Reducing Feed Cost in Tilapia Farming through Digestive and Metabolic Enhancement

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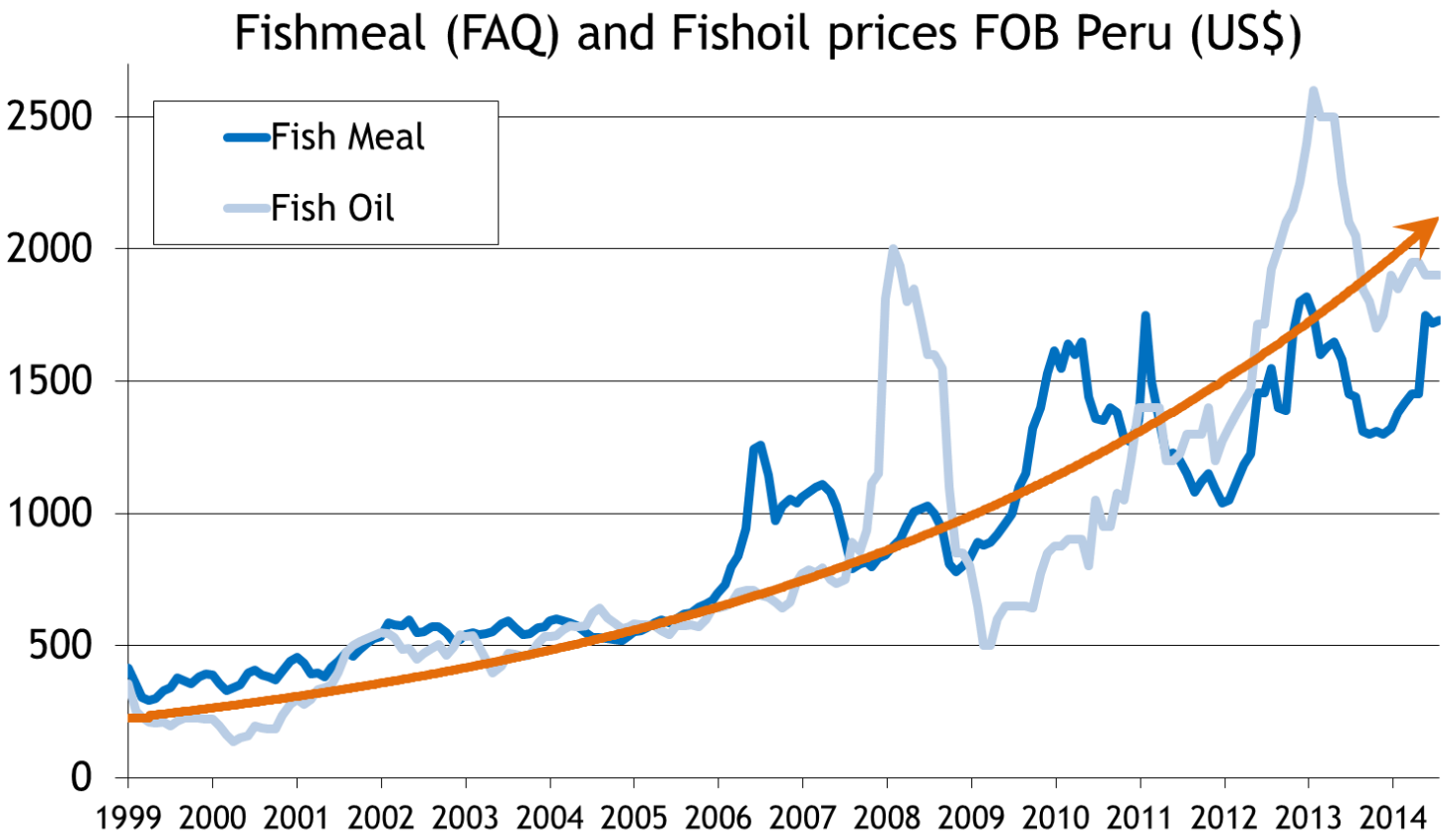
Challenges for the nutritionist



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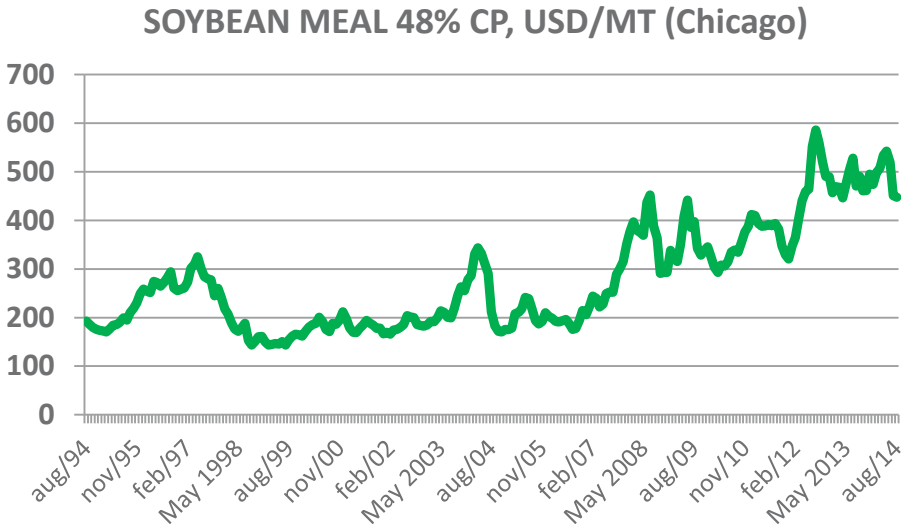
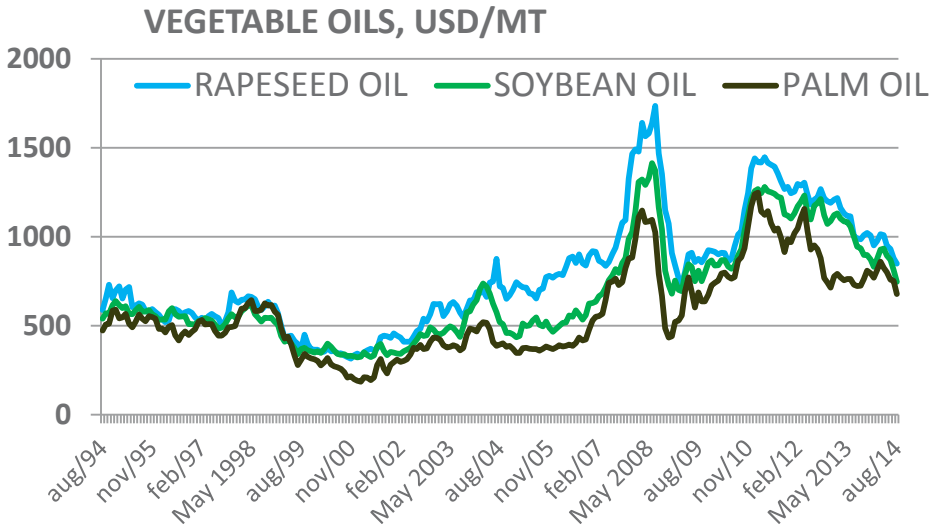
Agriculture commodities prices 1994-2014

Source: World Bank





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Improving feed utilization in aquaculture

- ⇨ **Enzymes**
  - Degrade non-starch polysaccharides (NSP)
  - Make phytate phosphorous available
- ⇨ **Herbal Extracts & Phytobotanical Compounds**
  - Stimulate enzyme & bile secretion
  - Improve gut health and modulate microflora
  - Reduce impact disease & parasites
- ⇨ **Organic Acids**
  - Enhance acidification of stomach, improving pepsine digestion
  - Bacteriostatic/bacteriocide activity
- ⇨ **Feed Emulsifiers**
  - Complement bile acid activity
  - Improve energy utilization
- ⇨ …

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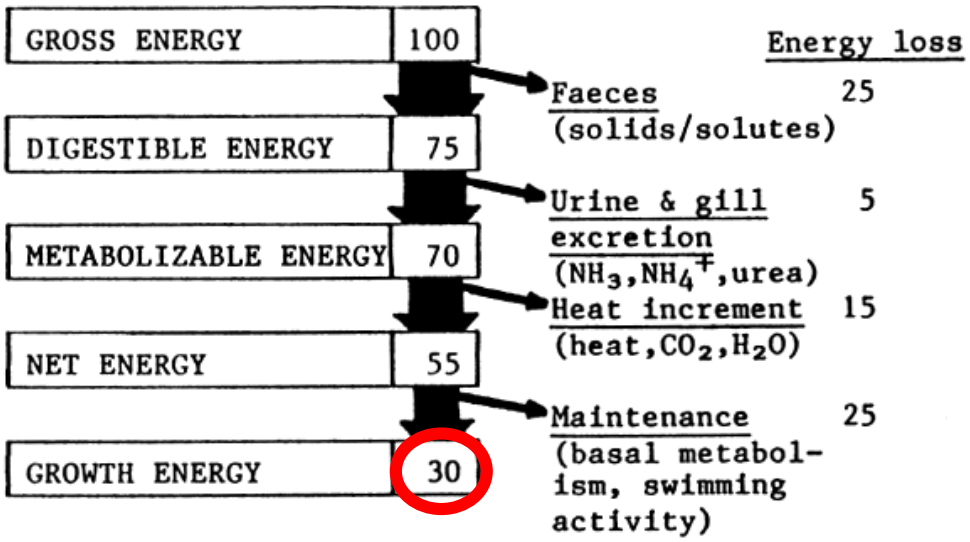
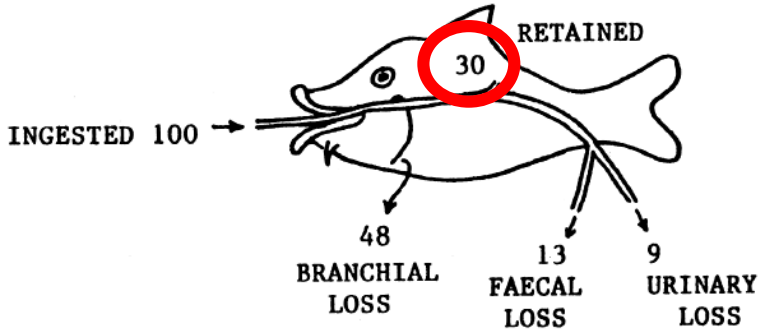
Promoting nutrient utilization in aquaculture: there is a lot to gain

Utilization of dietary energy in salmonids (after Luquet, 1982)





Nitrogen balance in fish (after Luquet, 1982)

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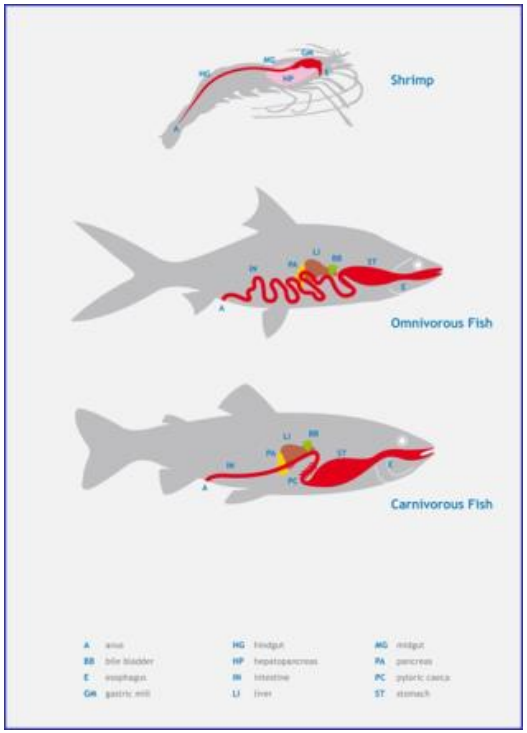
Species specific aqua additives

- Aquaculture species very different from livestock

- Aquaculture : wide range of species
  - Feeding biology
  - Digestive physiology
  - Culture methods
  - Feed formulations



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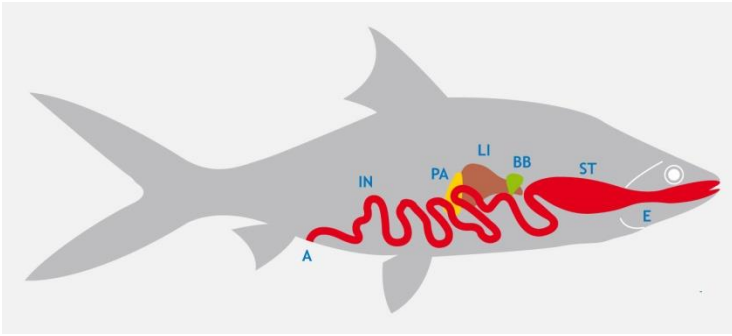
Omnivorous fish : challenges on feed efficiency

- Low cost ingredients
- Maximize nutrient digestibility
- Fileting yield: minimize feed cost per kg of filet
- Visceral fat deposition
- Reduce waste output into the environment



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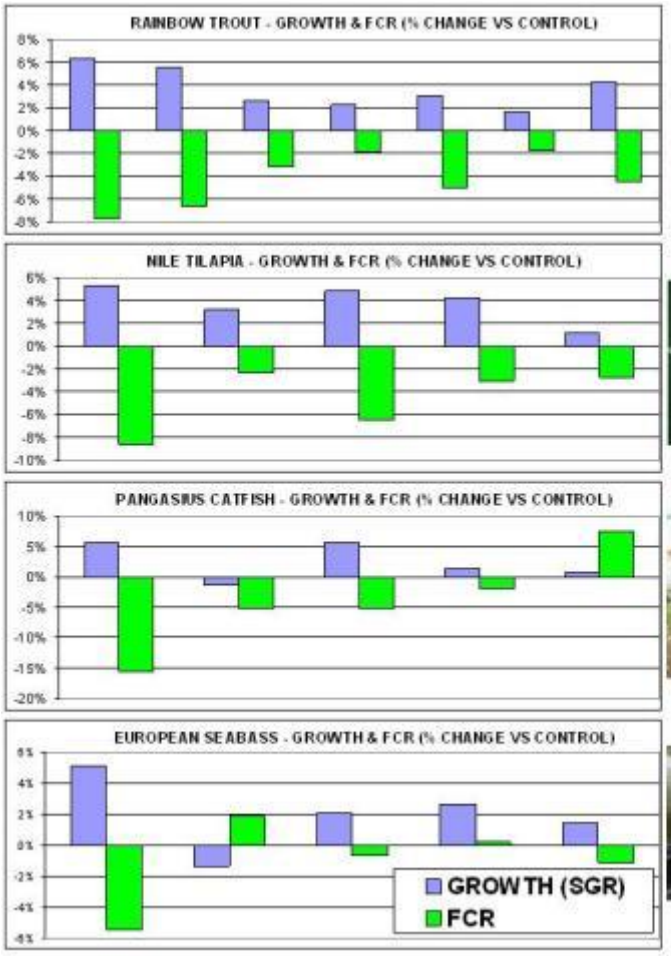
Species-specific screening for synergistic compounds



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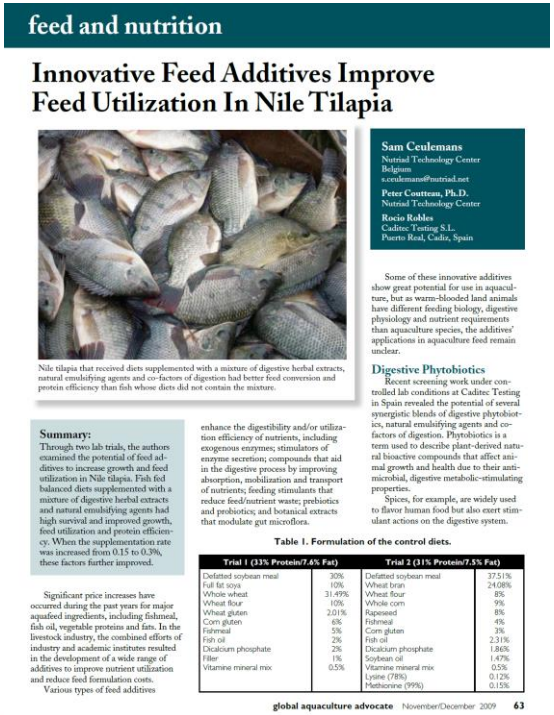
Development through feeding trials with *Tilapia*



feed and nutrition

Innovative Feed Additives Improve Feed Utilization In Nile Tilapia

Nile tilapia that received diets supplemented with a mixture of digestive herbal extracts, natural emulsifying agents and co-factors of digestion had better feed conversion and protein efficiency than fish whose diets did not contain the mixture.

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Summary:
Through two lab trials, the authors examined the potential of feed additives to increase growth and feed utilization in Nile tilapia. Fish fed balanced diets supplemented with a mixture of digestive herbal extracts and natural emulsifying agents had high survival and improved growth, feed utilization and protein efficiency. When the supplementation rate was increased from 0.15 to 0.3%, these factors further improved.

Significant price increases have occurred during the past years for major aquafeed ingredients, including fishmeal, fish oil, vegetable proteins and fats. In the livestock industry, the combined efforts of industry and academic institutes resulted in the development of a wide range of additives to improve nutrient utilization and reduce feed formulation costs.

Various types of feed additives enhance the digestibility and/or utilization efficiency of nutrients, including exogenous enzymes; stimulators of enzyme secretion; compounds that aid in the digestive process by improving absorption, mobilization and transport of nutrients; feeding stimulants that reduce feed/nutrient waste; prebiotics and probiotics; and botanical extracts that modulate gut microflora.

Some of these innovative additives show great potential for use in aquaculture, but as warm-blooded land animals have different feeding biology, digestive physiology and nutrient requirements than aquaculture species, the additives' applications in aquaculture feed remain unclear.

Digestive Phytobiotics

Recent screening work under controlled lab conditions at Caditec Testing in Spain revealed the potential of several synergistic blends of digestive phytobiotics, natural emulsifying agents and co-factors of digestion. Phytobiotics is a term used to describe plant-derived natural bioactive compounds that affect animal growth and health due to their antimicrobial, digestive metabolic-stimulating properties.

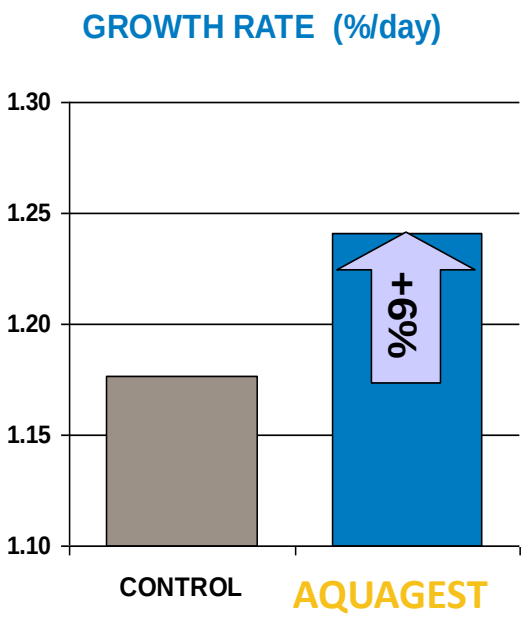
Spices, for example, are widely used to flavor human food but also exert stimulant actions on the digestive system.

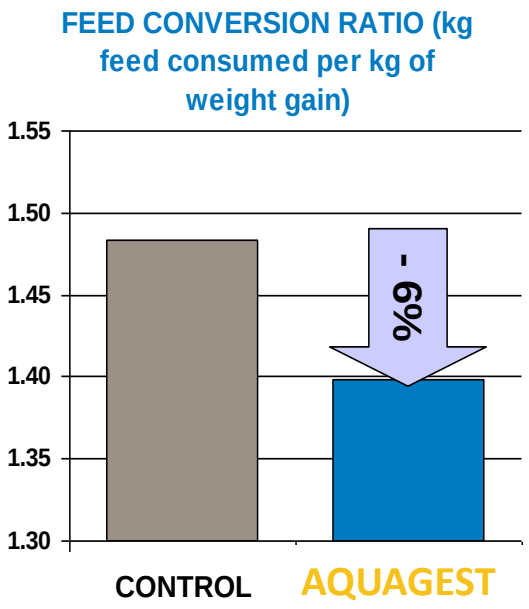
Table 1. Formulation of the control diets.

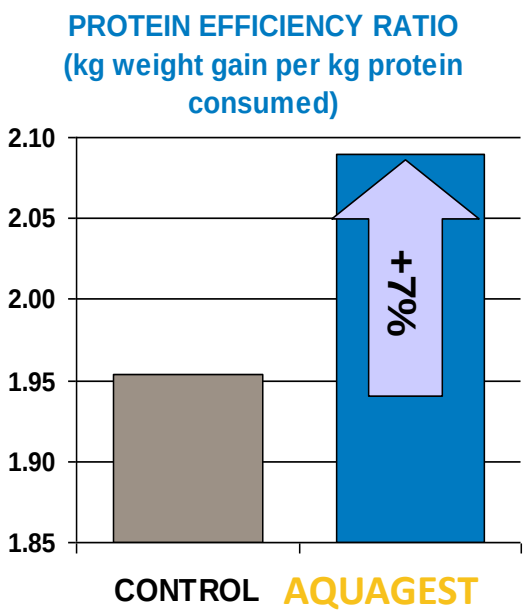
Trial 1 (33% Protein/7.6% Fat)		Trial 2 (31% Protein/7.5% Fat)	
Defatted soybean meal	30%	Defatted soybean meal	37.51%
Full fat soya	10%	Full fat soya	24.08%
Whole wheat	31.49%	Wheat flour	8%
Wheat flour	10%	Whole corn	9%
Wheat gluten	2.01%	Rapeseed	8%
Corn gluten	6%	Fishmeal	4%
Fishmeal	5%	Corn gluten	3%
Fish oil	2%	Fish oil	2.31%
Dicalcium phosphate	2%	Dicalcium phosphate	1.86%
Filler	1%	Soybean oil	1.47%
Vitamine mineral mix	0.5%	Vitamine mineral mix	0.5%
		Lysine (78%)	0.12%
		Methionine (99%)	0.15%

Ceulemans et al. (2009) Global Aquaculture Advocate Nov/Dec 2009

AQUAGEST® OMF improves FCR, Growth and PER in *Tilapia*







Data from a 70 day lab trial with Nile Tilapia using triplicate tanks of 100l per diet.

Fish were grown at 26°C from 16g til ± 70g while fed on a practical tilapia grow out diet with CP/CF of 33/7.6.

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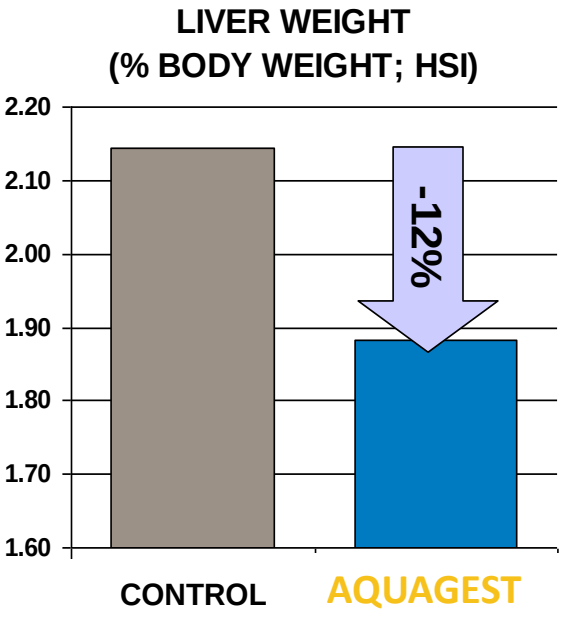
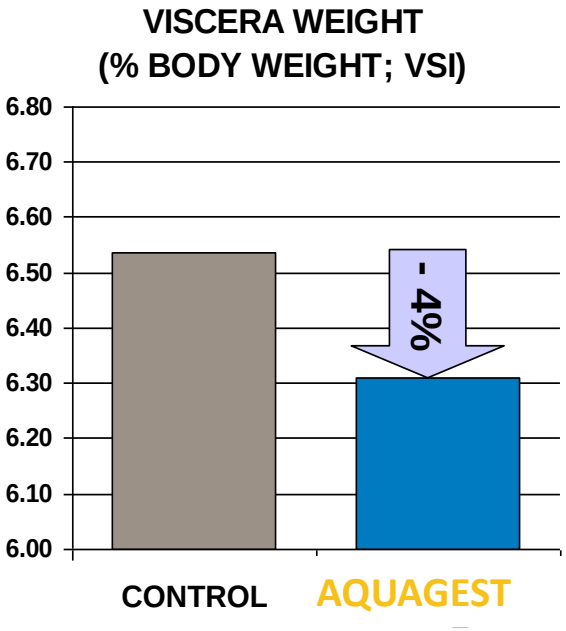
AQUAGEST® OMF reduces liver and visceral weight in *Tilapia*





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Dose-response AQUAGEST® OMF in *Tilapia*

	CONTROL	AQUAGEST® OMF 1.5 kg/MT feed	% vs control	AQUAGEST® OMF 3 kg/MT feed	**% of control**
Survival (%)	100 ± 0	100 ± 0		100 ± 0	
initial weight (g)	9.17 ± 0.04	9.15 ± 0.13		8.93 ± 0.21	
final weight (g)	41.84 ± 0.83	44.32 ± 1.25		44.3 ± 1.99	
SGR (%/day)	2.71 ± 0.03^{a}	2.82 ± 0.03^{ab}	**4.1%**	2.86 ± 0.08^{b}	**5.5%**
Feed Intake (g/ind)	37.86 ± 0.65	38.83 ± 1.18		38.3 ± 1.15	
Feed Conversion Ratio	1.16 ± 0.01^{a}	1.10 ± 0.01^{b}	**-5.2%**	1.08 ± 0.03^{b}	**-6.9%**
Protein Efficiency Ratio	2.75 ± 0.03^{a}	2.86 ± 0.02^{ab}	**4.0%**	2.92 ± 0.1^{b}	**6.2%**
Hepatosomatic Index (%)	1.60 ± 0.15	1.48 ± 0.11	**-7.5%**	1.43 ± 0.01	**-10.6%**
Viscerasomatic Index (%)	8.45 ± 0.09^{a}	7.79^{b} ± 0.11	**-7.8%**	8.41 ± 0.13^{a}	**-0.5%**

Data from a 56 day lab trial with Nile Tilapia using triplicate tanks of 100l per diet.

Fish were grown at 26°C from 9g til ± 44g while fed on a practical tilapia grow out diet with CP/CF of 33/7.6.

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Cage trial with *Tilapia* in Brazil

FEED TECHNOLOGY

Can tilapia get more out of your current feed formulation?

By Giovani Sampaio Gonçalves, Manoel Joaquim Peres Ribeiro, Diogo Villaça and Peter Coutteau

The study shows better cost efficiency of feeds for tilapia farmed in cages in Brazil with addition of digestibility enhancers and also underlines the importance of maintaining the nutritional balance in feed to maximize the benefits of a digestibility enhancing concept.

Feed represents the largest production cost in tilapia *Oreochromis niloticus* farming. As a result of increasing raw material prices, nutritionists are under continuous pressure to reduce formulation cost and search for cheaper, alternative ingredients. The use of feed additives to improve the digestibility of nutrients is an important tool to improve cost-efficiency in intensive production of tilapia.

Digestibility enhancing additives that are compatible with the digestive physiology of each fish species, have the potential to improve nutrient utilisation from cheap ingredients. Furthermore, they can stimulate the conversion of nutrients into meat gain and reduce the fat accumulation in muscle and viscera. Previous work has revealed the potential of synergistic blends of digestive phytobiotics, natural emulsifying agents and co-factors of digestion to improve feed efficiency and growth and to reduce visceral depositions in Nile tilapia under lab conditions (Ceulemans et al., 2009).

However, the optimal application of novel feed additives requires field evaluations to provide information on optimal dosage at different life stages of the fish, and their effects on farm economics and processing qualities of the fish. In the pangasius catfish in Vietnam, the optimal application of a digestibility enhancer for pond production was shown by van Halteren et al (2009). The economic gains for the farmer was up to 2.4% reduction in feed cost/kg of whole fish produced and 16.4% shortening of the production cycle. For the fish processor, it was up to 7.5% improvement in filleting yield.

In the current study, we compared the effect of different application strategies of a digestibility enhancing feed additive on productivity and profitability of tilapia production in cages in Brazil. Reserving a limited budget in the feed formula (often only a fraction of the increase of budget for standard ingredients) for performance enhancing feed additives seems a sound strategy to improve feed cost efficiency, particularly in situations where ingredients prices reach new historic records.

The cage trial

The study covered the entire production cycle of tilapia, including the processing of commercial size fish, and was carried out by the Instituto de Pesca in collaboration with a commercial tilapia integration in the Sao Paulo region of Brazil.

The cage trial was performed during two consecutive phases in 7m³ cages: phase 1 (from 28g to approximately 170g) and phase 2 (from 170g to 750g, i.e. commercial size). In phase 1,880 juveniles of Nile tilapia (GIFT strain, initial weight 28g) were stocked in each cage. Ten replicate cages were fed the control feed, consisting of a commercial feed (36% crude protein). The treatment feed consisted of the control feed supplemented with a digestibility enhancing feed additive (Aquagest® OMF, Nutriad, 3 kg/tonne of feed). The treatment group consisted of 15 replicate cages.

In phase 2, the stocking density was 800 fish/cage and 4 different treatments were run with 5 replicate cages per treatment:

- Control: fed a commercial feed with 32% crude protein;

Tilapia was grown from 28 g to commercial size in 7m³ cages

- AG3: control feed supplemented with the feed additive at 3 kg/tonne throughout the entire cycle;
- AG 3/1.5: control feed supplemented with the feed additive at 3 kg/tonne until 350g and subsequently at 1.5 kg/tonne until the end of the trial;
- LC-AG2: low cost feed, formulated with protein of lower digestibility and poorer amino acid profile, supplemented with 2 kg/tonne of the feed additive (7% reduced formula cost compared to the control feed).

During phase 2, the control group was stocked with fish originating from the control group during phase 1; whereas the other treatments were recruited from fish receiving the additive treatment diets during phase 1.

Feeds were produced in a commercial extrusion line and the additive was included directly in the mixer with all other ingredients prior to extrusion. Feed distribution was based on feeding tables. It was 4 times/day during phase 1 and 3 times/day during phase 2. At the end of phase 1, all fish were weighed, average daily weight gain and feed conversion ratios were determined. At the end of phase 2, all fish from each experimental cage were weighed and counted. At harvest, 5% of the population per cage was processed for filleting. The evaluated parameters included survival, daily weight gain, feed conversion, filleting yield, viscera weight, liver weight and visceral fat weight.

Better performance

At the end of phase 1, fish supplemented with the feed additive showed significant improvements on performance compared to the control group. Daily weight gain was 12% higher, survival, 5% higher and there was 6% improvement in feed conversion (Figure 1; Table 1).

Sampaio Gonçalves et al. (2012) Aquaculture Asia Pacific Magazine Nov/Dec 2012

Field verification with tilapia
Cage trial Tilapia, Brazil

Tilapia cages: 25 units (7m^3 each)
Instituto de Pesca
São José do Rio Preto, Brazil

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Cage trial Tilapia, Brazil - experimental conditions

Phase 1: pre-growing (from 28g to ±170g)

- Period: 111 days
- Stocking density: 880 fishes/cage
- GIFT strain

Treatments:

1. Control feed — n=10 replicate cages
2. Aquagest OMF (3kg/MT feed) — n=15 replicate cages

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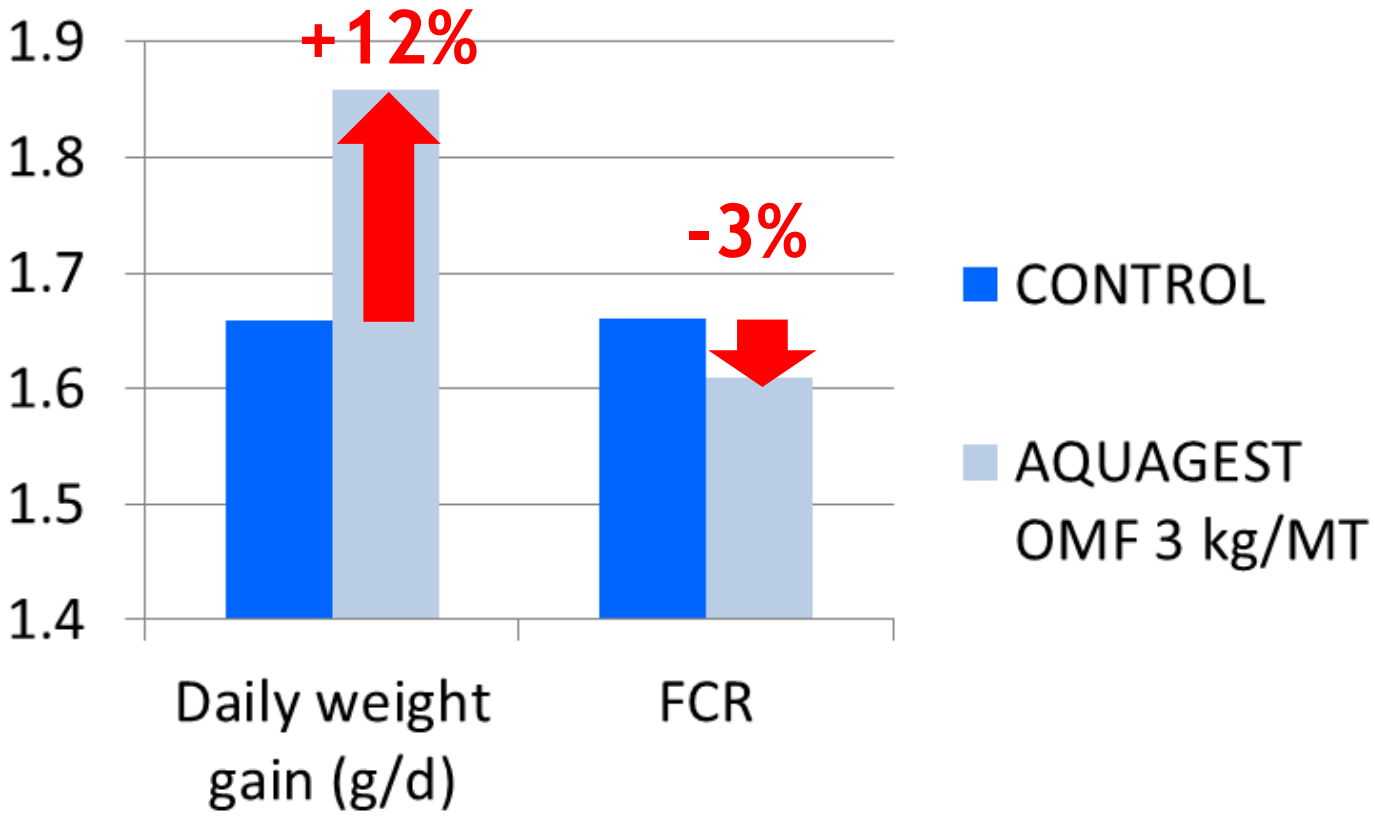
Cage trial Tilapia, Brazil - results Phase 1



Initial weight 28 g - DOC 85 days
cages/treatment: Control N=10; Aquagest N=15

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Cage trial Tilapia, Brazil - experimental conditions

Phase 2: growout (from ±170g till ± 750g)

- Period: 111 days
- Stocking density: 840 fishes/cage
- 5% of fish per replicate processed for determining fillet yield, visceral fat, liver and visceral weight

Phase 2: Treatments: (n=5 replicate cages per treatment)

- T1 : Control feed (commercial feed in use; CP32)
- T2 : CONTROL + Aquagest OMF 3kg/MT
- T3 : CONTROL + Aquagest OMF 3kg/MT (until 350g);
  + Aquagest OMF 1.5kg/MT (until 750g)
- T4 : LOW COST FEED + Aquagest OMF 2 kg/MT

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Cage trial Tilapia, Brazil - summary

Best economic return from AQUAGEST OMF 3 kg/MT:

- Reduced FCR (-3.0%)
- Improved growth (+5%)
- Improved survival (+2.8%)
- Improved fileting weight (+1.5%)
- Reduced visceral mass (-10.7%)

Integrator Brazil:

- Return on Investment (ROI) 1:3.8
- Increased revenues: +17%

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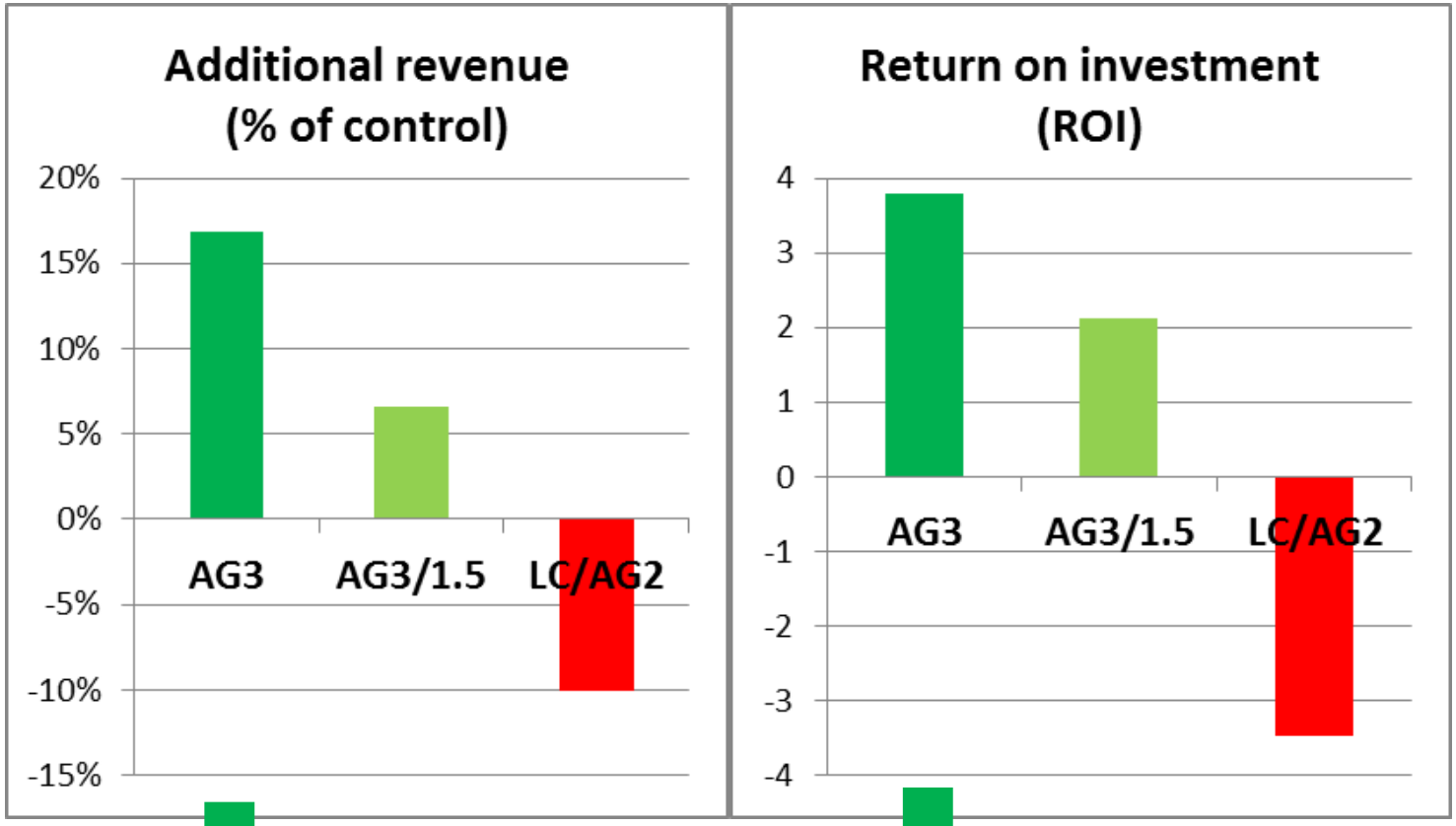
Cage trial Tilapia, Brazil
Economic analysis of different application dosages



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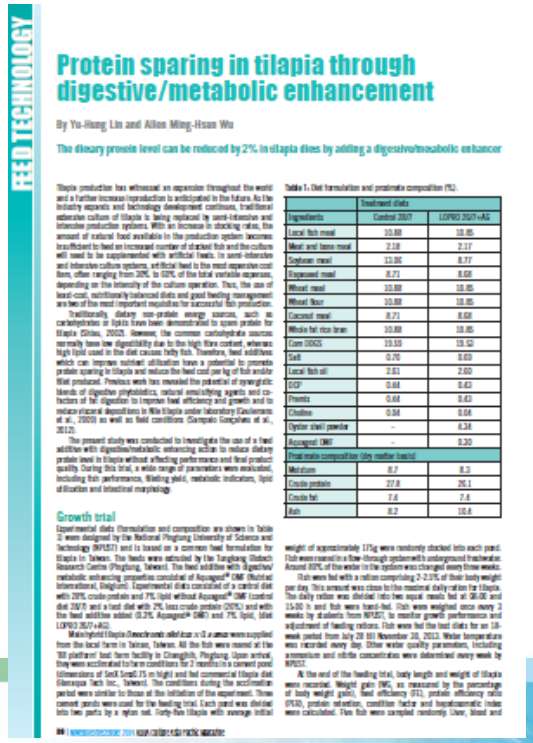
APPLICATION OF A METABOLIC/ DIGESTIVE ENHANCER TO REDUCE PROTEIN REQUIREMENTS IN TILAPIA



FEED TECHNOLOGY

Protein sparing in tilapia through digestive/metabolic enhancement

By Yu-Hung Lin and Allen Ming-Hsun Wu

The dietary protein level can be reduced by 2% in tilapia diets by adding a digestive/metabolic enhancer

Tilapia production has witnessed an expansion throughout the world and a further increase in production is anticipated in the future. As the industry expands and technology development continues, traditional extensive culture of tilapia is being replaced by semi-intensive and intensive production systems. With an increase in stocking rates, the amount of natural food available in the production system becomes insufficient to feed an increased number of stocked fish and the culture will need to be supplemented with artificial feeds. In semi-intensive and intensive culture systems, artificial feed is the most expensive cost item, often ranging from 20% to 60% of the total variable expenses, depending on the intensity of the culture operation. Thus, the use of least-cost, nutritionally balanced diets and good feeding management are two of the most important requisites for successful fish production.

Traditionally, dietary non-protein energy sources, such as carbohydrates or lipids have been demonstrated to spare protein for tilapia (Shiau, 2002). However, the common carbohydrate sources normally have low digestibility due to the high fibre content, whereas high lipid used in the diet causes fatty fish. Therefore, feed additives which can improve nutrient utilisation have a potential to promote protein sparing in tilapia and reduce the feed cost per kg of fish and/or fillet produced. Previous work has revealed the potential of synergistic blends of digestive phytobiotics, natural emulsifying agents and co-factors of fat digestion to improve feed efficiency and growth and to reduce visceral depositions in Nile tilapia under laboratory (Encinares et al., 2009) as well as field conditions (Sangsuto Sangchan et al., 2012).

The present study was conducted to investigate the use of a feed additive with digestive/metabolic enhancing action to reduce dietary protein level in tilapia without affecting performance and final product quality. During this trial, a wide range of parameters were evaluated, including fish performance, filleting yield, metabolic indicators, lipid utilisation and intestinal morphology.

Growth trial

Experimental diets (formulation and composition are shown in Table 1) were designed by the National Pingtung University of Science and Technology (NPUST) and is based on a common feed formulation for tilapia in Taiwan. The feeds were extruded by the Tungkang Biotech Research Centre (Pingtung, Taiwan). The feed additive with digestive/metabolic enhancing properties consisted of Aquagest® DME (Nutriad International, Belgium). Experimental diets consisted of a control diet with 29% crude protein and 7% lipid without Aquagest® DME (control diet 29/7) and a feed diet with 2% less crude protein (27/7) and with the feed additive added (0.2% Aquagest® DME) and 7% lipid, (diet LOPRO 27/7+AG).

Male hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) were supplied from the local farm in Taiwan, Taiwan. All the fish were reared at the 'All platform' test farm facility in Changhih, Pingtung. Upon arrival, they were acclimated to farm conditions for 2 months in a cement pond (dimensions of 5m×3.75 m high) and fed commercial tilapia diet (Uniaqua Tech Inc., Taiwan). The conditions during the acclimation period were similar to those at the initiation of the experiment. Three cement ponds were used for the feeding trial. Each pond was divided into two parts by a nylon net. Forty-five tilapia with average initial weight of approximately 175g were randomly stocked into each pond. Fish were reared in a flow-through system with underground freshwater. Around 30% of the water in the system was changed every three weeks.

Table 1. Diet formulation and proximate composition (%).

	Treatment diets	
Ingredients	Control 29/7	LOPRO 25/7+AG
Local fish meal	10.00	10.00
Meat and bone meal	2.18	2.17
Soybean meal	13.06	8.77
Rapeseed meal	8.71	8.69
Wheat meal	10.00	10.00
Wheat flour	10.00	10.00
Coconut meal	8.71	8.69
Whole fat rice bran	10.00	10.00
Corn DDGS	13.50	15.52
Salt	0.70	0.69
Local fish oil	2.61	2.60
DCP	0.44	0.43
Premix	0.44	0.43
Choline	0.04	0.04
Oyster shell powder	–	4.34
Aquagest DME	–	0.20
Proximate composition (dry matter basis)		
Moisture	8.7	8.3
Crude protein	27.8	26.1
Crude fat	7.4	7.4
Ash	8.2	10.4

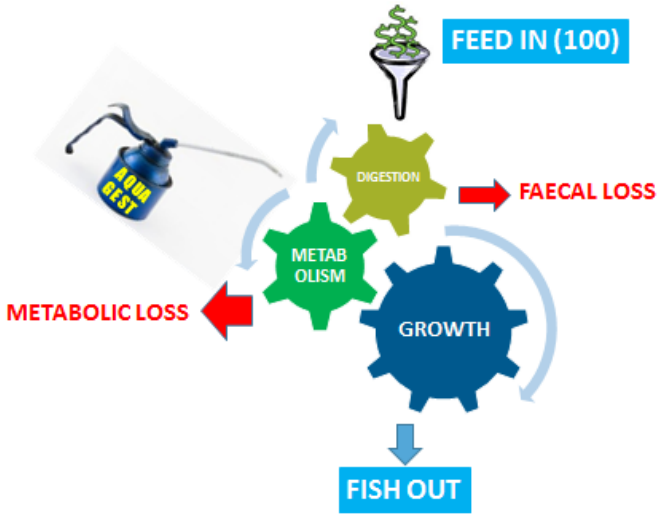
Fish were fed with a ration corresponding 2-2.5% of their body weight per day. This amount was close to the maximal daily ration for tilapia. The daily ration was divided into two equal meals fed at 08:00 and 15:00 h and fish were hand-fed. Fish were weighed once every 2 weeks by students from NPUST. To monitor growth performance and adjustment of feeding rations. Fish were fed the test diets for an 18-week period from July 28 till November 28, 2013. Water temperature was recorded every day. Other water quality parameters, including ammonium and nitrite concentrates were determined every week by NPUST.

At the end of the feeding trial, body length and weight of tilapia were recorded. Weight gain (WG, as measured by the percentage of body weight gain), feed efficiency (FE), protein efficiency ratio (PER), protein retention, condition factor and hepatosomatic index were calculated. Five fish were sampled randomly (liver, blood and

Lin & Wu (2014) Aquaculture Asia Pacific Magazine Nov/Dec 2014

Rationale

- digestive/metabolic enhancement
  - metabolic/faecal losses ↓
  - protein efficiency ↑
  - dietary protein requirement ↓
- Conditions for reducing protein level without affecting performance
  - Maintain protein quality (essential amino acid levels)
  - Maintain feed intake



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Experimental design

- Experimental design : reduce 2% protein in a standard growout feed for tilapia:
  - replacing 4.35% soybean meal with filler material (oyster shell)
  - Compensating with a digestive/metabolic enhancer (Aquagest OMF)

- Determine effects on
  - fish performance
  - fileting yield and carcass composition
  - Condition factor = W (g) /L(cm)3
  - a range of physiological parameters (haematological parameters, gut histology
  - Metabolic enzyme - Glucose-6-phosphate dehydrogenase (G6PDH): enzyme involved in, a metabolic pathway that supplies reducing energy to cells (pentose phosphate pathway); important for liver lipogenesis (biosynthesis of fatty acids) NOT related to fat content in body, but indirectly to nutrients utilization (CHO, Protein)

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Feed design and preparation

- Basal diet : common formula for Tilapia in Taiwan
- produced by Tungkang Biotech Research Center
- Treatments:
  1. CONTROL 28/7 CP/CF
  2. LOPRO 26/7 CP/CF + 3 kg/MT Aquagest OMF

Extruder in Tungkang Biotech Research Center, Pingtung, Taiwan

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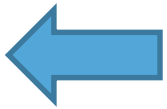
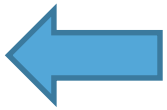
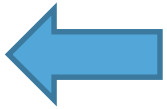
Experimental feeds

	CONTROL 28/7	LOPRO 26/7+AG
local fish meal	10.9	10.9
meat and bone meal	2.2	2.2
soybean meal	13.0	8.7
rapeseed meal	8.7	8.7
wheat meal	10.9	10.9
wheat flour (japan)	10.9	10.9
coconut meal	8.7	8.7
whole fat rice bran	10.9	10.9
corn DDGS	19.6	19.6
salt	0.7	0.7
local fish oil	2.6	2.6
DCP	0.4	0.4
premix	0.4	0.4
choline	0.0	0.0
oyster shell powder	-	4.3
AQUAGEST OMF	**-**	**0.3**
TOTAL	100	100
Proximate composition		
Moisture	8.7	8.3
Crude protein	27.8	26.1
Crude fat	7.4	7.4
Ash	8.2	10.4







Trial conditions

- Male hybrid tilapia (*Oreochromis niloticus* × *O. aureus*), initial weight 175 g (Tainan, Taiwan)
- Trial performed at a farm in Changjhih, Pingtung with monitoring and sampling by National Pingtung University of Science and Technology, Taiwan
- Fish were acclimated to farm conditions for 2 month fed commercial tilapia diet (Hanaqua Tech Inc., Taiwan)
- Trial units: cement tanks 5 m × 5 m (0.75 m depth) ; each tank was divided into two units using a nylon net
- flow-through system with underground freshwater (80% water change every three weeks)
- 45 fish per unit, 3 replicate units per treatment
- Culture period : 18 wks (July 28 - Nov 30, 2013)

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Trial conditions

- Fish were fed with 2-2.5% of their body weight per day (close to the maximal daily ration for tilapia according to feed consumption during the acclimation period of the study)
- The daily ration was divided into two equal meals (08:00 and 15:00 h) and hand-fed
- Fish were weighed once every 3 weeks by National Pingtung University of Science and Technology (NPUST), to monitor growth performance and adjust feeding rations
- Water temperature was recorded daily
- Water quality parameters (ammonium and nitrite) weekly

Fish performance (trial duration 18 weeks)

	CONTROL 28/7	LOPRO 26/7+AG	% change vs control	statistics
Survival (%)	93.3 ± 2.2	96.3 ± 2.6	+3.2%	
Initial weight (g)	177.3 ± 1.8	174.7 ± 2.1	-1.5%	
Final weight (g)	469.6 ± 13.2	482.0 ± 12.1	+2.6%	
Daily weight gain (g/d)	2.32 ± 0.11	2.44 ± 0.08	+5.2%	
Feed intake (g/fish)	860.5 ± 21.6	840.3 ± 17.0	-2.4%	
Food Conversion Ratio (FCR)	2.95 ± 0.20	2.74 ± 0.04	-7.1%	P<0.05
Protein Efficiency Ratio (PER)	1.22 ± 2.2	1.40 ± 0.02	+14.8%	P<0.05
Protein retention (%)	27.70 ± 1.73	29.72 ± 0.04	+7.3%	P<0.05

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Processing parameters (trial duration 18 weeks)

	CONTROL 28/7	LOPRO 26/7+AG	% change vs control	statistics
Hepatosomatic Index HSI (%)	3.30 ± 0.74	3.09 ± 0.26	-6.4%	
Visceral fat (%)	6.31 ± 1.81	5.83 ± 1.62	-7.6%	
Conditioning factor	1.88 ± 0.14	2.02 ± 0.04	+7.4%	
Filet yield (%) with skin	41.46 ± 0.17	41.91 ± 0.40	+1.1%	
Filet yield (%) without skin	34.82 ± 0.14	35.20 ± 0.34	+1.1%	

Processing the fish at Hung-Yi Frozen Food Factory, Pingtung

Visceral fat

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Fish composition (trial duration 18 weeks)

carcass composition	CONTROL 28/7	LOPRO 26/7+AG
moisture (%)	78.1 ± 0.4	77.6 ± 1.3
crude protein (%)	20.1 ± 1.3	19.3 ± 1.4
crude fat (%)	1.2 ± 0.7	1.7 ± 0.5
ash (%)	1.12 ± 0.10	1.07 ± 0.01

No significant effect on carcass composition

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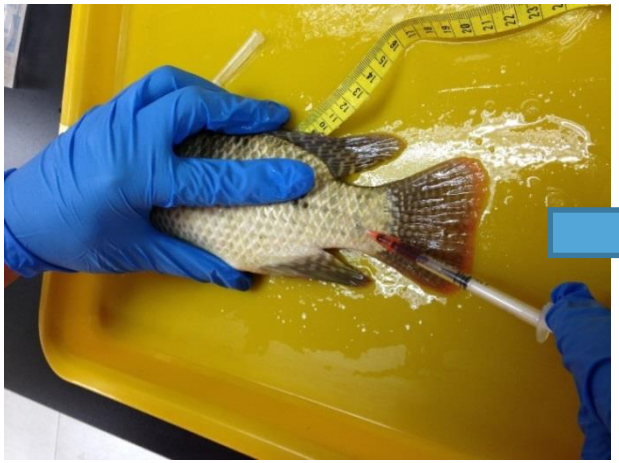
Haematological indices (trial duration 18 weeks)

haematological indices	CONTROL 28/7	LOPRO 26/7+AG	statistics
white blood cells	235 ± 11	236 ± 12	
red blood cells	2.55 ± 0.08	2.50 ± 0.24	
haemoglobin	10.12 ± 0.56	10.64 ± 0.82	
haematocrit	33.1 ± 2.3	31.6 ± 3.0	
plasma TG	15.73 ± 0.40	13.53 ± 0.80	P<0.05
G6PDH	163 ± 40	267 ± 29	P<0.05



- Blood cell counts not affected

Indicators metabolic enhancement:

- Decrease of plasma TG
- Boost of G6PDH activity

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Tank trial Tilapia, Taiwan - summary

LOPRO 26/7 + AQUAGEST OMF 3 kg/MT versus CONTROL 28/7:

- Improved fish performance
  - Reduced FCR (-7.1%)
  - Improved growth (+5.2%)
  - Improved survival (+3.2%)
- More efficient conversion of feed protein into fish
  - Improved protein retention (+7.3%)
  - Improved protein efficiency ratio (+14.8%)
- Improved processing yield
  - Improved condition factor (+7.4%)
  - Improved fileting weight (+1.1%)
  - Reduced visceral fat (-7.6%)
- Carcass composition and haematology not affected
- Physiological indicators confirming mode of action:
  - Reduced plasma TG
  - Increased G6PDH
  - Improved integrity of gut villi in the midgut

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Take home message :

- Increasing raw material costs is main drive to more efficient use of nutrients

- Functional feed additives can be used to improve the digestive and metabolic efficiency of tilapia resulting in better revenue for the farmer

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OBRIGADO !

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