Evaluation of the apparent phosphorus digestibility coefficients of inorganic feed phosphates for Tilapia (*Oreochromis niloticus*)

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Phosphorus (P) is an essential mineral in fish feed as it is a component of hard tissues (bone, exoskeleton, scales, and teeth) and also DNA and phospholipids. It is mainly supplied by feeding, since as opposed to calcium (Ca), P content in natural water is low. Dietary deficiency of P impairs metabolism resulting in reduced growth and feed conversion. Various skeletal malformations associated with reduced mineralization of hard tissues also occur at suboptimal P intake (NRC, 2011). Fishmeal was a good P source but its partial replacement - due to the reduction of this natural resource - by plant-source ingredients, leads to decreased availability of P (avP) in the diet. Indeed, most fish species are not able to digest phytate-P (P form from plant source). Inorganic feed phosphates (IFP) are also a common source of P in fish feed. P digestibility can vary depending on IFP source and digestive system of the fish. If it is too low, P accumulates in the environment and may causes eutrophication problems. Tilapia is widely cultured in many tropical and subtropical regions of the world and Nile tilapia (*Oreochromis niloticus*) is the most distributed and commercially cultured species globally (El-Sayed, 2006). Several studies on P requirement have been reported. Yao et al. (2014) observed optimal performances for Nile tilapia with 8.6 g avP/kg DM. Nevertheless only a few studies reported digestibility of IFP. Hua and Bureau (2010) developed a P digestibility model for Tilapia in which apparent digestibility coefficient (ADC) of P was 93% for Ca mono basic/Na/K phosphate and 62% for Ca dibasic phosphate. The aim of our study was to evaluate ADC of P from two IFP, monocalcium phosphate (MCP - 22.7% P) and dicalcium phosphate (DCP - 18% P) for Tilapia (*Oreochromis niloticus*).

Materials and Methods

Diets

Three diets were formulated, based on soybean meal (46%) and cassava meal (22.95%), to meet all nutrients requirements of tilapia juveniles. They were isonitrogenous and isolipidic. Ca:P was fixed at 0.92 (Table 1). The control diet (CTRL) contained no IFP. The first test diet (DCP_{18}) contained 1.8% of DCP_{18} and the second test diet ($MCP_{22.7}$) contained 1.35% of $MCP_{22.7}$. Chromic oxide was used as a market to determine P digestibility.

Added IFP have been characterized in table 2. They were finely ground just before mixing with the other ingredients. Feed was pelleted (2-3 mm), steamed and dried.

Animals and experimental design

135 fish (body weight 51.6 ± 1.7g) were randomly allocated in 9 faecal collection units of 150L (fiberglass tank), with 15 individual fish per tank. Fish were fed twice a day to satiation at 3-5% of body weight with the 3 experimental diets in triplicates. After 7 days of acclimation, feces were collected twice a day, for 4 weeks, uneaten feed was previously removed from the system.

Table 1: Composition of the diets

Composition	Diets		
	CTRL	DCP_{18}	$MCP_{22.7}$
Moisture (%)	8.28	8.24	8.67
Growth Energy (kcal/g)	399.13	396.7	394.98
Crude Protein (%)	31.37	31.89	31.63
Crude Lipid (%)	4.61	4.23	4.64
Ash (%)	7.57	8.87	8.44
Crude Fiber (%)	4.70	3.73	4.59
Calcium (%)	0.73	1.01	0.97
Total P (%)	0.80	1.07	1.05
Chromic oxide (%)	0.97	0.98	0.98

Table 2: Inorganic feed phosphate source characterization

Ingredients	DCP	MCP
P (%)	18	22.7
Ca (%)	27	15
P 2% citric acid solubility (%)	> 95	> 95
P water solubility (%)	< 10	> 85
Particle size	Powder	Micro-granule

The fecal samples were stored in the freezer at -30°C until ready for lyophilization in order to evaluate ADC of P. At the end of the experiment fish were weighted to evaluate their weight gain (WG). During the trial water parameters (temperature, dissolved oxygen, pH, NH_3-N and NO_2-N), survival and feed intake have been recorded in order to evaluate rearing condition, and survival rate (SR).

Determination of ADC of P from IFP

P content in the diet and feces has been determined according to ISO 6491:1998 and P from DCP and MCP was followed by AOAC 965.17.

ADC of P in experimental diets ($ADCP_{diet}$) were calculated according to the formula from Maynard & Loosli (1969):

$$ADCP_{diet}\,(\%) = 100 \times \left(1 - \frac{Cr2O3_{diet}}{Cr2O3_{feces}} \times \frac{P_{feces}}{P_{diet}}\right)$$

ADC of P from IFP ($ADCP_{IFP}$), based on the ADCP of the CTRL and test diets was calculated as follow (Forster, 1999; Bureau and Hua, 2006):

$$ADCP_{IFP}\,(\%) = \frac{(ADCP_{test\ diet} \times P_{testdiet}) - (\alpha \times P_{ctrl} \times ADCP_{ctrl})}{\beta \times P_{IFP}}$$

Where, $P_{test\ diet}$ is the % P in the test diet; P_{IFP} is the % P in the IFP; P_{CTRL} is % P in the CTRL; α is proportion of the CTRL diet in the test diet; β is proportion of the IFP in the test diet.

Statistical Analysis

Data were studied by analysis of variance followed by Duncan's multiple range tests using SPSS version 18. Differences were considered significant at $p < 0.05$.

Results and discussion

Fish performance

Water quality parameters (Table 3) were in a suitable range for health and growth of fish. There was a high SR in the 3 treatments without significant difference (Table 4). Final body weight (FBW) was significantly higher for fish fed DCP_{18} or $MCP_{22.7}$ than CTRL diet ($p<0.05$). WG seems to be higher for fish fed with added IFP.

What's in a name?

Last September TIMAB Phosphates changed its name to Phosphea to consolidate its position as feed phosphates specialist, and to support its development strategy, and get better visibility. The name, combined with a signature, a logo and a communication territory, portrays the teams' expertise, know-how and proximity to customers. European leader and 2nd worldwide player, Phosphea, a subsidiary of Groupe Roullier, has produced and sold feed phosphates for the animal nutrition industry for 40 years. Phosphea operates in over 100 countries worldwide, has a workforce of 280 employees, and generates a turnover of around €300 million.

From raw material sourcing to the delivery of finished products, Phosphea's teams strive for perfection: diversification of supplies, controlled industrial processes, physico-chemical and nutritional characterization of products, high quality standards, food safety, in-depth knowledge of the markets and appropriate logistics. According to Olivier Poli, General Manager, "The new corporate brand remains in line with its personality: conquering, inventive, strong, passionate and definitely humane."

Apparent digestibility coefficients of phosphorus

ADCs of test diets and IFP are presented in Table 5.

$ADCP_{diet}$ are significantly different among treatments ($p<0.05$). The highest ADCs of P was provided by the diet containing $MCP_{22.7}$ (49.99%) and followed by DCP_{18} (45.00%) and reference diet (38.30). The fish fed the reference diet without supplemented IFP presented significantly lower ADCs of P than those fed with supplemented IFP. In terms of $ADCP_{IFP}$, the data indicated that P digestibility values were significantly higher for $MCP_{22.7}$ (79.88 %) than for DCP_{18} (60.22%).

Conclusion

Among calcium phosphates, water soluble P sources as $MCP_{22.7}$ provide a highly digestible P for Tilapia which allows to improve P utilization and decrease its release in the environment. Moreover $MCP_{22.7}$ is a more concentrated source of P which allows to save space and optimize feed formulation. Finally, it brings less calcium than DCP_{18} which is already covered by ions absorption through the gills. This is an important fact especially as P absorption also depends on Ca:P ratio.

Table 3: Water quality parameters.

Parameters	Mean ± SD
Water temperature (°C)	28.3 ± 0.77
pH	7.44 ± 0.27
Dissolved oxygen (mg/l)	6.24 ± 0.18
NH_3-N (mg/l)	0.05 ± 0.05
NO_2-N (mg/l)	0.20 ± 0.25

Table 4: Survival rate (SR), initial body weight (IBW), Weight Gain (WG), and Feed Conversion Ratio (FCR) of Tilapia fed test diets (Mean ± SD).

	CTRL	DCP_{18}	$MCP_{22.7}$
SR (%)	95.57^{a} ± 7.68	97.77^{a} ± 3.87	100.00^{a} ± 0.00
IBW (g)	50.50^{a} ± 1.87	52.60^{a} ± 1.05	51.80^{a} ± 2.15
FBW (g)	101.94^{a} ± 0.10	107.70^{b} ± 1.57	105.82^{b} ± 1.13
WG (g)	51.40^{a} ± 1.80	55.10^{a} ± 2.48	54.03^{a} ± 3.21

a, b: values in the same row with different superscripts are significantly different ($p<0.05$).

Table 5: Apparent digestibility coefficient of phosphorus in the diet and test ingredient (Mean ±SD).

Parameters	CTRL	DCP_{18}	$MCP_{22.7}$
Diet	38.30^{a} ± 1.90	45.00^{b} ± 0.28	49.99^{c} ± 0.20
Ingredient		60.22^{a} ± 1.00	79.88^{b} ± 0.74

a, b: values in the same row with different superscripts are significantly different ($p<0.05$).

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More Information

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