Available online at www.sciencedirect.com
ScienceDirect
Aquaculture 272 (2007) 564–572
Aquaculture
www.elsevier.com/locate/aqua-online

Effect of a variety of animal, plant and single cell-based feed ingredients on diet digestibility and digestive enzyme activity in redclaw crayfish, *Cherax quadricarinatus* (Von Martens 1868)

Ana Pavasovic [a], Alex J. Anderson [b], Peter B. Mather [a], Neil A. Richardson [b,*]

[a] *School of Natural Resource Sciences, Queensland University of Technology, GPO Box 2434, Brisbane, Qld, Australia*
[b] *School of Life Sciences, Queensland University of Technology, GPO Box2434, Brisbane, Qld, Australia*

Received 4 June 2007; received in revised form 7 August 2007; accepted 8 August 2007

Abstract

Readily available agricultural products are often considered as feed ingredients when investigating cost-effective diet formulations for aquatic organisms. We investigated the potential use of fish meal (FM), meat and bone meal (MBM), poultry meal (PM), soybean meal (SBM), canola meal (CM), lupin meal (LM) and brewer's yeast (BY) in dietary formulations for redclaw crayfish, *Cherax quadricarinatus*. Test ingredients were incorporated at 30% inclusion level in a commercial redclaw pellet, and used in digestibility trials where apparent digestibility coefficients (ADCs) and digestive enzyme activities were measured and correlated. High ADC values were recorded for all treatments. The SBM diet had the highest apparent digestibility for dry matter (ADMD) (84.5%), crude protein (ACPD) (94.1%) and gross energy (AGED) (91.4%), while the lowest value was obtained for the diet containing MBM (75.9% ADMD; 88.5% ACPD; 85.5% AGED). Overall, ACPD was significantly higher ($P<0.05$) for diets containing plant-based ingredients (93.5%) than for animal-based ones (90.0%). Similar trends were observed when dry matter and crude protein digestibilities were compared for specific feed ingredients. Specific activities of protease, amylase, cellulase and lipase in mid gut (MG) gland extracts were also determined for redclaw fed test diets. Generally, carbohydrase and lipase activities in individuals fed plant-based diets were significantly higher than in those fed animal-based diets. A significant correlation was observed for enzyme activity and ADC values. Protease activity was negatively correlated with diet ADMD, ingredient (I) ADMD, IACPD and IAGED, while lipase activity was positively correlated with ACPD and IACPD. Amylase/protease ratio (A/P) was positively correlated with all digestibility coefficients except AGED. Based on these observations, we conclude that redclaw have the capacity to successfully utilize nutrients from a broad range of dietary ingredients including animal, single cell and in particular, plant matter in their diet. We also suggest that digestive enzyme secretions and the ratio in which they occur, play a key role in determining digestibility of nutrients by redclaw.

Keywords: *Cherax quadricarinatus*; Redclaw; Digestive enzymes; Digestibility; Nutrition

1. Introduction

Redclaw, *Cherax quadricarinatus,* (Von Martens 1868) is a decapod crustacean (Decapoda; Parastacidae) endemic to freshwater river systems and lakes of

* Corresponding author. Tel.: +61 7 3138 1388; fax: +61 7 3138 1534.
E-mail address: n.richardson@qut.edu.au (N.A. Richardson).

0044-8486/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.aquaculture.2007.08.027

northern Australia (Jones et al., 1998) and parts of Papua New Guinea (Holthuis, 1986). During the past 20 years, redclaw have been introduced to many countries and successful redclaw aquaculture industries established (Medley et al., 1994; Rouse, 1995; Romero, 1997; Chang, 2001). Suitability of redclaw for aquaculture can be attributed to a range of desirable traits (reviewed in García-Ulloa et al., 2003; Thompson et al., 2003; Campana-Torres et al., 2006) particularly a relatively simple life cycle (Morrissy, 1979) and an omnivorous feeding habit (Lawrence and Jones, 2002).

Understanding the nutritional requirements of redclaw will be essential to ensuring profitable production and long-term sustainability of the redclaw aquaculture industry. Consequently, several studies have looked at specific aspects of redclaw nutrition, such as determining optimum dietary protein (Cortés-Jacinto et al., 2003, 2004; Thompson et al., 2004) and lipid levels (Hernandez et al., 2002; Hernandez-Vergara et al., 2003). Significant work has also been done to investigate the potential replacement of fish meal in artificial diets for redclaw (García-Ulloa et al., 2003; Muzinic et al., 2004; Thompson et al., 2005, 2006; Campana-Torres et al., 2005, 2006). This follows a global trend towards minimizing reliance on marine animal proteins (primarily fish meal) and use of cheaper alternatives. For many aquaculture species, fish meal replacement has become a priority issue due to increasing price of fish meal and unsustainable pressures on wild fisheries to satisfy demand for this product (Manzi, 1989; Hardy and Kissil, 1997; Naylor et al., 2000). Potentially viable alternatives to fish meal come from many agricultural commodities, particularly those with high protein content such as animal meals, oilseeds and grain legumes.

Allan et al. (2000) identified the analysis of digestibility as the first step in estimating the potential of a new ingredient for use in artificial diets for aquaculture species. Studies that have investigated digestibility of various feed stuffs in freshwater crayfish are scarce however, despite the ability of crayfish to consume a wide range of food types. In general, natural food material consumed by freshwater crayfish consists of both animal and plant matter (Medley et al., 1994) with significant quantities of fungal and bacterial matter also ingested (Merrick, 1993). Campana-Torres et al. (2005) investigated protein and dry matter digestibility of some plant (soy paste, textured wheat, sorghum meal) and animal (sardine meal, squid meal and red crab meal) based ingredients in diets for juvenile redclaw. Their results show that redclaw appear to digest plant-based ingredients more efficiently than animal-based ones. This result was supported by Campana-Torres et al. (2006) who observed higher mean carbohydrate and lipid digestibility coefficients for plant-based ingredients than for animal-based ones. In contrast, Pavasovic et al. (2006) observed a significant reduction in digestibility of diets containing high levels of complex carbohydrates (cellulose). Nevertheless, very few studies have investigated digestibility coefficients for potential feed ingredients in redclaw.

Hofer and Köck (1989) (c.f. Furne et al., 2005) observed that it is possible to predict the ability of a species to utilize different nutrients based on its digestive enzyme profile. Redclaw, like most other freshwater crayfish species possess a broad suite of digestive enzymes (Figueiredo et al., 2001). These have been investigated in a number of studies, that focused on the range of digestive enzymes secreted by redclaw (Figueiredo et al., 2001), ontogenetic changes in digestive protease and carbohydrase activities (Figueiredo and Anderson, 2003) and characterisation of cellulase activity (Xue et al., 1999). Attempts have also been made to investigate the effects of different nutrient sources on digestive enzyme activity in redclaw (Lopez-Lopez et al., 2005; Pavasovic et al., 2006). Findings from such studies are essential to help explain nutrient digestibility (Kolkovski, 2001) in aquatic organisms. In fish, data pertaining to digestive enzyme activity and profiles have helped overcome nutritional problems associated with formulation of artificial diets that best meet an animals' nutritive capability (Furne et al., 2005). They can also help define the inclusion limits for macronutrients such as dietary protein (Twining et al., 1983) and carbohydrates (Spannhof and Plantikow, 1983). Although digestive enzyme profiles may help to better explain nutrient use and relative digestibility, very few studies have investigated the ability of redclaw to utilize different nutrient sources by observing digestive enzyme responses. In this study, we analysed seven different potential feed ingredients that are available commercially by measuring digestibility coefficients and their relationship to digestive enzyme secretions in redclaw.

2. Materials and methods

2.1. Experimental animals and laboratory facility

The adult redclaw (*C. quadricarinatus*), used in this study were obtained from a commercial crayfish producer, Sunshine Coast Crayfish Farmers (Yandina, Australia). Experiments were conducted in the recirculated aquaculture facility at the Queensland University of Technology, Brisbane, Australia. Prior to the commencement of the experiment, all experimental animals were weighed individually (average wet body weight 94.5 ± 3.5 g) and randomly assigned to treatments. Four crayfish were assigned per treatment diet ($n = 4$). The animals