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Aquaculture

Science & Solutions

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The impact on the bottomline

Phytogenics in aquafeeds

Aquafeeds benefit from the inclusion of phytogenics as a nutrient-sparing tool

Aquaculture in focus

Marrying sustainability and profitability, and innovations for the future

Editorial

Feeding for profit

Formulated aquaculture feeds are among the most expensive animal feeds on the market. Due to the increasing cost of raw materials, fish and shrimp nutritionists face the challenge of formulating feeds that not only meet the nutritional requirements of animals but also minimize production costs, limit environmental impacts and enhance product quality. These challenges of course add considerable complexity to finfish nutrition.

The first consideration for the formulation and production of cost-effective diets is the quality of feed ingredients. The chemical composition (nutrient, energy) of the ingredient obviously plays a determinant role, but understanding their limitations (anti-nutrients and contaminants) is also of major importance to animal performance. The increase in mycotoxin contamination of raw materials used in aquafeeds represents a good example of such limitations, and should not be disregarded.

Improving the cost-effectiveness of aquafeeds is more than just a least-cost formulation. A complex cost-benefit analysis based on ingredient characteristics (composition, limitation and cost), manufacturing cost, fish performance (growth rate, FCR) and production constraints is necessary. It is therefore important to improve efficiencies and add value through other means, such as more precise feed formulation using a combination of cost-effective feed ingredients and additives that best enhance the animal's health and performance.

At Biomin, we are continuously working to find effective solutions based on sound scientific knowledge that provides a basis for the development of optimal feeding concepts and economically viable aquaculture production. We hope you enjoy this issue of **Science & Solutions** for aquaculture.

Pedro ENCARNAÇÃO
Director Business Development

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Mycotoxins

and their economic impact on aquaculture

Over the past years, aquaculture has moved away from dependence on fishmeal as the main protein source, with increasing reliance on plant protein sources. What does this mean for mycotoxin exposure in aquatic animals?

Photo: Shutterstock/ Juan Gaertner

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With fishmeal and oil becoming increasingly expensive, the inclusion of terrestrial plant-based proteins in commercial aquaculture feeds has gained widespread acceptance. Even feeds for carnivore species are now formulated to contain more than 50-70% of plant-derived matter. The most common plant feedstuffs used in aquafeeds are soybean meal, canola, corn, cottonseed, peas/lupins, rice bran, cassava and wheat.

A common problem that arises from the use of plant ingredients is the presence of mycotoxins—toxic secondary metabolites produced by filamentous fungi which frequently contaminate agricultural commodities.

The Council for Agricultural Sciences and Technology (CAST) in 2003 estimated that 25% of the world's crop production was contaminated with mycotoxins; the Biomin Mycotoxin Survey, however, estimates that this contamination rate is much higher. With more plant-derived materials used in commercial fish formulations, the risk of mycotoxin exposure increases, affecting fish growth performance as well as product quality.

These toxins are mainly produced under warm and moist conditions typical of the tropical and subtropical countries where most aquaculture is practiced. Temperature resistant, mycotoxins are not destroyed under the heat and pressure of pelleting and extrusion.

The main five

In the annual Biomin Mycotoxin Survey for 2013, a higher number of samples tested were related to ingredients intended for the aquaculture industry. Such samples included corn, corn DDGS, soybean meal, wheat, wheat bran, rice bran, cassava and cottonseed. In addition, a specific survey for aquafeeds (fish/shrimp) from the Asian region was included.

The five most common mycotoxins found worldwide—aflatoxins (Afla), zearalenone (ZEN), deoxynivalenol (DON), fumonisins (FUM) and ochratoxin A (OTA)—were analysed in all of the samples.

Out of a total of 43 finished aquafeed samples collected from the Asian region, 77% were found to be co-contaminated with more than one mycotoxin. The highest incidence was observed for ZEN, as 63% of all finished feed samples contained this estrogen-like substance. Average Afla concentrations were also quite high at 37 ppb, with some samples showing values above 100 ppb.

Looking at the level of contamination in major ingredients, corn samples contained the highest average and maximum concentrations of ZEN among all samples. As expected, DON and FUM were the most frequently found mycotoxins in corn with a prevalence of 73% and 63%, respectively.

Table 1. Survey results for various ingredients and by-products.

Finished aquafeed	Afla	ZEN	DON	FUM	OTA
Number of tests	43	43	43	43	43
% positive	47%	63%	40%	19%	51%
Average of positive (µg/kg)	37	23	142	359	2
Maximum (µg/kg)	180	51	262	615	9
Corn	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	732	775	810	695	642
% positive	30%	36%	63%	73%	12%
Average of positive (µg/kg)	61	177	669	1,995	4
Maximum (µg/kg)	1,563	5,324	9,910	23,180	44
Corn DDGS	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	58	58	59	56	52
% positive	60%	52%	73%	79%	27%
Average of positive (µg/kg)	9	94	1,241	2,852	13
Maximum (µg/kg)	23	434	7,030	26,828	43
Soybean meal	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	50	55	55	52	51
% positive	16%	22%	11%	15%	12%
Average of positive (µg/kg)	2	27	428	226	2
Maximum (µg/kg)	6	99	1,680	549	4
Wheat	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	264	382	501	261	261
% positive	6%	12%	64%	7%	10%
Average of positive (µg/kg)	2	100	1,070	746	3
Maximum (µg/kg)	8	892	12,000	3,687	14
Wheat bran	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	57	63	56	58	47
% positive	2%	44%	95%	21%	21%
Average of positive (µg/kg)	2	28	2,111	336	2
Maximum (µg/kg)	2	91	11,008	610	4
Cassava	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	13	13	13	13	13
% positive	8%	23%	0%	38%	8%
Average of positive (µg/kg)	4	105	-	271	1
Maximum (µg/kg)	4	201	-	355	1
Rice bran	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	33	33	33	33	32
% positive	42%	64%	42%	42%	31%
Average of positive (µg/kg)	16	105	141	219	2
Maximum (µg/kg)	96	337	547	533	12.2
Cottonseed	**Afla**	**ZEN**	**DON**	**FUM**	**OTA**
Number of tests	14	10	10	9	9
% positive	57	10	10	22	56
Average of positive (µg/kg)	279	16	164	200	4
Maximum (µg/kg)	1081	16	164	257	15

Source: Biomin Mycotoxin Survey, 2013

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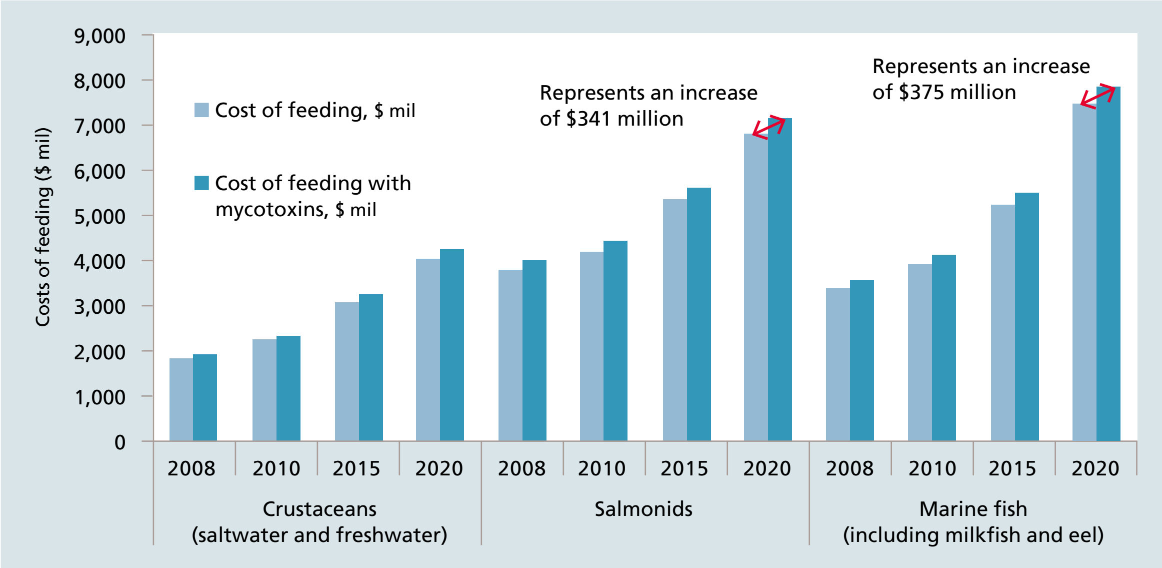
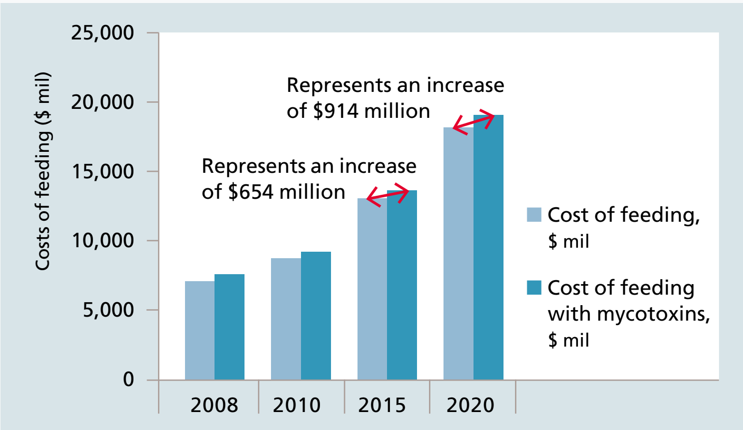
Figure 1. Economic impact of a 5% increase in FCR for crustaceans, salmonids and marine fish.



Sources: Tacon et al.*, 2011; Feed company reports and magazines; Peer-review literature on mycotoxin consequences on fish growth performance*

Figure 2. Economic impact of a theoretical 5% increase in FCR for freshwater fishes.



Source: Tacon et al.*, 2011; Feed company's reports and magazines; Peer-review literature on mycotoxins consequences in fish growth performance*

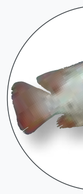
Table 2. Summary of the most important aquaculture species.

	Species
Freshwater fish	Fed carps (excluding silver carp, bighead carp and major Indian carps)
	Tilapia
	Catfish
	Crustaceans
	Miscellaneous freshwater fish
Salmonids	Salmon and trout
Marine fish	Milkfish
	Eel
	Crustaceans

The highest DON, FUM and OTA average values were observed in corn DDGS, as mycotoxin concentrations are known to increase after the distillation of corn for bio-ethanol production. The highest maximum FUM was observed in corn DDGS at 26,828 ppb.

DON is the most common mycotoxin found in wheat samples with an incidence of 64%. The highest average DON concentration was detected in wheat bran samples (2,111 ppb) which is twice the level found in wheat samples. Compared to wheat bran, rice bran samples contained higher average Afla (16 ppb) and ZEN (105 ppb).

The concentration of mycotoxins in soybean meal was relatively low compared to other cereals. Also the incidence of mycotoxins in cassava is relatively low. Cottonseed samples showed a high prevalence of Afla (57%). The highest Afla values were also determined in cottonseed (*Table 1*).



Mycotoxin impact on FCR

The biological effects of mycotoxins in aquatic species are thought to be directly linked to their concentration in the feed and to age and species. In aquaculture production, mycotoxins may, among other factors, influence growth performance and feed efficiency.

According to Tacon *et al.* (2011) the projected increase in aquaculture production until 2020 takes into account the increase in feeds used by different aquaculture species and improvements in FCR during this time period, as technology improves overall. This was done for the more representative aquaculture species (*Table 2*).

The authors' projected the theoretical economic

*With an FCR increase of 5%, total feed costs due to mycotoxins would increase to $5.2 billion, which is **$250 million in extra costs.***

Table 3. Economic estimation of extra costs in feeding due to mycotoxin contaminated feed for catfish production.

Year	Total production[1] ('000 tonnes)	% of aquaculture using feeds[1]	FCR_1	Total feeds ('000 tonnes)	Price of feed/ tonne[2] ($)	Cost of feeding ($'000)	FCR increase of 5%[3]	Feed needed to produce the same volume of fish ('000 tonnes)	Cost of feeding ($'000)	Extra costs due to mycotoxins ($'000)
2008	2,718	72%	1.5	2,935	400	1,174,176.00	1.58	3,082	1,232,884.80	**58,780.80**
2010	3,872	73%	1.5	4,240	400	1,695,936.00	1.58	4,452	1,780,732.80	**84,796.80**
2015	7,456	75%	1.4	7,829	400	3,131,520.00	1.47	8,220	3,288,096.00	**156,576.00**
2020	12,008	80%	1.3	12,488	400	4,995,328.00	1.37	13,113	5,245,094.40	**249,766.40**

'000 tonnes = thousand tonnes; $'000 = thousand US$
Sources: [1]Tacon et al., *2011; [2]Feed company reports and magazines; [3]Peer-review literature on mycotoxins consequences in fish growth performance*

losses due to the presence of mycotoxins in aquafeeds. These losses were calculated plus an average 5% increase in FCR (taking into account the existing literature on mycotoxins' impact on fish growth performance) and feeding costs (average values obtained from feed company reports and magazines) (*Figures 1 and 2*).

Taking the example of catfish production (*Table 3*), in 2020, it is expected that 80% of total production will utilize aquafeeds, with a total feed cost of $5.0 billion. Based on this production increase and a 5% increase in FCR, total feed costs due to mycotoxins contaminations can increase to $5.2 billion; that is, $250 million in extra costs are required to produce the same quantity of fish.

The Food and Agriculture Organization of the United Nations (FAO) reported a global production of fish of around 148 million tonnes for 2010 (with a total value of $217.5 billion). With an annual average increase of about 10% since 1984, compared to a 3% increase for livestock meat, aquaculture has become the fastest growing food production sector in the world.
However, sustaining such increasing rates of production requires a corresponding increase in fish feed production. As a consequence, aquafeed production is currently one of the fastest expanding agricultural sectors in the world. In 2013, aquafeed production was 59.9 million tonnes, up 17% from the previous year.

Further challenges

This simulation does not take into account the replacement of fishmeal on aquaculture diets. It is predicted that after 2015, catfish diets will not include fishmeal anymore, which will probably be replaced by plant proteins. Thus, there is a higher probability that catfish diets will be contaminated with mycotoxins. Even with a conservative 5% increase in FCR, the economic losses are highly significant.

Another important factor indirectly related to an increase in FCR, carbon footprint was not taken into account in this simple simulation, but will nonetheless have economic and social consequences.

The ingestion of mycotoxins decreases overall performance which may ultimately result in economic losses. Preventing mycotoxin-related diseases in the first place is surely more cost effective than treating ill animals. Mycotoxin risk management is therefore crucial in order to eliminate the effect of fungal toxins.

Photo: iStockphoto_Inga Ivanova

Phytogenics

A nutrient-sparing tool for efficient aquafeeds

Feed is the single largest cost item in aquatic production. Because of this, the aquaculture industry strives to reduce feed costs by buying cheaper feeds. Reformulating diets to include non-traditional feed sources may be necessary to fulfill this objective, and should be viewed as a worthwhile investment that yields returns for the producer.

Plant active ingredients can exert multiple effects such as antimicrobial action and direct reduction of gut bacteria.

Photos: Digitalpress-Fotolia, Picture-Factory-Fotolia

The increasing reliance on less costly protein sources and low nutrient dense diets will most likely see greater utilization of raw materials with lower protein digestibility, higher amino acid imbalance, and higher carbohydrate and fiber content. This can lead to an inefficient utilization of the nutrients in the feed, resulting in increased feed usage and costs to produce 1kg of lean fish, in addition to sub-optimal animal performance.

Nevertheless, when presented with accurate nutrient and energy utilization data, fish nutritionists, feed manufacturers and fish producers may balance the combination of cost effective feed ingredients and make use of certain feed additives that can improve nutrient utilization and enhance the animal's health and performance.

Phytogenics comprise a relatively young class of feed additives that are gaining interest within the aquaculture industry. Phytogenic feed additives (PFAs) are plant-derived substances which are added to the feed in order to improve animal performance. These plant active ingredients (e.g. phenolics and flavanoids) can exert multiple effects on the animal, such as antimicrobial action and direct reduction of gut bacteria, stimulation of gastric juices, support of liver function, anti-inflammatory and antioxidant properties. Due to their proven effects on improving feed efficiency, PFAs could be an important tool to reduce feed costs in the context of high prices of feed ingredients such as fishmeal (FM) and increasing reliance on cheaper raw materials.

Biomin has been conducting extensive research on the application of PFAs in aquatic species focusing on the improvement in feed efficiency and development of cost-effective diets. To test whether PFAs can be used as a nutrient-sparing tool in aquafeed formulations, a series of trials were conducted in different aquatic species.

Phytogenics with less fishmeal

One feeding trial was conducted in collaboration with Ningbo University (China) to evaluate whether a PFA (Digestarom® P.E.P. MGE) could be used as a tool to reduce the level of FM in shrimp diets.

The treatments consisted of 5 isoproteic diets (40% crude protein) with a positive control diet with 25% FM inclusion, and four test diets with two lower levels of FM (22% and 19%) with or without tDigestarom® P.E.P. MGE (*Table 1*). Each diet was randomly assigned to 5 replicates of 30 juvenile white shrimp (approximately 0.33±0.00g) and fed over 8 weeks.

The results indicated that the reduction in FM reduced shrimp performance with the control diet (25% FM) having the best performance. Weight gain, specific growth rate (*Figure 1*), feed conversion ratio (*Figure 2*) and protein efficiency were improved for shrimp fed the supplemented diets compared to the lower FM, unsupplemented diets. Analysis of midgut ultrastructure by transmission electron microscope indicated that shrimp fed the supplemented diets had an improved midgut microvilli structure compared to those fed the lower FM diets only (*Figure 3 & 4*). This translated to better nutrient

Table 1. Formulation and proximate composition of the experimental diet (% dry matter).

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Peruvian fishmeal	25.00	22.00	22.00	19.00	19.00
Soybean meal (solvent extracted)	28.00	31.00	31.00	32.00	32.00
Peanut meal (groundnut meal)	10.38	11.80	11.80	14.88	14.88
Brewer's yeast	3.00	3.00	3.00	3.00	3.00
Wheat flour	22.81	22.81	22.81	22.81	22.81
Soybean oil	1.42	1.50	1.50	1.59	1.59
Fish oil	1.42	1.50	1.50	1.58	1.58
Soy lecithin	2.00	2.00	2.00	2.00	2.00
Vitamin premix	0.50	0.50	0.50	0.50	0.50
Mineral premix	1.00	1.00	1.00	1.00	1.00
Calcium dihydrogen phosphate, Ca(H2PO4)2	1.50	1.50	1.50	1.50	1.50
Lysine	0.00	0.03	0.03	0.06	0.06
Methionine	0.00	0.03	0.03	0.06	0.06
Digestarom® P.E.P. MGE	0.00	0.00	0.02	0.00	0.02
Cellulose	2.97	1.33	1.31	0.02	0.00
Proximate composition (%)					
Moisture	9.04	8.90	9.28	9.25	9.45
Protein	39.43	39.71	40.12	40.08	39.98
Lipid	8.52	8.55	9.00	8.65	9.09
Ash	10.07	9.70	9.82	9.34	9.60
Cost $/tonne	985	960	969	933	942

Figure 1. Specific growth rate (SGR, %/day) of shrimp fed diets with different levels of fishmeal, with and without Digestarom® P.E.P. MGE supplementation.

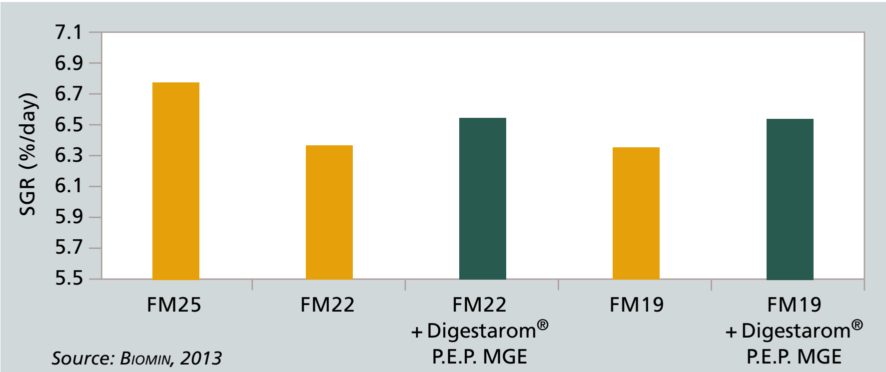
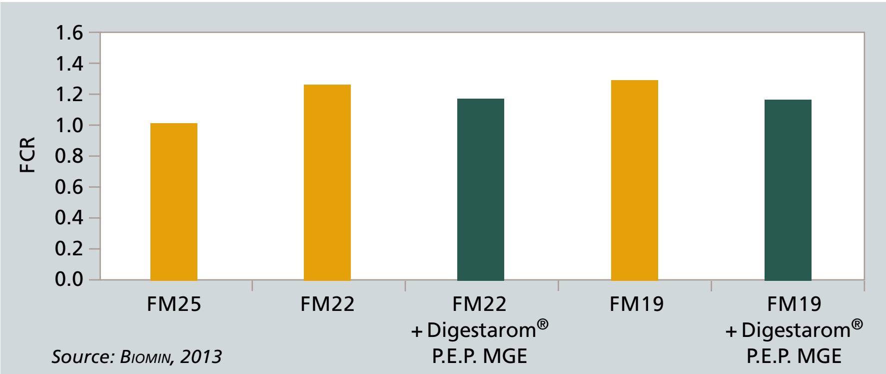


Figure 2. Feed conversion ratio of shrimp fed diets with different levels of fishmeal, with and without Digestarom® P.E.P. MGE supplementation.



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absorption and supported the highest performance as observed in the phytogenic supplemented group.

The performance improvement of the group given lower FM diets supplemented with Digestarom® P.E.P. MGE is an important result as part of a strategy to reduce costs.

Figure 3. Ultrastructure of midgut of shrimp fed the experimental diets. A) Control (25% FM). B) 22% FM. C) 22% FM + Digestarom® P.E.P. MGE (Transmission electron microscopy TEM, 8,900 times).

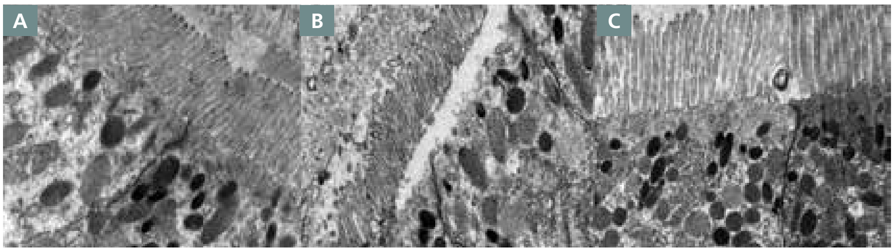

Figure 4. Ultrastructure of midgut of shrimp fed the experimental diets.
A) Control (25% FM). B) 19% FM. C) 19% FM + Digestarom® P.E.P. MGE (TEM, 8,900 times).

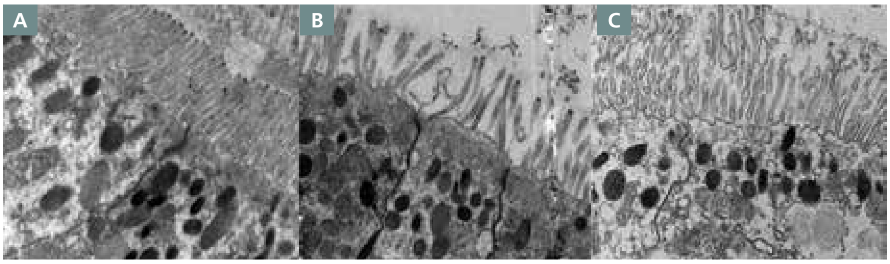

Table 2. Trial design to test the effects of Digestarom® P.E.P. MGE on the reduction of DP in the diets (% total feed).

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4
Cassava flour	12.0	12.0	14.0	14.0
Soybean meal	32.0	32.0	30.0	30.0
Wheat flour	13.6	13.6	13.6	13.6
Rice bran	26.0	26.0	26.0	26.0
Fishmeal	6.0	6.0	5.0	5.0
Meat & bone meal	7.0	7.0	8.0	8.0
Vitamin premix	0.3	0.3	0.3	0.3
Fish oil	1.5	1.5	1.5	1.5
Soybean oil	1.5	1.5	1.5	1.5
Methionine	0.1	0.1	0.1	0.1
Digestarom® P.E.P. MGE		0.02		0.02
Proximate composition %				
Moisture	9.3	9.4	9.1	9.1
Digestible protein	26.8	26.8	25.7	25.7
Lipids	6.6	6.6	6.7	6.7
Ash	9.5	9.5	9.6	9.6
Cost $/tonne feed	$503.6	$511.4	$487.8	$495.6

Phytogenics with less digestible protein

In another trial, the effects of Digestarom® P.E.P. MGE were tested on red tilapia feeds where digestible protein (DP) was reduced by 1%. Treatments consisted of 4 diets with 2 DP levels (26% and 27%). Each DP level was with or without supplementation with Digestarom® P.E.P. MGE at an inclusion level of 0.2g/kg feed (*Table 2*).

Each treatment had 4 replicates and 80 fish (initial weight 7.3 ± 0.0 g) randomly assigned to each of the 20 tanks (volume 120L). The experiment lasted for 56 days.

Trial results showed that a reduction in DP levels in the feed from 27% to 26% caused a slight loss in weight gain and final body weight and an increase in FCR. However, the inclusion of the phytogenic product was effective in offsetting any decline in fish performance (weight gain and FCR) observed in feeds with lower DP.

In economic terms, the cost of including Digestarom® P.E.P. MGE can be compensated by the reduction in feed costs achieved by the lower nutrient density ($504/tonne for the 27% DP vs. $496/tonne for the 26% DP + Digestarom® P.E.P. MGE). The economic returns on fish production were even further compensated by the improvement in feed efficiency on the supplemented diets resulting in a lower cost of production expressed in $/tonne fish produced. This is obtained when we take into account feed cost and FCR.

Thus, for the diet with 27% DP, the cost of feeding to produce 1 tonne fish is $664.80 ($503.60 x 1.32) while the cost for the 27% DP + Digestarom® P.E.P. MGE diet is $644.40 ($511.40 x 1.28). This means a reduction in costs of $20.40 per tonne of fish produced. Similar cost reductions were observed for the 26% DP diets—feed costs were $663.40 for the unsupplemented diet vs. $644.3 for the supplemented diet.

This shows that the phytogenic feed additive Digestarom® P.E.P. MGE can be used as a nutrient-sparing tool for more efficient and cost-effective diets.

WORLD NUTRITION FORUM

MUNICH 2014
15-18 October

SUSTAIN:
ABILITY

1. Sustain:ability = Profit:ability ?

The theme of sustainable aquaculture explores feed management and two important regions for aquaculture—tropical Asia and Norway. Presentations will marry two overarching themes in aquaculture farming—that of sustainability and profitability—to finally address the question: How may sustainable practices be profitable?

2. Future innovation

Innovation trends that drive the future of aquaculture are the focus of this session. Among the trends discussed are quorem sensing for pathogen control, the use of bacteriophages in aquaculture and functional aquafeeds. The session also covers the application of NutriEconomics® in aquaculture.

A tradition of the **World Nutrition Forum (WNF)** since 2010, the species-specific Breakout sessions address timely topics in aquaculture farming and other animal production sectors.

Each four-hour long Breakout session covers two topics. Sessions for each species are held in parallel on the afternoon of the first day (Thursday, 16 October 2014).

The World Nutrition Forum, sponsored by BIOMIN, is a premier biennial industry event where leading professionals, scientists and decision-makers gather to brain-storm and exchange ideas and strategic prospects on the future of animal nutrition. To be held in Munich, Germany, the WNF 2014 will explore the theme of "sustain:ability".

For up-to-date information, please visit **www.worldnutritionforum.info**.