Available online at www.sciencedirect.com
ScienceDirect
Aquaculture 267 (2007) 300–307
Aquaculture
www.elsevier.com/locate/aqua-online

# Phosphorus availability of inorganic phosphates and fish meals in European sea bass (*Dicentrarchus labrax* L.) juveniles

A. Pimentel-Rodrigues, A. Oliva-Teles *

*Departamento de Zoologia e Antropologia, Faculdade de Ciências, Universidade do Porto, Praça Gomes Teixeira, 4099-002 Porto, Portugal*
*CIIMAR, -Centro Interdisciplinar de Investigação Marinha e Ambiental, 4050-123 Porto, Portugal*

Received 15 November 2006; received in revised form 15 January 2007; accepted 16 January 2007

**Abstract**

A trial was conducted to evaluate the apparent availability of phosphorus (P) of five fish meals and three inorganic phosphorus sources (mono-, di- and tricalcium phosphate) to European sea bass juveniles.

A corn gluten based diet containing 0.2% P was used as the basal diet. Test diets were formulated with different proportions of basal diet and test ingredients in order to have final phosphorus levels of 0.5%. This level was used as it is marginally lower than the estimated P requirement of sea bass, aiming that P availability is not affected by excessive dietary P concentration. Moreover, three other test diets were formulated to include only 0.3% of inorganic P sources, to evaluate the effect of dietary P levels on availability.

ADC of P of fish meals ranged from 49 to 63% and was generally related to the fish meal ash content. Within the inorganic phosphorus sources, ADC of P was not affected by dietary phosphorus level but was significantly affected by supplement source. Mean P availability decreased in the following order: dicalcium phosphate (68%)>monocalcium phosphate (56%)>tricalcium phosphate (50%).


*Keywords:* Phosphorus; Apparent digestibility; Availability; Sea bass; Feedstuffs

## 1. Introduction

Phosphorus (P) and nitrogen are the two main nutrients responsible for water eutrophication. The need for sustainable aquaculture development and the increasing public sensitisation for the need of reducing water pollution make it a priority to reduce discharges of these nutrients into the environment (Bureau and Cho, 1999).

Although fish can absorb P from water, its concentration both in freshwater and salt water is low. Therefore, diets are the main source of P in intensive aquaculture production units (Lall, 1991). It is thus crucial to optimize dietary P utilisation by the animals in order to reduce P losses into the environment. To accomplish this it is necessary to formulate diets that meet but not exceed P requirement of the animals, and to incorporate in the diets only highly available P ingredients (Cho and Bureau, 2001; Lall, 2002; Sugiura et al., 2004). Therefore, research is necessary to accurately establish P requirement of the species under consideration and to evaluate the availability of P in potential ingredients to include in practical diets.

Nowadays this is even more of a priority due to the need to reduce fish meal content of practical diets, replacing it with alternative protein sources (Watanabe,

* Corresponding author. Departamento de Zoologia e Antropologia, Faculdade de Ciências, Universidade do Porto, Pr. Gomes Teixeira, 4099-002 Porto, Portugal. Tel.: +351 223 401 507; fax: +351 223 401 511.
*E-mail address:* aoteles@fc.up.pt (A. Oliva-Teles).

0044-8486/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.aquaculture.2007.01.018

2002; Tacon, 2004). Fish meal is usually used as the main protein source in carnivorous fish diets, as it has high protein levels of high biological value. Fish meal has a high P content, which is fairly available to fish (Lall, 1991) and often contributes a significant proportion of total P of feeds for fish (Hua et al., 2005). Indeed, among common feedstuffs used in fish feed formulation, fish meal and meat and bone meal are the richest source of Ca and P (Lall, 2002). Therefore, deficiencies in P are not expected when fish meal based diets are used, reducing the concern for accurate P requirement estimations (Hardy, 2001; Oliva-Teles and Pimentel-Rodrigues, 2004). Reducing dietary P levels usually also implies to reduce dietary fish meal inclusion level or to use fish meal sources with lower P content (Satoh et al., 2003; Hernandez et al., 2004; Kaushik et al., 2004; Sugiura et al., 2004). This associated with the increasing prices and reduced availability of this commodity in the world market, makes it necessary to find alternative protein sources to include in the diets.

In Europe, due to BSE problems, animal feedstuffs which are also good sources of high available P are no longer an alternative. Therefore plant protein sources are the main practical alternative to fish meal inclusion in the diets. Plant feedstuffs have lower P levels than fish meals, this way allowing a reduction of total P content of the diets. However, P in plant feedstuffs is mainly present in the form of phytic acid and its salts and it is therefore poorly available to fish (Oliva-Teles et al., 1998). Indeed, fish as other monogastric animals do not have the enzyme phytase and therefore are not able to digest phytic P unless phytase is included in the diets. Inclusion of phytase into the diets has proved to be effective in improving availability of P in plant feedstuffs in different fish species (Lall, 2002) as well as in sea bass juveniles (Oliva-Teles et al., 1998).

Availability of P in inorganic supplements is affected by their solubility (Lall, 1991; Hua and Bureau, 2006) with availability usually increasing with salt solubility. Therefore, monocalcium and dicalcium phosphates are more digestible than tricalcium phosphates (Lall, 1991; Ogino et al., 1979; Sakamoto and Yone, 1979).

A correct evaluation of P availability in feedstuffs is critical for the production of highly available low P diets. Although mechanisms of P absorption and transport in the intestines are not yet well studied in fish, an $Na^+$-dependent P transporter in the intestine has been reported which is tightly regulated by dietary P (Lall, 2002). Moreover, dietary P restriction increases intestinal uptake (Avila et al., 2000; Sugiura et al., 2003). This suggests that the efficacy of the phosphate transport system, decreases when dietary P levels are very high (Coloso et al., 2003).

Therefore, availability of P is not independent of its dietary inclusion level (Satoh et al., 1997; Rodehutscord et al., 2000a,b). For instance, rainbow trout respond to supplements of P in a curvilinear manner, P absorption approaching an upper asymptote at a certain inclusion level and decreasing thereafter (Rodehutscord et al., 2000a,b). Efficiency of P utilisation in rainbow trout is maximal at a dietary level that is nearly half of the dietary level required for maximum P deposition and two-thirds of the dietary level required for maximum growth rate (Rodehutscord, 1996). This implies that for a correct evaluation of P availability of feedstuffs it is important that estimations are performed under conditions that maximize P utilisation by the fish, and consequently minimize P excreted in the faeces.

Also in rainbow trout, Riche and Brown (1996) observed that maximum apparent P availability occurred when experimental diets contained dietary P concentrations near the requirement and that P availability decreased with dietary P levels above and below that value. Based on that observation, the authors recommend that in studies of P availability dietary P levels should be maintained at or near estimated requirement. Furthermore, Sugiura et al. (2000a) found that P concentration in faeces of rainbow trout fed semi-purified diets with incremental P levels was similar when dietary P levels were lower or similar to requirement while it was significantly higher at a P level above the estimated requirement. Satoh et al. (1997) also observed that supplement of diets with P at levels two to three times the requirement reduced P absorption both in rainbow trout and common carp, though response was different in the two species, which may be explained by the absence of stomach in carp (Lall, 2002).

European sea bass is an important aquaculture species in the Mediterranean (Oliva-Teles, 2000). The dietary P requirement of sea bass juveniles was recently estimated to be 6.5 g/kg diet (Oliva-Teles and Pimentel-Rodrigues, 2004) using dicalcium phosphate as dietary P source. However, data on P availability of feedstuffs for this species is rather scarce (Gomes da Silva and Oliva-Teles, 1998; Tulli and Tibaldi, 2001) and was determined in conditions of variable dietary P levels, usually exceeding the estimated P requirement of the species.

Therefore, the aim of this study was to estimate, at a dietary inclusion level near requirement, the apparent availability of P in different fish meals and inorganic