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Chapter 5

COBIA (*RACHYCENTRON CANADUM*): A MARINE FISH NATIVE TO BRAZIL WITH BIOLOGICAL CHARACTERISTICS TO CAPTIVE ENVIRONMENT

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ABSTRACT

In this review *Rachycentron canadum* will be approached, a species with best biological characteristics for marine fish cultivation. Aquaculture is recognized as an important activity to promote commercial increase in Americas from cobia, a marine fish native to Brazil, neritic and with migratory behavior. The species is widely distributed in tropical and subtropical waters of all oceans, except the Central and Eastern Pacific. Cobia does have favorable characteristics to be qualified such as high rates of growth, good feed conversion and adaptation to environmental captivity, low mortality, high market value as well as excellent meat quality. The external morphological appearance of this species is characterized by a dorsoventral flattening in the head, an elongated body and the skin covered with tiny scales. Along the sides of the body are stretched two silver bands, contrasting with a dark-brown body and yellowish color of womb; cobia can reach up to 68 kg and 2 m in length. Cobia has carnivorous feeding habits of preferably fish and crabs, although it can consume shellfish; in its diet is also included zoobenthos and nekton. Cobia has already been successfully cultivated in several countries such as China, Taiwan, Puerto Rico, Vietnam, United States, Bahamas, Thailand, Iran, Dominican Republic, Martinique, Panama, Mexico, Philippines, Belize, Japan, Indonesia, Reunion Island, Mayotte and Brazil. It is a very strong fish, but occasionally needs the control of diseases mainly caused by parasites, bacteria and virus. Economic indicators, such as production cost and return on investment, have shown the viability of cobia cultivation. A lectin has been detected in the serum of cobia with hemmagglutinating activity inhibited

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by methyl-α-D-mannopyranoside, *R. canadum* lectin, RcaL. Lectins have been described with potential function in the immune defense of fish. This paper evaluates the perspectives of cobia, with favorable biological characteristics, to succeed in environmental captivity cultivation and reveals that this species may contribute to unravel immune and biotechnological purposes.

Keywords: *Rachycentron canadum*; cobia

1. INTRODUCTION

Aquaculture is a farming activity for production of organisms in captivity with predominantly aquatic habitat such as fish, crustaceans, molluscs and aquatic plants (Bursztyn and Assad, 2000); it is based on profitable production, environmental conservation and social development (Valenti et al., 2000).

Aquaculture represents an alternative to the exploitation of natural resources and presents itself as the fastest-growing food production in the world. In assessing the state of world fisheries, the FAO (2009) - United Nations Food and Agriculture - considers likely that fishery has reached its maximum catch potential in the oceans, tending to capture stabilization of about 90 million tons, with 1.2% growth rates per year. This means that aquaculture continues to grow at a faster rate than other production sectors of animal production.

According to estimates, population growth by 2020 will result in increased fish consumption in the order of 30 million tons/year, and such increase in demand will have to be supplied by aquaculture (Chang, 2003). Thus, the various activities related to aquaculture have been perfected over the years including marine fish farming.

Aquaculture is recognized as materially important to the increased commercial activity of *Rachycentron canadum* (cobia species) in the Americas (Hernández-Rodriguez et al., 2001). In this context, with growing demand for fish originating products and the continued pressure on the finite wild stocks, the prognosis is the significant increase in aquaculture production of freshwater cobia for the next 10 years (Rojas and Wadsworth, 2007).

The seafood industry in several countries of Latin America, with extensive infrastructure already in place, benefits from recent technological advances.The introduction of commercial operations for growing cobia on commercial farms is due to increased market demand for high quality fish seen in the U.S. (Benetti et al., 2007) as well as Asian countries like China and Taiwan.

In Brazil, despite the growing research in this area in the last decade, aquaculture has never existed in practice as commercial activity, with no national official records of marine fish production (Ostrensky and Boerger, 2008; FAO, 2010).

On the other hand, although not all technological aspects of marine fish farming are as advanced as those of freshwater fish farming, this activity is considered very promising (Tsuzuki, 2006).

According to Cavalli and Hamilton (2007), to be considered ideal for growing, fish needs to dispose of animal husbandry and biological characteristics that justify the investment in research to knowledge of the species and development of appropriate technology to farming.

Characteristics are related to weight gain, feeding habit, adaptation to artificial food, disease resistance, ease eggs and larvae production, good acceptance by market and economic conditions. Cobia in Brazil occupies the first place ranking in this classification, followed by snook (*Centropomus undecimalis* and *C. parallelus*). Cobia also stands out among the more cultured marine fish worldwide (Table 1).

Despite the obvious interest in the cultivation of *R. canadum* species, there are few scientific studies about the fish (Cavalli and Hamilton, 2007; Ostrensky and Boerger, 2008). This paper will address biological characteristics and capability for farming in captivity as well as potential biotechnological applications of this species.

2. *RACHYCENTRON CANADUM*

Rachycentron canadum is a fish species historically appreciated in Brazil. Reports of the work "Descriptive Treaty from Brazil in 1587" reveals some peculiar features of cobia, as the most esteemed Brazilian fish, brown in color, large head covered with scales, very tasty meat; head formed by very delicate bones; females have yellow eggs (Sousa, 1987).

The species *R. canadum* (Linnaeus, 1766), the sole representative of the family Rachycentridae, receives various names around the world, commonly called beijupira or bijupira in Portuguese; cobia, black kingfish or ling, in English; mafou in French; cabi, in Spanish; suji, in Japanese; runner on Italy and bacalao, medregal or esmedregal, in Central and South Americas.

Cobia is a neritic fish of active swimming habit; it has migratory behavior and can be found in shallow waters with rocky or reef bottoms, as well as in estuaries and bays (Figueiredo and Menezes, 2000). The species is widely distributed in tropical and subtropical waters of all oceans, except for the central and eastern Pacific. Cobia in the wild does not form large schools (Shaffer and Nakamura, 1989). Figure 1 represents cobia's taxonomic classification (Fishbase, 2010).

Among the favorable characteristics that qualify cobia as a potential candidate for marine aquaculture are included the high growth rates from 4 to 6 kg/year, compensatory growth when grown at lower temperatures (18° C), good feed conversion in open-ocean growing systems, adaptation to confinement, transport tolerance, ease of spawning in captivity, high market value and excellent meat quality (Chou et al., 2001; Arnold et al., 2002; Liao et al., 2004; Kaiser and Holt, 2005; Wang et al, 2005; Faulk and Holt, 2006; Sun et al., 2006; Schwarz et al., 2007; Benetti et al., 2010). In addition, cobia easily accepts extruded diets (Craig et al., 2006).

According to Benetti et al. (2007) and Liao et al. (2004), many other features give the cobia, the quality of excellent species for farming as well as acceptance to artificial food (Kilduff et al., 2002; Liao et al., 2004) low mortality rate (Benetti et al., 2007), excellent use for human consumption, once 60% can be used for this purpose (Kilduff et al., 2002); easily adaptation to captive environment (Holt et al., 2007) in addition to tolerating variations of water quality (Kilduff et al., 2002).

2.1. Morphology

The external morphological appearance of this species is characterized by a dorsoventral flattening in the head and elongated body, the skin covered with tiny scales. Two silver bands stretch along the body sides, contrasting with its dark brown and yellowish ventral color. This species has seven to nine spines and 31 dorsal-fin rays as well as and two spines and 24 rays in the anal fin. It can reach up to 68 kg and over 2 m in length (Froese and Pauly, 2009). It is known as "scale dogfish" among fishermen due to its resemblance to a small shark or dogfish. The cobia's appearance is similar to a remora (Echeneididae), but morphological analyses on the larvae indicate a closer phylogenetic relationship with the goldfish (Coryphaenidae) (Ditty and Shaw, 1992). Figure 2 (A and B) shows cobia specimens in breeding ponds.

2.2. Feeding Habit

Cobia, carnivorous feeding habit, includes zoobenthos and nekton on the diet, feeding preferably on fish and crabs, although it can consume shellfish. During larval stages, their food is made preferably by copepods (Shaffer and Nakamura, 1989). On the other hand, cobia has feeding behavior associated with food availability from where they live in, which characterizes the species as fast swimmer and aggressive predator able to catching its prey in full motion, usually feeding in the water column (Chou et al., 2001).

Phylum
Cordata

Class
Actinopterygii

Subclass
Neopterigii

Infraclass
Teleostei

Superorder
Acanthopterygii

Order
Perciformes

Suborder
Percoidei

Family
Rachycentridae

Genus
Rachycentron

Species
Rachycentron canadum

Figure 1. Taxonomic classification of cobia (Linnaeus, 1766). Modified from Fishbase (2010).

Table 1. Major marine fish species grown in the world

Species	Major producing countries
Rachycentron canadum	** Bahamas, Belize, United States, Belize, Puerto Rico, Dominican Republic, Mexico, Philippines, Vietnam, China, Taiwan; and Brazil.
Lates calcarifer	*Malaysia, Indonesia.
Dicentrarchus labrax	*Italy, Greece, Egypt.
Salmo salar	*Norway, Chile.
Oncorhyncus keta	*Japan, Chile.
Seriola quinqueradiata	*Japan.
Pagrus pagrus	*Japan.
Mugi cephalus	*Egypt, Italy, Israel.
Paralichthys orbignyanus	*Japan, Korea, Spain, France.
Epinephelus sp	*Thailand, Malaysia.

*(Duarte, 2008) and **(FAO, 2010).

A

B

Figure 2. Cobia specimens, *Rachycentron canadum*. Source: Laboratory of Aquaculture from the Aqualider Company in the State of Pernambuco, Northeastern Brazil (author's photos, *M. C. Coriolano*). A: Side view of cobia specimens. B: Cobia specimens seen from above.

2.3. Farming

The first report on the cobia farming occurred in 1975 on the coast of North Carolina (USA) (Hassler and Rainville, 1975). Despite the good initial results, it was only in late 1980 and early 1990 that researches on the farming were conducted in the United States and Taiwan. Since then, cobia has been grown successfully, especially in China and Taiwan (Liao et al., 2004); other countries such as Puerto Rico and Vietnam are also listed as producers of cobia (Benetti et al., 2006; Nhu, 2009). Years later the growing of cobia were reported in the United States, Bahamas, Thailand, Iran, Dominican Republic, Martinique and Panama Benetti et al, 2006), Mexico (Segovia-Valle et al., 2006), Belize (Sampaio, 2006), Japan and Indonesia (Liao and Leaño, 2007), Reunion Island and Mayotte (Gaumet et al., 2007). The first report of *R. canadum* in Brazil occurred in 2006 in the State of Bahia. In recent years, the commercial and experimental farming of cobia has been reported in the States of Pernambuco, Sao Paulo, Rio de Janeiro, Bahia, Espírito Santo, Rio Grande do Norte and Paraná. According to the Information System for Authorizations of Union-Domain Water Use for Aquaculture - SINAU (2009), there were ongoing requests of projects with cobia's fattening for the States of Bahia, Parana, Rio de Janeiro and São Paulo.

Food is responsible for more than 50% of costs in intensive fish farming (Lovell, 2002). The cost of food may be even higher due to the eating habits of the species and ingredients used in the diet. Overall, carnivorous fish such as cobia have high protein requirements. Brazil uses one or two daily feeding in commercial farming in the open ocean (Cavalli et al., 2011). The same feeding frequency is used in farming at ponds set in the State of Bahia (Carvalho, 2010).

According to Chang (2003), the ideal temperature range for cobia growth is between 22 and 32° C. The Brazilian coast has favorable conditions of surface water temperature for cobia farming; in particular, the Northeast Brazilian Region has average temperature ranging among 25.3 and 29.5° C over the year (Medeiros et al., 2009). Researchers found decrease in growth and high mortality rates, when water temperature goes below 16° C (Liao and Leaño, 2005). According to Faulk and Holt (2006), some studies also showed that cobia have tolerance to variations of salinity in larval and juvenile stages. The cobia farming not necessarily needs coastal areas with high salinities. Studies have shown that juvenile cobia can be farmed in salinities between 5 to 30 ppt (Resley et al., 2006). However, the survival rates observed in 5 ppt salinity were lower than the others.

Brazil has excellent conditions for cobia farming development. Since 2003 studies have been conducted, being the Northeast a pioneer with the States of Bahia, Pernambuco and São Paulo (Carvalho, 2006). Research has shown that the species moves to reproduce in the open ocean at the natural environment (Carvalho, 1999). In this context, the necessary conditions for cobia farming in captivity will certainly have a decisive role in the development of aquaculture of this species.

2.4. Diseases

Pavanelli et al. (2000) warn of risks associated with the onset of diseases when promoting the intensification of cropping systems. Pavanelli et al. (2008) stated that regarding the increment of aquaculture in these environments, parasite species considered as problems for fish health can emerge as promoters of disease.The increased prevalence and intensity of parasitism establishes a direct relationship with high stocking densities.

Relating to the attributes necessary for indication of a species for fish farming, it is of great importance to consider its ability to resist diseases. Holt et al. (2007) mentioned that cobia is a very resistant fish to captivity conditions, feeds voraciously and grows rapidly.

However, diseases occasionally arise and need to be controlled. According to Pavanelli et al. (2008), the fish containment at high stocking densities, characteristic of intensive farming model, encourages the development of epidemics that have minimal expression under natural conditions. High population densities combined with the type of food, water quality degradation, treatment and management practices typical to intensive models, cause physiological stress in fish (chronic stress) which is reflected in its homeostasis, resulting in decreased immune responsiveness. Consequently, it generates lower resistance to infections of various etiologies that can cause serious threat to the farming success, foremost among them the parasites.

Currently, parasite species considered problems for health of marine fish are few in number; however, increased farming activity in marine environments worldwide, parasites emerge with great potential to cause damage to crops. The *Amyloodinium ocellatum* Brown, 1931, among the parasites that cause problems to marine fish health, stands out as the most important pathogen that can cause serious threats to marine aquaculture (Paperna, 1980; Noga et al., 1991; Eiras et al., 2006). The *Amyloodinium ocellatum* is a dinoflagellate, mandatory fish ectoparasit, commonly found in wild populations of marine environments; it has been a major obstacle in the development of marine fish, causing great economic losses (Reed and Francis-Floyd, 1994; Eiras et al., 2006). It is a parasite commonly found in wild populations of marine environments. At the firstmoment of parasitosis, *Amyloodinium* invades the gills, but shortly thereafter installs across the fish surface, giving it a velvety appearance (Eiras et al., 2006). The main signs of ectoparasite infestation are behavioral changes which include reduction or complete loss of appetite. The fish scraps against objects, walls or substrate in the tanks, water backflow through the gills (coughing), with rapid breathing, erratically swimming, crowding of fish near the aerators as well as on the water surface. The disease process evolution promotes congestion and erosion of fins, mucus hypersecretion, loss of scales, stomach dilation, in addition to affecting the eyes and may cause depigmentation patches (Paperna, 1980; Reed and Francis-Floyd, 1994). The outbreaks resulting from this disease induce in high rates of morbidity and mortality (Sindermann, 1990).

The control of amyloodiniosis outbreaks represents a major barrier in the development of marine aquaculture. There is no chemical treatment registered such as parasiticide in the Food and Drug Administration - FDA for fish intended for consumption (Smith and Schwarz, 2009).

Chemical treatments have not been sufficient to control the *Amyloodinium* in species affected by the parasite. On the other hand, the copper sulfate is the most widely used form in controlling this disease (Reed and Francis-Floyd, 1994).

This substance has strong astringent effect on the gill epithelium and is hepatotoxic to fish (Scott, 2000). In addition to being a toxic chemical to the environment and requiring great care with the application, there is no knowledge as to ensure safety results and efficiency in reducing the infestation (Reed and Francis-Floyd, 1994).

Fish diseases are important factors limiting the development of aquaculture systems; bacteria and fungi, among the various pathogens, constitute other groups of economically significant etiologic agents. (Frerichs and Millar, 1993). In most cases, diseases related to bacteria and fungi are detected as secondary diseases, resulting from wounds caused by infestation with ectoparasites. The main symptom observed is the occurrence of red sores on the fish body.

Antibiotics have been the most common agents used to treat such diseases. However, the development of microbial pathogens with high resistance, with consequent food and environmental contamination are emerging problems that urgently need effective and environmentally safe solutions (Hameed et al., 2003).

Outbreaks of campylobacteriosis, mycobacteriosis, furunculosis and streptococcosis are commonly found (Liao et al., 2004) and a bacterial disease caused by *Photobacterium sp.* has been identified as one of the main problems emerging for cobia (Lopez et al., 2002; Rajan et al., 2003; Chen and Hsu, 2005).

Clinical signs of photobacteriosis or pasteurellosis or pseudotuberculosis include skin ulceration, whitish granuloma on the liver, kidney and spleen. Cobia nurseries when affected by this disease can cause up to 80% mortality, leading researchers to evaluate the usefulness of vaccines (Chen, 2001) and immunostimulant dietary to control or reduce in losses caused by outbreaks of *P. damselae* and *Streptococcus iniae* (Chang et al., 2006). Information about viral diseases in cobias is limited. However, Chi et al. (2003) reported deaths in cobia due to the β-nodavirus NNV (nervous necrosis virus). About 30% of the stocked animals succumb to the disease, which has stimulated interest in a recombinant vaccine. According to Rodgers and Furon (1998), nodavirus is overall associated with mass mortality of larvae and this infection is often accompanied by changes in fish behavior.

In Brazil, the great difficulty found when trying to apply treatment in fish is the few studies demonstrating the efficacy and mechanisms of action through which drugs are used to control the diseases act on the biochemical and physiological functions of animals (Pavenelli et al., 2008).

2.5. Economic importance

Economic indicators evaluated in studies by Sanches et al. (2008) demonstrated the feasibility of cobia farming in offshore system, being an attractive economic activity when considering the potential production of marine species. However, this type of system is not adapted to the small fisherman or family farming due to the high investments required for projecting implementation and funding the activity. Luz (2001) warns that despite the various characteristics conferred on carnivorous species, the commercial production still faces difficulties related to the high rate of cannibalism, feeding difficulties, as well as high costs required to maintain this fish. On the other hand, studies indicate that cobia, with statistic records of little significant catches when compared to other fish production, still represents one of species with potential for marine aquaculture by holding several characteristics favorable to husbandry and market farming.

Benetti et al. (2008), Benetti et al. (2010), Benetti and O `Hanlon et al. (2010) claim that cobia is a species of great commercial interest in marine aquaculture worldwide by presenting various qualities and great market demand. These factors have led to a rapid development of farming technology in the last decade in Taiwan and elsewhere. Sampaio et al. (2010) complemented informing that most production is still concentrated in China and Taiwan, with global production of farmed cobia approximately of 23 000 ton/year.

3. RCAL: A Lectin Detected in the Serum of Cobia

The discovery of lectins in animal tissues was one of the greatest advances in glycobiology and these proteins have been much studied in recent decades (Sharon, 2008).

These molecules are very useful tools to recognize carbohydrates in cell-molecule and cell-cell interactions in a variety of biological systems (Sharon and Lis, 2004).

A new dimension has been added in fish to the study of lectins (Dutta et al., 2005), which have been purified from tissues and biological fluids of various species. Watanabe et al. (2009) isolated a lectin from *Oncorhynchus keta* that binds to L-rhamnose and induces the production of proinflammatory cytokines.

The effect of mitogenic activity of *Cyprinus carpio* lectin is evidenced by the induction of IL-2 and INF-γ in mouse splenocytes (Roitt et al., 1986; Lam and Ng, 2002); Ng et al. (2003) carp lectin has mitogenic effect on splenocytes from mice and stimulating action on the phagocytic activity of supernatant macrophages. Dutta et al. (2005) analyzing a lectin of *Clarias batrachus*, noted that this protein was able to induce the proliferation of lymphocytes in head kidney.

Fish roe lectins from *Coregonus clupeoides, Rutilus rutilus* and *Perca flavescens* have mitogenic activity or indirect cytotoxity mediated by macrophages or cytotoxins (Krajhanzl et al., 1985). Lectins are a heterogeneous group of proteins, widely distributed in nature; these proteins bind specifically to carbohydrates inducing cell agglutination. Hemagglutination is a simple method to demonstrate the lectin activity and can be performed on microscope slides and plastic microtiter plates (Rudiger, 1993). Erythrocytes exhibit a wide variety of glycans on the cell surface that are recognized by lectins, causing cells agglutination (Khan et al., 2002). In our research, a lectin was detected in serum of cobia fish (*R. canadum*) which was fractionated with ammonium sulphate saturation (40-60%; F3). Inhibition hemagglutinating activity of F3 was performed with methyl-α-D-mannopyranoside; F3 showed hemagglutinating activity for rabbit erythrocytes, as showed in Figure 3. Currently, our research group has been dedicated to the purification of the lectin RcaL, also performing in parallel studies on immune system functions with lectin, such as immunomodulatory activity, cytokine release, nitric oxide production, cell proliferation and cytotoxicity. Similarly, another protein was isolated from serum of *Oreochromis niloticus*, OniL, lectin that recognizes mannose, with hemagglutinating activity for rabbit erythrocytes, a potential immunomodulator which has preferentially Th1-type immune response (Silva et al., 2012).

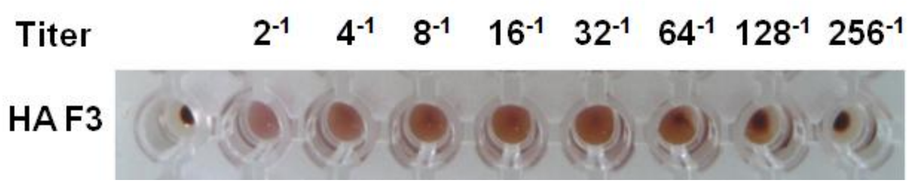

Figure 3. Hemagglutinating activity (HA) of F3. In the activity evaluated, each lectin molecule forms a network of lectin-cell-lectin interaction, maintaining the cells in suspension. The agglutinating assays were performed in 96-wells microtiter plates. Lectin preparations (50 μL) were serially two-fold diluted in 0.15 M NaCl, and an equal volume of rabbit erythrocyte (2.5%) suspension was added to each well. The plates were incubated at room temperature for 1 h.

CONCLUSION

This study addressed the biological characteristics of cobia, favorable to success at captivity environment; also, revealed that this species can contribute to unravel fish immune responses and be applied to biotechnological purposes.

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REFERENCES

Arnold, C.R.; Kaiser, J.B.; Holt, G.J. Spawning of cobia (*Rachycentron canadum*) in captivity. (2002*). Journal of the World Aquaculture Society,* 33, 2, 205-208.

Benetti, D.D.; O'Hanlon, B.; Brand, L.; Orhun, R.; Zink, I.; Doulliet, P.; Collins, J.; Maxey, C.; Danylchuk, A.; Alston, D.; Cabarcas, A. (2006). Hatchery, on growing technology and environmental monitoring of open ocean aquaculture of cobia *Rachycentron canadum* in the Caribbean. World AquacultureSociety Annual Meeting, Florence, Italy, 9-13.

Benetti, D.D. et al. (2007). Aquaculture of cobia (*Rachycentron canadum*) in the Americas and the Caribbean. In: Liao, I.C.; Leaño, E.M. (org.) Cobia aquaculture: research, development and commercial production. Department of Aquaculture National Taiwan Ocean University Keelung. Taiwan, 57-78.

Benetti, D.D.; Orhum, M.R.; Sardemberg, B.; O'Hanlon, B.; Hoenig, A.R. et al. (2008). Advances in hatchery and grow-out technology of cobia *Rachycentroncanadum* (Linnaeus). *Aquaculture Research,* 39, 701-711.

Benetti, D.D.; O' Hanlon, B.; Riviera, J.A.; Welch, A.W.; Maxey, C.; Orhun, M.R. (2010). Growth rates of cobia (*Rachycentron canadum*) cultured in open ocean submerged cages in the Caribbean. *Aquaculture*, 302, 195-201.

Benetti, D.D.; Sardemberg, B.; Hoening, R. et al. (2010). Cobia (*Rachycentron canadum)* hatchery-to-market aquaculture technology: recent advances at the Universityof Miami Experimental Hatchery (UMEH). Revista Brasileira de Zootecnia, 39, 60-67.

Bursztyn, M.; Assad, L.T. Aquicultura sustentável. (2000). In: Valenti, W.C. et al.(org.). Aquicultura no Brasil: bases para um desenvolvimento sustentável. Brasília, CNPq/MCT, 33-72.

Carvalho Filho, A. (1999). Peixes: Costa Brasileira. (3. ed., 320p.). São Paulo: Editora Melro Ltda.

Carvalho Filho, J. (2006). O êxito da primeira desova do bijupirá. Panorama da Aqüicultura, 16, 197, 40-45.

Carvalho Filho, J. (2010). Bijupirá em viveiro de terra. Panorama da Aquicultura, 20, 120, 46-49.

Cavalli, R.O.; Hamilton, S. (2007). A piscicultura marinha no Brasil - Afinal, quais as espécies boas para cultivar? *Panorama da Aqüicultura*, 50-55.

Cavalli, R.O.; Domingues, E.C.; Hamilton, S. (2011). Desenvolvimento da produção de peixes em mar aberto no Brasil: possibilidades e desafios. Revista Brasileira deZootecnia, 40, 155-164.

Chang, D. (2003). O cultivo do bijupirá em Taiwan: a escolha de um peixe de carne branca para consumidores exigentes. *Panorama da Aqüicultura*, 13, 79, 43- 49.

Chang, C.F.; Yang, J.H.; Chang, S. L. (2006). Application of dietary â–1, 3–1, 6–glucan in enhancing resistance of cobia (*Rachycentron canadum*) against *Photbacterium damselae* subsp. *piscicida* and *Sreptococcus iniae* infections. *Journal of Taiwan Fisheries Research*, 14, 75–87.

Chen, H.E. (2001). Evaluation of antigens from *Photobacterium damselae* subsp. *piscicida* using cobia (*Rachycentron canadum*) antiserum. M.Sc.Thesis, National Cheng Kung University, Tainan, Taiwan.

Chen, S.C.; Hsu, C. (2005). Studies on the pathogenicity and pathology of photobacterium damselae subsp. piscicida on *Rachycentron canadum*. *Journal of the Fisheries Society of Taiwan*, 32, 4.

Chi, S.C.; Shieh, J.R.; Lin, S. (2003). Genetic and antigenic analysis of betanodaviruses isolated from aquatic organisms in Taiwan. *Diseases of Aquatic Organisms*, 55, 221–228.

Chou, R.L.; Su, M.S.; Chen, H.Y. (2001). Optimal dietary protein and lipid levels for juvenile cobia (*Rachycentron canadum*). *Aquaculture*, 193, 81-89.

Craig, S.R.; Schwarz, M.H.; McClean, E. (2006). Juvenile cobia (*Rachycentron canadum*) can utilize range of protein and lipid levels without impacts on productioncharacteristics. *Aquaculture*, 261, 384-391.

Ditty, J.G.; Shaw, R.F. (1992). Larval development, distribution, and ecology of cobia *Rachycentron canadum* (family: Rachycentridae) in the northern Gulf of Mexico. FisheryBulletim, 90, 4, 668-677.

Duarte, M. InfoEscola. http://www.infoescola.com/zootecnia/piscicultura-com-especies-marinhas/. (2008). Accessed 27/12/11.

Dutta, S.; Sinha, B.; Bhattacharya, B.; Chatterjee, B.; Mazumder, S. (2005). Characterization of a galactose binding serum lectin from the Indian catfish, *Clarias batrachus*: Possible involvement of fish lectins in differential recognition of pathogens.*Comparative Biochemistry and Physiology*, 141:76-84.

Eiras, G.J.C.; Takemoto, R.M.; Pavanelli, G.C. (2006). Métodos de estudo e técnicas laboratoriais em parasitologia de peixes. *Maringá: EDUEM*.

FAO, Food and Agriculture Organization of the United Nations. (2009). Fishery Departament, Fishery Information, Data and Statistic Unit. FishStar Plus version 2.3.2000, Rome, Italy.

FAO, Fisheries and Aquaculture Rachycentron canadum. (2010). http://www.fao.org/fishery/culturedspecies/Rachycentron_canadum/en. Accessed 10/04/2010.

FAO, Fishstat. (2010). http://www.fao.org/fishery/statistics/software/fishstat/en. Accessed 12/05/11.

Faulk, C.K.; Holt, G.J. (2006). Responses of cobia *Rachycentron canadum* larvae to abrupt or gradual changes in salinity. *Aquaculture*, 254, 275-283.

Figueiredo, J.L.; Menezes, N.A. (2000). Manual de peixes marinhos do Sudeste do Brasil. VI. Teleostei (5). São Paulo: Museu de Zoologia/USP, 1, 116 p.

Fishbase.http://www.fishbase.de/summary/speciessummary.php.rachycentroncandaum. Accessed 16/11/10.

Frerichs, G.N.; Millar, S.D. (1993). Manual for the isolation and identification of fish bacterial pathogens. Stirling: Pisces Press. 60p.

Froese, R.; D. Pauly. Editors. (2009). Fishbase. www.fishbase.org, version (08/2009).

Gaumet, F.; Babet, M.C.; Bettes, A., Toullec, A.L., Schires, G.; Bosc, P. (2007). Advances in cobia *Rachycentron canadum*, research in La Reunion Island (France): problems and perspectives. In: Liao, I.C.; Leaño, E.M. (Eds.). *Cobia Aquaculture: Research Development and Commercial Production.* Asian Fisheries Society, Manila, Philippines, 115-129.

Hameed, A.S.S.; Rahaman, K.H.; Alagan, A.; Yoganandhan, K. (2003). Antibiotic resistance in bacteria isolated from hatchery-reared larvae and post-larvae of *Macrobrachium rosenbergii*. *Aquaculture*, 217, 39-48.

Hassler, W.W.; Rainville, R.P. (1975). Techniques for hatching and rearing cobia, *Rachycentron canadum*, through larval and juvenile stages. *Univ. N.C. Sea Grant Coll. Prog.*UNC-SG-75-30.

Hernández-Rodriguez, A.; Alceste-Oliviero, C.; Sanchez, R.; Jory, D.; Vidal, L. and ConstainFranco, L.F. (2001). *Aquaculture development trends in Latin America and the Caribbean.* In: Subasinghe, R.P.; Bueno, P.; Phillips, M.J.; Hough, C.; McGladdery, S.E. and Arthur, J.R. (Eds.). Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium. Bangkok, Thailand, NACA, Bangkok and FAO, Rome, 317-340.

Holt, G. J. et al. (2007). Advances in Cobia Research in Texas. In: Liao, I.C.; Leaño, E.M. (org.) Cobia aquaculture: research, development and commercial production. Department of Aquaculture National Taiwan Ocean University Keelung. Taiwan, 45-56.

Kaiser, J.B.; Holt, G.J. (2005). Species Profile Cobia. Southern Regional. *Aquaculture Center Publication*, 7202, 6.

Khan, F.; Khan, R.H.; Sherwani, A.; Mohmood, S.; Azfer, M.A. (2002). Lectins as markers for blood grouping. *Med. Sci. Monit*., 8, 293–300.

Kilduff, P. et al. (2002). Induced tank spawning of cobia, *Rachycentron canadum*, and early larval husbandry. *World Aquac*., 33, 35–39.

Krajhanzl, A.; Danisova, A.; Kocourek, J.; Pancoska, P. (1985). In: Bog- Hansen, T.C.; Spengler, G.A. (Eds.). Lectins—biology and biochemistry, and clinical biochemistry, Gruyter, Berlin, 4, 397–408.

Lam, Y.W. and Ng, T.B. (2002) Purification and characterization of a rhamnose-binding lectin with immunoenhancing activity from grass carp (*Ctenopharyngodon idellus*) ovaries. *Protein Expr. Purif*., 26, 378-85.

Liao, I.C.; Huang, T.S.; Tsai, W,-S.; Hsueh, C.M.; Chang, S.L.; Leaño, E.M. (2004). Cobia culture in Taiwan: current status and problems. *Aquaculture*, 237, 155-165.

Liao, I. C.; Leaño, E. M. (2005). Cobia aquaculture in Taiwan. *World Aquaculture*, 36, 31-36.

Liao, I.C.; Leaño, E.M. (2007). Cobia aquaculture: research, development and commercial production. Asian Fisheries Society Taiwan, 178.

Lopez, C.; Rajan, P.R.; Lin, J.H.; Kuo, T.; Yang, H. (2002). Disease outbreak in seafarmed cobia (*Rachycentron canadum*) associated with *Vibrio* spp., *Photobacterium damselae* ssp. *piscicida*, mongenean and myxosporean parasites. *Bulletin of the European Association of Fish Pathologists*, 22, 3, 206–211.

Lovell, R.T. Diet and Fish Husbandry. (2002). In: Halver, J.E.; Hardy, R.W. Fish nutrition (3. ed., 703-754). *Washington: Academic Press*.

Luz, R.K. et al. (2001). Desenvolvimento de alevinos de trairão alimentados com dietas artificiais em tanques de cultivo. Revista Brasileira de Zootecnia, 30, 4, 1159-1163.

Medeiros, C.; Araújo, M.; Rolinic, M.; Freitas, I. (2009). Estrutura termohalina da região oeste do atlântico Tropical - ZEE/NE. In: F.H.V. Hazin (Ed.). Meteorologia e

Sensoriamento Remoto, Oceanografia Física, Oceanografia Química, Oceanografia Geológica. Programa REVIZEE- Score Nordeste. Fortaleza, *Martins e Cordeiro Ltda*, 1, 40-55.

Ministério da Pesca e Aquicultura - MPA. Sistemas de Informações das Autorizações de Uso de águas de Domínio da União para fins de *Aquicultura-SINAU* (2009).

Ng, T.B.; LAM, Y.W.; WOO, N.Y.S. (2003) The immunostimulatory activity and stability of grass carp (*Cteropharyngodon idellus*) roe lectin.*Vet.Immunol. Immunop*., 94, 105-112.

Nhu, V.C. (2009). Optimization of the larviculture of the tropical fish cobia *Rachycentron canadum* in Vietnam. PhD thesis, *Ghent University*, Belgium.

Noga, E.J., Landsberg, J.H.; Smith, S.A. (1991). Amyloodiniosis in cultured hybrid striped bass (Morone saxatilis X M. Chrysops) in North Carolina. *Journal of Aquatic AnimalHealth*, 3, 294-297.

Ostrensky, A.; Boerger, W.A. (2008). Principais problemas enfrentados atualmente pela aqüicultura brasileira. In: Ostrensky, A.; Borghetti, Jr.; Soto, D.Aqüicultura no Brasil: o desafio é crescer. *Brasília: SEAP*, 135-138.

Paperna, I. (1980). *Amyloodinium ocellatum* (Brown, 1931) (Dinoflagellida) infestations in cultured marine fish at Eilat, Red Sea: epizootiology and pathology. *Journal of FishDiseases*, 3, 363-372.

Pavanelli, G.C. et al. (2000). Sanidade de peixes, rãs, crustáceos e moluscos. In: Valenti, W.C.; Poli, C.R.; Pereira, J.A.; Borghetti, J.R. (Ed.). Aquicultura no Brasil: bases para um desenvolvimento sustentável. Brasília, CNPq/MCT, 197-245.

Pavanelli, G.C.; Eiras, J.C.; Takemoto, R.M. (2008). Doenças de peixes: profilaxia, diagnóstico e tratamento. *Maringá: EDUEM*.

Rajan, P.R.; Lin, J.H.; Ho, M.S.; Yang, H.L. (2003). Simple and rapid detection of *Photobacterium damselae* ssp. *piscicida* by a PCR technique and plating method. *Journal of Applied Microbiology*, 95, 1375–1380.

Reed, P.; Francis-Floyd R. (1994). *Amyloodinium* infections of marine fish. Florida: University of Florida. Florida Cooperative Extension Service. Fact Sheet VM-90.

Resley, M.J.; Webb, J.K.A.; Holt, G.J. (2006). Growth and survival of juvenile cobia, *Rachycentron canadum*, at different salinities in a recirculating aquaculture system. *Aquaculture*, 253, 398-407.

Rodgers, C.J.; Furones, M.D. (1998): Disease problems in cultured marine fish in the Mediterranean. Fish Pathology, 33, 157–164.

Roitt, I.; Brostoff, J.; Male, D. (1986). Immunology (4. ed.). Mosby: *Times Mirror International Publisher*.

Rojas, A.; Wadsworth, S. (2007). In: A review of cage aquaculture: Latin America and the Caribbean. In Halwart, M.; Soto, D. and Arthur, J.R. (Eds). Cage aquaculture –Regional reviews and global overview, 70–100.

Rudiger H. (1993). Isolation of plant lectins. In: Gabius H-J, Gabius S (Eds). Lectins and glycobiology. Berlin: Springer-Verlag, 31–46.

Sampaio, L.A. (2006). Marine fish culture in Latin America: Current trends. *World Aquaculture Society Annual Meeting*, Florence, Italy, 832.

Sampaio, L.A.; Tesser, M.B.; Wasielesk, W. Jr. (2010). Avanços da maricultura na primeira década do século XXI: piscicultura e carcinocultura marinha. RevistaBrasileira de Zootecnia, 39.

Sanches, E.G.; Sckendorff, R.W.V.; Henriques, M.B.; Fagundes, L.; Sebasttiani, E.F. (2008). Viabilidade Econômica do Cultivo do Bijupirá (*Rachycentroncanadum*) em Sistema Offshore. Revista Informações Econômicas, 38,12.

Schwarz, M.H.; Mowry, D.; McClean, E., Craig, S.R. (2007). Performance of advanced juvenile cobia, *Rachycentron canadum*, reared under different thermal regimes: evidence for compensatory growth and a method for cold banking. *Journal ofApplied Aquaculture*, 19, 71-84.

Scott, P. (2000). Terapéutica em acuicultura. In: Brown, L. (org.). Aquicultura para veterinarios: producción y clínica de peces. Zaragoza: *ACRIBIA*, 137-160.

Segovia-Valle, E.; Segovia-Cruz, G.; Segovia-Cruz, M.; Segovia-Cruz,W.; Carmona-Osalde, C.; Rodríguez-Serna, M. (2006). Study of growth in oceanic plataform of *Rachycentron canadum* in Yucatan peninsula. *WorldAquaculture Society Annual Meeting*,Florence, Italy.

Shaffer, R.V.; Nakamura, E.L. (1989). Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae). *FAO Fisheries Synopsis*, v. 153.

Sharon, N. e LIS, H. (2004). Lectins (2. ed.). *Heildelberg: Springer*, 470p.

Sharon, N. (2008). Lectins: past, present and future. *Biochem. Soc. Trans*., 36, 1457–1460.

Silva, C.D.C.; Coriolano, M.C.; Lino, M.A.S.; Melo, C.M.L.; Bezerra, R.S.; Maciel Carvalho, E.V.M.; Santos, A.J.G.; Pereira, V.R.A.; Coelho, L.C.B.B. (2012).Purification and characterization of a mannose-recognition lectin from *Oreochromis niloticus* (Tilapia fish): cytokine production in mice splenocytes. Applied Biochemistry and Biotechnology, 166, 424-435.

Sindermann, C.J. (1990). Principal Diseases of Marine Fish and Shellfish. (2. ed., 516 p.*). California: Academic Press*.

Smith, S.A.; Schwarz, M.H. (2009). Getting Acquainted with *Amyloodinium ocellatum*, *Virginia Cooperative Extension*, 1-2.

Sousa, G.S. (1987). Tratado Descritivo do Brasil em 1587 (5. ed., 387 p.). São Paulo: *Companhia Editora Nacional.*

Sun, L.; Chen, H.; Huang, L. (2006). Effect of temperature on growth and energy budget of juvenile cobia (*Rachycentron canadum*). Aquaculture, 261, 872-878.

Tsuzuki, M.Y. (2006). Cultivo de peixes marinhos. In:Souza-Silva, A.T. (org.) Sanidade de organismos aquáticos no Brasil. Maringá: *Abrapoa*, 189-210.

Valenti, W.C. et al.(org.) (2000) Aquicultura no Brasil: bases para um desenvolvimento sustentável. Brasília, CNPq/MCT, 107-141.

Wang, J-T.; Liu, Y-J.; Tian, L-X.; Mai, K-S.; Du, Z-Y.; Wang, Y.; Yang, H-J. (2005). Effect of dietary lipid level on growth performance, lipid deposition, hepatic lipogenesis in juvenile cobia (*Rachycentron canadum*). *Aquaculture*,249, 439-447.

Watanabe, Y.; Tateno, H.; Nakamura-Tsuruta, S.; Kominami, J.; Hirabayashi, J.; Nakamura, O.; Watanabe T.; Kamiya, H.; Naganuma, T.; Ogawa, T.; Naude, R.J.; Muramoto, K. (2009). The function of rhamnose-binding lectin in innate immunity by restricted binding to Gb3. *Developmental and Comparative Immunology*, 33, 187-197.