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Replacement of fish meal with poultry by-product meal in practical diets for redclaw crayfish (*Cherax quadricarinatus*)

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Abstract

Aquaculture of redclaw crayfish, *Cherax quadricarinatus*, is rapidly developing in tropical and sub-tropical regions of the world. As the industry is still in its infancy, grow out diets are generally not formulated specifically for this species as there is limited data on nutrient requirements and the acceptability of various ingredients. Given the recent increases in the price of fish meal (FM), the use of alternative protein sources such as poultry by-product meal (PBM) may be more cost effective. The present research evaluated the response of juvenile redclaw to practical diets utilizing PBM as a replacement for FM. Juvenile redclaw crayfish (0.45 g ± 0.01) were stocked into 24, 600-L, outdoor round tanks at a density of 12.5 m^{-2}. Tanks were supplied water from a watershed reservoir and maintained on a flow through regime. Crayfish in four replicate tanks were maintained on one of the six diets formulated to contain 260 g kg^{-1} crude protein and 70 g kg^{-1} crude fat which had previously demonstrated good growth under similar conditions. FM in the basal diets was replaced with PBM at various levels, on an iso-nitrogenous basis, so that the diets contained 150, 120, 90, 60, 30 and 0 g FM kg^{-1} diet and 78, 105, 132, 158, 185 and 212 g PBM kg^{-1} diet, respectively. At the conclusion of the 56-day growth trial, survival (>83%) and growth (>11.3 g or 2400%) of the crayfish were not significantly different among treatments. Based on these results, PBM appears to be a viable candidate as a replacement for FM in redclaw crayfish diets.

KEY WORDS: fish meal, nutrition, poultry by-product meal, redclaw crayfish

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Introduction

Aquaculture of redclaw crayfish, *Cherax quadricarinatus*, is rapidly developing in tropical and sub-tropical regions of the world. As the industry is still in its infancy, there are no specific grow out diet formulations developed for the species. Aquaculturists in several countries have used a variety of diets for redclaw grow out. Jones & Ruscoe (2000, 2001) used a crayfish diet (Athmaize™) containing 170 g kg^{-1} protein; Karplus *et al.* (1995) used a commercial carp pellet containing 250 g kg^{-1} protein; Pinto & Rouse (1996) used a commercial crayfish pellet with 250 g kg^{-1} protein; and Barki & Karplus (2000) used a 40 g kg^{-1} protein commercial trout pellet. Farmers in Mexico and Ecuador are currently using commercial shrimp feeds formulated to contain 360 g kg^{-1} protein with fish meal (FM) as a primary protein source. However, FM production has been nearly constant, averaging annually about 6 500 000 tons (Hardy 2006), and demand for FM is growing, putting pressure on fishery stocks and causing FM prices to increase. It is therefore necessary to find alternate sources of protein for crayfish diets.

Quantity and quality of dietary protein are primary factors influencing crayfish growth, nitrogen loading of culture systems and feed costs. Marine protein sources are often utilized in aquatic feeds because they are an excellent source of indispensable amino acids, essential fatty acids, vitamins, minerals and generally enhance palatability. Moreover, considerable research has been conducted to evaluate the acceptability of alternate feed ingredients as protein sources for crustaceans other than redclaw crayfish (Tacon & Akiyama 1997). Protein ingredients that can be utilized to replace marine protein sources, either partially or completely include terrestrial plant and animal ingredients readily available on world markets. Considerable attention has been given to other crustaceans with regards to the use of plant proteins such as: soybean meal (Lim & Dominy 1990; Tidwell *et al.* 1993; Sudaryono *et al.* 1995), solvent-extracted cottonseed meal (Lim 1996), various legumes (cowpea, green mungbean, rice bean) and leaf meals (Eusebio 1991; Eusebio & Coloso 1998). Because of their low price and consistent quality, plant proteins are often an economically and nutritionally viable source of protein. However, because of potential problems associated with insufficient levels of indispensable amino acids (e.g., lysine and methionine), anti-nutrients and poor palatability, their use is often limited. Other authors, report that FM can be replaced by a number of plant proteins (e.g., brewer's grains with yeast and soybean meal) without detrimental effects on redclaw survival or growth (Webster *et al.* 2002; Muzinic *et al.* 2004; Kenneth *et al.* 2005).

Another alternative is to use sources of terrestrial animal protein which are primarily rendered by-products such as meat and bone meal and poultry by-product meal (PBM). PBM, which generally contains 450–650 g kg^{-1} protein are often good sources of indispensable amino acids. Moreover, PBM seems to be more palatable than proteins of plant origin (Kureshy *et al.* 2000). Information about the use of alternative protein sources as replacements for FM in *C. quadricarinatus* diets is limited. The present study was designed to evaluate the suitability of using PBM as a substitute for FM in practical redclaw diets.

Materials and methods

The research was conducted at the North Auburn Fisheries Research Station, Auburn, Alabama. Juvenile redclaw crayfish released by three females during a 48-h period were collected and placed in an outdoor nursery tank for 4 weeks. Juveniles were then harvested, manually size-sorted eliminating large and small outliers and separated into groups of 10 individuals. Each group was sorted to ensure that its weight was within 10% of the mean weight for all groups. Later analysis of variance indicated no significant differences in initial weight among groups ($P = 0.52$). Each replicate group was then individually weighed and stocked into one of 24 circular tanks (600-L volume, 0.8 m^{-2} bottom area) that received water from a watershed storage reservoir. Water flow through the system was approximately 20 L h^{-1} for the duration of the experiment. Each tank contained 10 pieces of 5-cm diameter polyvinyl chloride (PVC) pipe used for refuge and two submerged air diffusers for aeration and water mixing. Four replicate tanks were randomly assigned one of six experimental diets (Table 1) and stocked with 10 redclaw (12.5 m^{-2}). Based on previous work, mean weights of the crayfish were assumed to double during the first two weeks and thereafter have a weekly growth rate of 2.0 g per week. Based on the expected growth rates and a feed conversion of 1.5, a feeding table

Table 1 Ingredient composition of the test diets (g kg^{-1} dry wt.)

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Fish meal[a]	150	120	90	60	30	–
Poultry meal[b]	78	105	132	158	185	212
Soybean meal[c]	190	190	190	190	190	190
Menhaden fish oil[d]	39	39	39	39	39	39
Wheat starch[e]	375	378	381	380	383	386
Whole wheat[e]	125	125	125	125	125	125
Trace mineral premix[f]	5	5	5	5	5	5
Vitamin premix[g]	20	20	20	20	20	20
Stay C 250 mg kg^{-1} [h]	0.7	0.7	0.7	0.7	0.7	0.7
CaP-mono[i]	15	15	15	20	20	20
Cellufil[e]	2	2	2	2	2	2

[a] Special SelectÔ, Zapata Protein USA, Randeville LA, USA.
[b] Flash-dried poultry by-product meal, Griffin Industries, Cold Spring, KY, USA.
[c] Solvent-extracted soybean meal.
[d] Omega protein, Reedville VA, USA.
[e] United States Biochemical, Cleveland OH, USA.
[f] g per 100 g premix: cobalt chloride 0.004, cupric sulfate pentahyrate 0.250, ferrous sulfate 4.0, magnesium sulfate heptahydrate 28.398, manganous sulfate monohydrate 0.650, potassium iodide 0.067, sodium selenite 0.010, zinc sulfate heptahydrate 13.193, filler 53.428.
[g] g kg^{-1} premix: HCl 0.5, riboflavin 3.0, pyrodoxine HCl 1.0, D,L Ca-pantothenate 5.0, nicotinic acid 5.0, biotin 0.05, folic acid 0.18, vitamin B12 0.002, inositol 5.0, menadione 2.0, vitamin A acetate (20,000 IU/g) 5.0, vitamin D_3 (400,000 IU/g) 0.002, D,L-alpha-tocopheryl acetate (250 IU g^{-1}) 8.0, alpha-cellulose 865.266, choline chloride 100.0.
[h] 250 mg kg^{-1} active C supplied by Stay C© (L-ascorbyl-2-polyphosphate 35% active C), Roche Vitamins, Parsippany NJ, USA.
[i] Cefkaphos © (primarily monobasic calcium phosphate), BASF, Mount Olive, NJ, USA.

was built for the 58-day growth trial. Daily ration was weighed every morning, divided into two equal portions, and offered to the crayfish in the morning (~8:00 h) and evening (~16:00 h).

The six diets used in the present work were formulated to contain 260 g of crude protein per kilogram diet, 69 g of lipids per kilogram diet and total phosphorus levels above 10 g kg^{-1} diet. FM was progressively replaced with PBM on an iso-nitrogenous basis. To make the various diets, bulk dry feed ingredients were ground to an appropriate size and mixed with fish oil in a food mixer. Hot water was blended into the mash to attain a consistency appropriate for pelleting. Each feed was extruded through a 2-mm die in a meat grinder. Pellets were dried at 40 °C in a forced air oven until the moisture content was less than 100 g kg^{-1}. Pellets were crumbled and sieved to the desired size and stored at –20 °C.

Dissolved oxygen (DO) concentrations and temperature were measured twice daily using YSI 55 DO meter (Yellow Spring Instrument Co., Yellow Springs, OH, USA). Values for water temperature were 28.7 °C ± 1.42 (mean ± SD), with a maximum of 30.8 °C and a minimum of 25.4 °C. Oxygen concentration was never found to be less than 5 mg L^{-1}. Ammonia was measured weekly using the Solorzano (1969) phenol hypochlorite method, and was always below detectable levels.

At the conclusion of the growth trial, crayfish were counted and individually weighed. Feed efficiency (FE = wet weight gain × 100/dry weight feed offered), percent weight gain (wet weight gain × 100/initial weight), percent survival and specific growth rate [SGR = $(\ln W_F - \ln W_I) \times 100/$ days] were calculated.

Data from the feeding trial were analyzed using one-way analysis of variance (ANOVA) and Student-Newman-Keuls test (Steel & Torrie 1980) to determine significant differences ($P \leq 0.05$) among treatment means. All statistical analyses were performed using SAS (version 8.2; SAS Institute, Cary, NC, USA).

Results and discussion

There were no differences in survival or growth among treatments in the experiment. Survival was greater than 80%, and growth was greater than 2400% in all treatments (Table 2). Feed efficiencies were around 60%. Significant differences in feeding efficiency occurred only between the 12 : 3 diet and the 0 : 15 diet ($P = 0.04$) (Table 2). These results are typical for *C. quadricarinatus* under these conditions and would be considered good production results. Although, it is difficult to compare growth rates across production systems and years, growth rates were comparable with previous results (Hernández-Vergara *et al.* 2003) conducted in tank systems as well as growth rates reported at other facilities (Jones 1995; Muzinic *et al.* 2004; Thompson *et al.* 2005). As growth rates in the system were good and tissue replacement was more than adequate for most nutritional deficiencies, all diets appeared to support good performance.

Results of the present experiment suggest that PBM is a suitable replacement for FM in well-balanced practical diets formulated for juvenile redclaw. While some significant differences were found in feeding efficiency, they were only noted between two diets (12 : 3 and 0 : 15). These differences are considered to be noise in the data because of the lack of differences in feed efficiency between the 15 : 0 and 0 : 15 diets. Weight gain was not statistically different among treatments indicating that PBM has good potential as a nutrient source. PBM, from the same source, was also found to be a suitable substitute for FM in properly formulated diets for red drum, *Sciaenops ocellatus* (Kureshy *et al.* 2000)

Table 2 Survival, weight gain, percent growth, specific growth rate (SGR) and feed efficiency of redclaw crayfish (initial wt. 0.45 g ± 0.01; mean ± SE) maintained for 58 days on diets containing varying levels of fish meal and poultry by-product meal

Treatment FM : PBM[1]	Survival (%)	Weight gain (g)	Growth (%)	SGR	Feed efficiency (%)[2]
15 : 0	96.7	12.2	2611	5.7	60.3[ab]
12 : 3	90.0	12.7	2722	5.8	63.7[a]
9 : 6	83.0	12.0	2567	5.7	60.4[ab]
6 : 9	90.0	11.5	2456	5.6	57.8[ab]
3 : 12	85.0	12.4	2656	5.7	62.3[ab]
0 : 15	85.0	11.3	2411	5.6	56.6[b]
PSE	4.00	0.33	81.9	0.05	1.64
P-value	0.79	0.06	0.24	0.24	0.04

[1] FM = percent fish meal in the diet; PBM = percent poultry by-product meal in the diet. Based on analysis of variance there were no significant differences ($P > 0.05$) found among any of the treatment means.

[2] Based on Student-Newman-Keuls test, values within the column with different superscript are significantly different.

and Pacific white shrimp, *Litopenaeus vannameii* (Davis & Arnold 2000). In both experiments, PBM did not appear to negatively impact palatability of the feed. However, it should be noted that Kureshy *et al*. (2000) and Davis & Arnold (2000) did not test diets with 100% replacement of FM with PBM. The small amounts of FM in their diets might have contributed to attractability and palatability of their feeds. In the present experiment, the attractability and palatability of feeds with 100% PBM were not empirically evaluated but results do suggest that the absence of FM did not negatively impact the attractability of the feed.

Although the results of the present study suggest that PBM is a suitable substitute for FM in redclaw diets, we should not assume that farmers everywhere would benefit from such an ingredient substitution in the diets they use. The FM used in the present study was of high quality. Cost effectiveness of substituting FM with PBM or any other ingredient will vary depending on location and local cost of ingredients. Similar to FM, PBM can also vary considerably in quality and should be tested before being used in redclaw diets. Finally, further research evaluating additional nonmarine sources of protein in redclaw diets should be performed.

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