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Aquaculture 248 (2005) 3–11
Aquaculture
www.elsevier.com/locate/aqua-online

Supplementation of citric acid and amino acid-chelated trace element to develop environment-friendly feed for red sea bream, Pagrus major

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Abstract

Nutrient dense diets often challenge the physiological capabilities of fish and lead to discharge of the excess amounts into the environment. This study investigated the effect of phosphorus (P), citric acid (CA), and amino acid-chelated trace element (AA-CTE) supplemented in diets on growth, nutrient retention, and loading in red sea bream. Eight fish meal-based diets were prepared and coded as F0, F1, F2, F3, C0, C2, A0, and A2, respectively. Diet F0 was the diet without addition of P, CA, and AA-CTE. Diet F1, F2, and F3 were supplemented with 0.25, 0.50, and 0.75% P, respectively. Diets C0 and C2 were similar to diets F0 and F2, respectively, but supplemented with 3% CA. Diets A0 and A2 were akin to diets F0 and F2, respectively, but contained 0.1% AA-CTE instead of the inorganic trace element. All diets were fed until satiation to duplicate groups of 30 fish (mean initial body weight 7.14 ± 0.01 g) for 12 weeks. Growth and feed performance were lowest in the fish fed F0 diet, and were significantly improved ($P<0.05$) by supplementing with P, CA, or AA-CTE. The final average weight of the control group fish was 46.1 g and feed conversion ratio (FCR) value was 1.14. The C2 group showed the best growth (final average weight 54.9 g) while A2 group showed the best FCR (1.00). Absorption of P was significantly higher ($P<0.01$) in the CA (C0) and AA-CTE (A2) supplemented group compared to the F0. The P and N retention values of the F0 diet were 54% and 33%, respectively, while, 74%, 38% for the diet C0 and 63%, 38% for diet A0, respectively. The P and nitrogen (N) retention values for diets C0 and A0 were significantly greater ($P<0.01$), in turn reducing ($P<0.05$) their excretion. Hence, the present study demonstrated that, without additional P in the fish meal-based diets, CA and AA-CTE supplement improved fish growth, FCR, nutrient retention, and reduced both N and P loading; thus, they can better be incorporated to develop environment-friendly feed for red sea bream.

Keywords: Citric acid; Amino acid-chelates; Trace elements; Red sea bream; Phosphorus; Nitrogen; Retention; Excretion

1. Introduction

Red sea bream is considered a potential species for aquaculture throughout the world. It is one of the most popular finfish for marine aquaculture in Japan. Due

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doi:10.1016/j.aquaculture.2005.04.012

to its economic feasibility and traditional food habits of the Japanese people, culture of this fish is increasing gradually. The aquaculture production of red sea bream is the second largest in Japan after yellowtail (Koshio, 2002). However, with the increase in total culture, subsequent pollution of farm sites becomes more frequent. Thus, development of environment-friendly feed is required, considering the need to keep the environment clean and to produce high quality and healthy red sea bream.

Aquaculture wastes contain mainly P and nitrogen (N), which can contribute to excessive algae and macrophyte growth in the receiving waters (Pillay, 1992). Since the ultimate source of aquaculture waste is the feed fed to fish, one effective way to reduce the waste load of fish farm effluent is to improve mineral utilization, the feed quality, and achieve a reduction in excretion of P and N and total solids relative to fish growth (Lall, 1989; Talbot and Hole, 1994). Management of aquaculture waste can be approached through improvements in nutrient utilization and feed formulation (Lall, 1989). Like in other animals, P is an essential nutrient for fish, being a major constituent of skeletal tissues, nucleic acids DNA and RNA, energy transport compounds like ATP, and of phospholipids in cell membranes (Lall, 1991). The mechanism of P absorption and transport in fish has not been well studied. Information concerning P metabolism of fish and crustacean is rather limited (Gatlin, 2000). However, the necessity of P supplementation in a fish meal-based diet has been reported for some post juvenile stage (Masumoto, 2002). Fish meal is the source of most dietary P in fish diets, wherein it exists as hydroxyapatite and/or tricalcium phosphate (TCP). Due to its structural complexity, P and Ca from TCP have been reported to be less available to some fish species (Takamatsu et al., 1975; Shitanda et al., 1979; Watanabe et al., 1980) as a result of which, large amounts of P are excreted in feces, leading to wastage, and environmental pollution. On the other hand, inorganic phosphorus from sodium phosphate is highly available to all fish. Therefore, it is required to investigate the necessity of readily available P supplementation in the diets of red sea bream.

Citric acid (CA) has been reported to be a substance that intensifies phytate dephosphorylation in vitro (Zyla et al., 1995). It has been reported that citric acid has potential effects on bioavailability of minerals in terrestrial animals (Pak et al., 1987; Ravindran and Kornegay, 1993; Crawford, 1995; Misra, 1996). Gastric acidity influences the bioavailability of dietary minerals (Wood and Serfatty-Lacrosniere, 1992) by regulating the chelation and complex formation of the element and by altering the transport mechanisms of minerals (Cross et al., 1990; Ravindran and Kornegay, 1993). Vielma et al. (1999) reported that dietary acidification by citric acid significantly increased whole body iron in fish. Boling et al. (2000) observed that citric acid (2–6%) is very effective in improving P utilization in chickens fed on maize soybean meal diets containing no supplemental P. They also reported that in chickens Zn utilization increased by the addition of citric acid (Boling et al., 2001). Sugiura et al. (1998) also observed an increase in the apparent availability of Ca, P, Mg, manganese (Mn), and iron (Fe) in rainbow trout fed fish meal-based diets supplemented with citric acid.

Fish meal and plant protein sources contain antrinutritional substances particularly tricalcium phosphate and phytate that inhibit mineral availability (Hardy and Shearer, 1985; Richardson et al., 1985; Satoh et al., 1987a,b,c; Lovell, 1989; Francis et al., 2001). It has been reported that chelates have the ability to compete with dietary mineral inhibitors thus making minerals more available to animals (Ashmead, 1992). One of the factors that affect mineral absorption and utilization is their chemical form. Structural configuration of chelate limits the interaction of other dietary component thus gives higher bioavailability in practical diets compared to inorganic salts (Garcia-Aranda et al., 1983; Ashmead, 1992). Low molecular weight ligands such as amino acid may facilitate the uptake of elements in the intestinal tract (Davis and Gatlin, 1996). Recently, interest in using alternative mineral sources, particularly those chelated with proteins or amino acids, has increased due to their reportedly higher availability compared to inorganic sources (Ashmead, 1992; Wang and Lovell, 1997, Apines et al., 2003). Chelate minerals are extensively used in poultry and life stock industries, yet, studies with these components with respect to fish have been very limited. In the red sea bream, there may be an influence of dietary supplementation of P, CA, and AA-CTE on growth and retention of P and N with reduction of their loading.