tbody>
</table>
resulted in a significant decrease in MDA formation in trout fillets. In addition, GST activity was significantly greater in fillets of fish fed the phytogenic feed additive (Table 1).

**Phytogenics and Growth Promotion**

Low levels of antibiotics in animal feeds, known as antibiotic growth promoters (AGPs), result in antibiotic resistance and the emergence of so-called ‘superbugs.’ In recent years, antibiotic growth promoters have been banned from aquaculture production in nearly all countries. Farmers who still use AGPs have limited or no access to high-value markets. Phytogenics can act as natural growth promoters that improve diet palatability, stimulate appetite and increase feed consumption and growth performance. Phytogenics also induce transcription, increasing RNA, which leads to an increase in total amino acids available, therefore enhancing the production of proteins in cells.

The effect of phytogenics on growth performance was evaluated in a study carried out with channel catfish *Ictalurus punctatus* at the National Warmwater Aquaculture Center, Mississippi, USA. Catfish fed diets with Digestarom® had significantly enhanced weight gain (from 86 to 109 g) (Fig. 8) and FCR was reduced from 1.50 (control) to 1.36. Furthermore, fish in the control group reduced feed intake during days with large variations of water temperature, while fish fed Digestarom® maintained feed intake at an adequate level.

**Making Sustainability Profitable**

Given high feed prices, the pressure to optimize the use of alternative ingredients and consumer awareness about sustainability, it is imperative to improve the digestibility of commercial diets, optimize feed utilization and reduce nitrogen discharges and the use of AGPs. Phytogenic feed additives can improve feed digestibility, especially of proteins and amino acids, thus reducing feed costs and nitrogen output. It also can be a valuable tool for preventive health management, enhancing fillet quality or as a sustainable replacement for AGPs. Therefore, phytogenic feed additives are considered a valuable tool to support the profitability of aquaculture businesses, following guiding principles of sustainability (Fig. 9).

**Notes**

Rui Gonçalves, Technical Manager – Aquaculture, Biomin Holding GmbH, Erber Campus 1, 3131 Getzersdorf, Austria  
rui.goncalves@biomin.net

Gonçalo Santos, R&D Manager – Aquaculture, Biomin Holding GmbH, Erber Campus 1, 3131 Getzersdorf, Austria  
1 Digestarom® P.E.P. MGE, BIOMIN Holding GmbH, Austria