Comparative evaluation of the biofloc system versus the recirculation system with *Macrobrachium amazonicum*

Avaliação comparativa do sistema bioflocos versus o sistema de recirculação com *Macrobrachium amazonicum*

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ABSTRACT
The aim of this study was to evaluate the efficiency of the biofloc system versus the recirculation system using the native Amazonian freshwater shrimp Macrobrachium amazonicum (Heller, 1862) as a cultivation organism. In this initial evaluation, the water quality parameters of each system were measured and the survival rate in the biofloc system showed similar values for M. amazonicum grown in a super-intensive recirculation system with averages values of 60%. The results indicated that both systems were within acceptable limits in terms of parameters (physical-chemical) and the survival rate of both systems showed similar values for M. amazonicum.

Keywords: Amazonian shrimp, Water quality, Survival.

RESUMO
O objetivo deste estudo foi avaliar a eficiência do sistema de bioflocos versus o sistema de recirculação usando o camarão de água doce nativo da Amazônia *Macrobrachium amazonicum* (Heller, 1862) como organismo de cultivo. Nesta avaliação inicial, os parâmetros de qualidade da água de cada sistema foram medidos e a taxa de sobrevivência no sistema biofloco apresentou valores semelhantes para *M. amazonicum* cultivado em sistema de recirculação superintensivo com valores médios de 60%. Os resultados indicaram que ambos os sistemas estavam dentro de limites aceitáveis em termos de parâmetros (físico-químicos) e a taxa de sobrevivência de ambos os sistemas apresentou valores semelhantes para *M. amazonicum*.

Palavras-chave: Camarão Amazônico, Qualidade de água, Sobrevivência .

1 INTRODUCTION

Aquaculture is the cultivation of several aquatic organisms and among them, shrimp farming represents shrimp cultivation. According to FAO (2016), global shrimp catches have been stable since 2012 (at 3.5 million tons) and shrimp is currently the second most important product in terms of value, enabling the growth of shrimp farming to meet global demands. Moreover, the world production of freshwater shrimps estimated in 2018 was 500 tons per year (FAO, 2016). In Brazil, both marine and freshwater shrimp farming are dominated by the cultivation of exotic species, mainly *Macrobrachium roserbergii* (de Man 1879) (OSTRENSKY, BORGHETTI and SOTO, 2008). Within the genus *Macrobrachium*, *M. amazonicum* is a native species which has potential for cultivation (VALENTI, 1988). *M. amazonicum* is poorly understood, economically and biologically, the people's knowledge on the species varies according to location in the Brazilian Northern region (MORAES-RIODADES, KIMPARA and VALENTI, 2004). In the state of Pará, this species is exploited by artisanal fishing (ARAUJO et al., 2014).

In terms of shrimp production, since the 1990s, the cultivation of closed systems with greater biosecurity is being implemented in the Americas and Brazil is no exception (WASIELESKY, 2006). According to Kubitza (2006), among the closed systems the recirculation system (RAS) is sustainable because it is more biosafe and reduces impacts to the environment. However, it requires additional processes and equipment to improve the efficiency of water quality control.

Aquaculture has been directed to sustainable, biosafe systems, with high productivity, use of rations and low levels of water exchange. According to Samocha et al. (2017), the Biofloc System or "Biofloc Technology System" (BFT) stands out because it aims to cultivate organisms in high densities, with little water exchange, high productivity and reduction of effluent emissions to the environment. According to Krummenauer et al. (2012), these conditions are provided by stimulating the growth of heterotrophic bacteria through the addition of extra carbon sources to cultivation. Thus, the aim of this study was to evaluate the development of the BFT with sugar versus the RAS with juvenile shrimps of *M. amazonicum*.

2 MATERIAL AND METHODS

The study was carried out at the Aquaculture Research and Production Station - EPPA, , located at the Federal Institute of Education, Science and Technology of Pará, Campus Santarém. Shrimps of the species M. amazonicum were purchased directly from fishermen. The purchased specimens underwent a process of acclimatization and food training for seven days according to Machado et al. (2018). The species was identified according to Melo (2003), Santos et al. (2016) and Da Silva (2006) and there was a previous selection by total weight (g) with portable precision scale of (0.01g) for biometrics, one at time zero and another at time 28 days.

The shrimps were populated in stocking density proportional to 20 shrimps/m^2, two shrimps per repetition, and 10 per system totaling 20 shrimps. The initial weight of the shrimps varied in the range (mean ± standard error) for α=5% in the BFT of 1.96g ± 0.16g, n=10 and for the RAS of 1.87 g ± 0.10 g, n=10. The data presented normal distribution according to the Shapiro-Wilk test for the RAS (p=0.8344) and for the BFT (p=0.6766). According to the Student's t-test, there was no significant difference (p=0.1808). The study lasted 28 days.

Both systems had the cultivation structure and design adapted according to Machado et al. (2018) where treatment A (BFT) had a central box called macrocosm (without mechanical and biological filter) of 100 L with 20 L of useful volume and five replications formed by water bottles of 100% polycarbonate of 20 L of useful volume. The BFT was prepared with the sources of carbon 100% crystal sugar, 100% wheat bran and 28% crude protein ration according to the recommendations of Ebeling et al. (2006) and Avnimelech (1999).

Treatment B (RAS) had a central box of 100 L with 20 L of useful volume (with mechanical and biological filter) according to Kubitza (2006) containing filter media with the internal area of 525 m^2/m^3 proportional to the useful volume where the biological filter was contained, serving for the fixation of nitrifying bacteria and five replications formed by water bottles of 100% polycarbonate of 20 L of useful volume. Both systems had recirculation of the 100 L central box to the 20 L production units. In the recirculation system, nitrifying bacteria (biological filter) produced in the mature BFT were added. The experiment started only when both systems were mature.

In this study, shrimps were fed with commercial ration of 36% PB under 4% of biomass in two daily treatments: one in the morning between 7am and 7:30am and another in the afternoon between 5pm and 5:30pm according to the adaptation of Machado et al. (2018). For the cultivation structure and repetitions, the Normality test (Shapiro-Wilk) and the Student's t-test for parametric data and mann-whitney U test for nonparametric data, were used. The dependent variables in the study were all water quality parameters and survival rate and independent variables, treatments: treatment A (BFT) and treatment B (RAS). Tests were performed in software BIOETAT 5.3.

The water quality indicators for BFT were adapted according to Azim and Little (2008) for tropical fish and shrimp and the RAS was adapted according to Kubitza (2006). The parameter temperature of *M. amazonicum* was adapted to both systems according to Bentes et al. (2011). Dissolved oxygen (mg/L) and temperature (°C) were measured by the AK 77 multiparameter probe; pH was measured by digital portable pH-meter AK 95; total ammonia (mg/L), nitrite (mg/L), and nitrate (mg/L) by ACQUA ALFAKIT photocolorimeter and toxic ammonia according to Kubitza (2003) by equation is %NH_3= total ammonia (mg/L) * (tabled factor/100) = results expressed in mg/L of toxic ammonia, percentage is determined according to the pH and temperature tabled values.

Sedimentable solids were measured according to Avnimelech (2007) per Imhoff cone and decanting and 1L of biofloc volume (mL/L) for 20 minutes. Alkalinity was determined by the HIDROAALL disposable kit.

The zootechnical index survival rate was determined according to Machado et al., (2018) and measured by the formula: survival - (under%)=$\frac{number\ of\ alive\ shrimps}{total\ number\ of\ shrimps\ in\ tank}$ *100%.

The values of the survival rate parameter were transformed according to Ivo and Fonteles-Filho (1997) for arc sine for the application of statistical tests.

3 RESULTS AND DISCUSSION

According to Table 1 from October 16 to 30, 2019, the mean nitrite value remained lower than 1 mg/L in line with Azim and Little (2008). The mean nitrate value (see table 1) exceeded the limits according to Azim and Little (2008), however the CL 50 (mg/L) dosage of acute nitrate toxicity for *Macrobrachium amazonicum* juveniles is 1069.73 mg/L (ALAB et al., 2017), thus, although in our study the mean nitrate value is higher than that of Azim and Little (2008) we corroborated with ALAB et al. (2017) for presenting the average value lower than the toxic dosage in the studied period.

Table 1. Water quality parameters of the sugar biofloc system at EPPA, IFPA, Campus Santarém according to recommended literature.

Parameters	(Mean± SE)	Frequency	Recommended values	Literature
Nitrite (mg/L)	(0.24±0.08)	Weekly	< 1	Azim and Little (2008)
Nitrate (mg/L)	(82.96±71.11)	Weekly	< 60	Azim and Little (2008)
Toxic ammonia (mg/L)	(0.02 ± 0.004)	Weekly	< 0.03	Kubitza (2003)
Dissolved oxygen (mg/L)	(7.14±0.34)	Daily	4.0-5.0	Azim and Little (2008)
Morning temperature (°C)	(27.36±0.78)	Daily	23.5-29.0	Bentes *et al.* (2011)
PH	(7.48±0.26)	Daily	7.2-8.0	Azim and Little (2008)
Afternoon temperature (°C)	(29.70±0.12)	Daily	23.5-29.0	Bentes *et al.* (2011)
Sedimentable solids (mL/L)	(24.67±10.70)	Biweekly	> 20	Azim and Little (2008)
Total alkalinity (mg/L $CaCO_3$)	(257.14±48.59)	Weekly	> 100	Azim and Little (2008)

$\underline{x}$ = arithmetic mean; SE = standard error for α = 5%.

According to Alab et al. (2017), in toxicity studies prolonged exposure time to nitrate values causes injuries to a lesser degree than ammonia and nitrite values, in addition to causing regressive lesions or injuries to the gill epithelium. According to Kubitza (2017), nitrate can affect closed systems such as the biofloc system by its accumulation. However according to Silva (2018), nitrate presents low toxicity for freshwater shrimps. Moreover, there are gaps in studies relating the isolated and combined effects of nitrate toxicity versus performance studies of these organisms in cultivation systems.

Toxic ammonia (NH_3) was determined by total ammonia (NH_3 + NH_4) and presented the mean value in line with the methodology of Azim and Little (2008). It is noteworthy that the percentage of toxic ammonia from the total ammonia of 1.35 mg/L for the tabled values of pH 7.0 and temperature 30°C was 0.788% of this total ammonia, being 0.01 mg/L. The other values ranging in (total ammonia mg/L: toxic ammonia mg/L) reads total ammonia for toxic ammonia were: 0.93 mg/L: 0.02 mg/L; 0.69mg/L: 0.02 mg/L; 0.52 mg/L: 0.01 mg/L and 0.82 mg/L: 0.02 mg/L. The tabled values of pH 7 and pH 7.5 and temperature of 30°C were used to calculate the toxic ammonia values from 0.93 to 0.52 mg/L.

However, when the table according to Sá (2012) was used to estimate the percentages of toxic ammonia, the total ammonia value of 0.93mg/L was at the limit of toxic ammonia in the Azim and Little table (2008) with 0.03 mg/L. Also to calculate the values of toxic ammonia, the table values of pH 7.6 and temperature 30°C were used. The total ammonia value of 0.82mg/L exceeded the toxic ammonia limit according to Azim and Little (2008) with 0.04mg/L for pH 7.8 and temperature 30°C. The mean oxygen values and pH of table 1 were in line with Azim and Little (2008).

The mean temperature in table 1 during the morning and afternoon varied significantly according to student's t-test (p-value=0.0044). This significant difference in the mean temperature between the shifts was maintained considering all the days of the experiment according to the Student's t-test ($p<0.0001$). Despite being point values obtained in the morning between 7am and 7:30am and in the afternoon between 5pm and 5:30pm, the variation in the afternoon exceeded the recommended temperature limits for this species according to our suggestion of Bentes et al. (2011) in table 1. However, it does not reflect the hourly variation in each shift, which was not verified in this study. In general, considering the periods we can infer that in the morning these values were in line with Bentes et al. (2011) for shrimp *M. amazonicum* and in the afternoon exceeded the maximum temperature predicted for the species.

The mean volume of suspended solids according to table 1 was 24.67 mL/L ± 10.70 mL/L, in line with Azim and Little (2018) ranging from 32 to 20 mg/L. In our study the likely reduction of volume was associated with fertilization according to our biofloc formation methodology. The mean alkalinity value according to table 1 was 257,14mg/l de $CaCO_3$ ± 48,59 mg/L de $CaCO_3$, in line with Azim and Little (2008). These values were the result of adjustments for maintenance of pH around 7.0.

Table 2. Water quality parameters of the recirculation system at EPPA, IFPA, Campus Santarém compared with Kubitza (2006).

Parameters	(Mean± SE)	Frequency	Recommended values	Literature
Nitrite (mg/L)	(0.17±0.08)	Semanal	< 0.3	Kubitza (2006)
Nitrate (mg/L)	(63.74±46.04)	Semanal	< 50	Kubitza (2006)
Toxic ammonia (mg/L)	(0.05 ± 0.03)	Semanal	< 0.2	Kubitza (2003)
Dissolved oxygen (mg/L)	(7.24±0.25)	Diária	> 4.0	Kubitza (2006)
Morning temperature (°C)	(27.36±0.44)	Diária	23.5-29.0	Bentes *et al.*, (2011)
PH	(7.53±0.16)	Diária	7.0 a 8.0	Kubitza (2006)
Afternoon temperature (°C)	(28.78±0.23)	Diária	23.5-29.0	Bentes *et al.*, (2011)
Sedimentable solids (mL/L)	X	Quinzenal	< 20	Kubitza (2006)
Total alkalinity (mg/L $CaCO_3$)	(147.14±47.57)	Semanal	> 100	Kubitza (2006)

$\underline{x}$ = arithmetic mean; SE = standard error for α = 5%.

According to the results of table 2 for the RAS for the period from October 6 to 30, 2019, the mean nitrite values were in line with Kubitza (2006) for the RAS. On the other hand, the mean nitrate values according to table 2 were not in agreement with Kubitza (2006). However, as well as in the BFT, although the mean nitrate value was higher than Kubitza (2006), it was lower than the toxic dosage evaluated by Alab et al. (2017), thus we corroborated their results.

of the RAS or BFT had the pH around 7.0 and was covered with styrofoam plates and 50% shading screen to not let in light or any dirt that could affect pH and temperature Alkalinity was controlled and kept with values greater than 100 mg/L of $CaCO_3$. The mean values of The mean value of toxic ammonia was in agreement with Kubitza (2006) according to table 2. This value was calculated following Kubitza (2003) and ranged from: total ammonia: toxic ammonia reads from total ammonia to toxic ammonia: 0.49: 0.01; 0,88: 0,03; 0,74:0,03; 1.04:0.06 and 1.42:0.10 and the tabled values of pH and temperature were: for the total ammonia of: 0.49; 0,88; 0,74; 1.04 pH 7.5 and 30°C and 1.42 pH 7.8 and 30°C. Using the parameters of Sá (2012) all were consonant with Kubitza (2006): 0.49: 0.01; 0,88: 0,02; 0,74:0,02; 1.04:0.03 and 1.42:0.08 and the tabled values of pH and temperature were: for total ammonia 0.49 pH 7.3 and 30°C; 0.88 pH 7.4 and 30°C; 0.74 and 1.04 pH 7.6 and 30°C; 1.42 pH 7.8 and 30°C.

In our study on RAS, nitrite and nitrate control was made by partial exchange of 50% of water and weekly replacement of nitrifiers of the BFT. It is noteworthy that the spare water tank dissolved oxygen and pH were in line with Kubitza (2006) in table 2. The average morning and afternoon temperatures in table 2 varied significantly according to student's t-test (p=0.0005) and were in line with Bentes et al. (2011) for *M. amazonicum* (Table 2). The mean alkalinity value was 147.14mg/L $CaCO_3$ ± 47.57 mg/L $CaCO_3$ and was in line with Kubitza (2006) in table 2. These values were also the result of adjustments to maintain the pH around 7.0.

Table 3. Quality parameters of the BFT versus RAS during the experimental period.

Parameters	BFT	RAS	p-value
Nitrite	0.24± 0.08^a	0.17± 0.08^a	0.274
Nitrate	82.96± 71.11^a	63.74± 46.04^a	0.7209
Toxic ammonia	0.02± 0.004^a	0.05± 0.03^a	0.0758
Dissolved oxygen	7.14± 0.34^a	7.28± 0.27^a	0.5487
Morning temperature	27.36± 0.38^a	27.24± 0.60^a	0.0746
Afternoon temperature	29.70± 0.12^a	28.58±0.29^b	0.0001
PH	7.48± 0.26^a	7.58± 0.15^a	0.5081

Subscript equal letters: no significant difference (p-value > 0.05) and different letters: there is significant difference (p-value <0.05).

Comparing both BFT versus RAS (table 3), we found that the mean parameters: nitrite, nitrate, toxic ammonia, dissolved oxygen, morning temperature and pH did not differ significantly, only the afternoon temperature differed because the mean value in the BFT was higher than in RAS. All parameters evaluated were in line with Azim and Little (2008) in the BFT and Kubitza (2006) in the RAS according to tables 1 and 2, but nitrate was not in line with Azim and Little (2008) in the BFT and kubitza (2006) in the RAS. Afternoon temperature was not in line with Bentes et al. (2011) for *M. amazonicum* in the BFT.

Evaluating the mean survival rate of *M. amazonicum*, it was verified that at the end of the experimental period at 28 days the mean survival rate for the BFT was 60% ± 36.66% and for the RAS it was 20% ± 24% with no significant difference in the mean survival rate according to the Mann-Whitney U test and p=0.1437 between these systems. Machado et al. (2018) studying the cultivation of juvenile *M. amazonicum* shrimps, in the RAS and under the same conditions and in different stocking densities, verified a negative correlation between survival rate and stocking density. At the density of 20 shrimps/m^2 the survival rate was 100%, reducing to 75%; 50%; 58.33% and 40% in densities of 40, 60, 80 and 100 shrimps/m^2 respectively. In our study in the stocking density of 20 shrimps/m^2, we found that the BFT presented a survival rate of 60%, superior to survival rates of 50.33% and 58% for the median densities of 60 and 80 shrimps/m^2 tested by Machado et al. (2018).

In our results we infer one hypothesis for the high survival rate in the BFT and two hypotheses for the low survival rate, one in the RAS and the other in both systems. For the hypothesis of high survival rate in BFT: we infer that shrimps may probably have fed from the flake. Emerenciano et al. (2007) studied the cultivation of *Farfantepennaeus brasiliensis* (marine shrimps) in biofloc testing the zootechnical performance in the treatments: bioflocs plus ration; bioflocs only; clear water plus ration; and clear water only. They verified that the final weight and weight gain was higher in the treatments: bioflocs more ration and bioflocs only than with the treatments clear water plus ration and only clear water at the end of 30 days. In our BFT the shrimps had ration more bioflocs and in the RAS had ration plus clear water with recirculation, so this event may have happened in the BFT. The hypothesis for reducing the survival rate in RAS is that in this system there was only ration and clear water with recirculation. The other hypothesis for both systems is the occurrence of the event changes. According to Valenti (1988) about three days before the seedling the shrimps stop feeding and after the seedling are weakened, with little mobility and vulnerable to predators. In our study, in both systems, all surviving or dead specimens performed the seedling due to the presence of shells in the tanks.

4 CONCLUSION

Thus supported by our results in the experimental conditions we can conclude that the BFT with sugar as the carbon source offers conditions for the cultivation of freshwater shrimps.

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REFERENCES

ALAB, H. J.; DUTRA, F. M. R. M. B. E. L. C. **Efeito da amônia e nitrito sobre pós-larvas, juvenis e adultos do camarão da Amazônia *Macrobrachium amazonicum*** (Heller, 1862), 2017.

ARAÚJO, M.V.L.F.; ARAÚJO K.C. S.; SILVA B.B.; FERREIRA I.L.S.; CINTRA, I.H.A. Pesca e procedimentos de captura do camarão-da-Amazônia à jusante de uma usina hidrelétrica na Amazônia brasileira. **Biota Amazônia**, v. 4, p. 102-112, 2014.

AVNIMELECH, Y. Carbon/nitrogenratio as a controlelement in Aquaculture systems. Aquaculture, Amsterdam, v. 176 p. 227-235, fev, 1999.

AVNIMELECH, Y. Feedingwith microbial flocsbytilapia in minimaldischargebio-flocstecnology. **Aquaculture.** v. 264 p. 140-147, 2007.

AZIM, M. E.; LITTLE, D.C. The biofloctechnology (BFT) in indoor tanks: Waterquality, biofloccomposition, andgrowthandwelfareofNiletilapia (Oreochromisniloticus). **Aquaculture Amsterdam**, v.283, p.29-35, out, 2008.

BENTES, B.S.; MARTINELLI, J. M.; SOUZA, L.S.; CAVALCANTE, D.V.; ALMEIDA, M. C.; ISAAC, V. J. Spatial distribution of the Amazon River prawn *Macrobrachium amazonicum* (Heller 1862) (Decapoda, Caridea, Palaemonidae) in two perennial creeks of an estuaryon the northern coast of Brazil (Guajará Bay, Belém, Pará). **Brazilian Journal of Biology**, São Carlos, v.71, p. 925-935, 2011.

DA SILVA, G.M. **Estudo estrutural e ultra-estrutural das gônadas dos diferentes morfotipos de Macrobrachium amazonicum (Heller, 1962) (Crustacea, Decapoda, Paleomonidae).** 2006. 56f. Dissertação (Mestrado em Ciência Animal) - Universidade Federal do Pará, Belém, 2006.

EBELING, J.M.; TIMMONS, M.B.; BISOGNI, J.J. Enginee ringanaly siso fthestoichio metry of hoto autotrophic, autotrophic, and heterotrophic control of ammonia-nitrogen in aquaculture production systems**. Aquaculture,** v. 257, p. 346-358, 2006.

EMERENCIANO, M.G.C. **Flocos microbianos: aspectos zootécnicos do cultivo do camarão-rosa *Farfantepenaeus paulensis* e *Farfantepenaeus brasiliensis*.** Dissertação (Mestrado em Aquicultura). Fundação Universidade Federal do Rio Grande, Rio Grande, 2007.

FAO, 2012. **El estado mundial de la pesca y laacuicultura.** Roma, FAO Information Division. 231 p.

FAO, 2016. **El estado mundial de la pesca y laacuicultura.** Roma, FAO Informati on Division. 213 p.

IVO, C.T.C.; FONTELES-FILHO, A.A. **Estatística Pesqueira** – Aplicação em Engenharia de Pesca. Fortaleza: TOM Gráfica e Editora. 1997.

KUBITZA, F. Ajustes na nutrição e alimentação das tilápias. **Panorama da Aqüicultura,** v. 16, n. 98, p. 14-24, 2006.

KUBITZA, F. Sistemas de recirculação: sistemas fechados com tratamento e reuso de água. **Panorama da Aquicultura**, v. 16, n. 95, p. 15-22, 2006.

KUBITZA, F. O impacto da amônia, do nitrito e do nitrato sobre o desempenho e a saúde dos peixes e camarões. **Panorama da Aquicultura**. v. 17, n. 164, 2017.

MACHADO, I.D.S.; NUNES, C.A.R.; SANTOS, H.B.L.; LIMA, J.A.; MEIRA, T.M.; SENA, E.D.; SILVA, W.N. Desempenho do camarão *Macrobrachium amazonicum* (Heller, 1862) (Crustacea: Decapoda: Palaemonidae), em diferentes densidades. Revista Brasileira de Engenharia de Pesca, v. 11, p. 29-37, 2018.

MELO, G.A.S. 2003. **Manual de identificação dos Crustacea Decapoda de água doce do Brasil.** São Paulo: LOYOLA, 2003, 430p.

MORAES-RIODADES, P.M.C.; KIMPARA, J.M.; VALENTI, W.C. Effect of the amazona river prawn *Macrobrachium amazonicum* culture intensification on ponds hydrobiology. **Acta Limnologica Brasiliensia**, v. 18, p. 311-319. 2004.

OSTRENSKY, A.; BORGHETTI, J. R.; SOTO, D. (Ed.). **Aqüicultura no Brasil**: o desafio é crescer. Brasília, DF: FAO, 2008. v. 1. 270 p.

SÁ, MARCELO, V.C. **Limnocultura:** limnologia para aquicultura. Ed, UFC, p. 218, 2012. SAMOCHA, T.M.; PATNAIK, S.; SPEED, M.; ALI, A.; BURGER, J.M.; ALMEIDA, R.V.; AYUB, Z.; HARISANTO, M.; HOROWITZ, A.; BROCK, D.L. Use of molasses as source in limited discharge nursery and grow-out systems for *Litopenaeus vannamei*. Aquacultural Engineering v. 36, p. 184-191, 2017.

SANTOS, M.R., RODRIGUES, C.G., VALENTI, W.C. Effectof habitat diversity on population development of the Amazon river prawn. **Journal of Shellfish Research**, v. 35, p. 1075-1082, 2016.

SILVA, A.M**. Efeitos tóxicos de amônia, nitrito e nitrato em Palemonídeos**: revisão bibliográfica. Trabalho de Conclusão de curso (Graduação) – Universidade Federal do Paraná, Palotina, 2018.

VALENTI, W.C. **Carcinicultura de água doce: tecnologia para a produção de camarões.** Jaboticabal: FUNEP, 383pp, 1988.

1. WASIELESKY, W.J.; ATWOOD, H.I.; STOKES, A.; BROWDY, C.L. Effect of natural production in Brown water super-intensive culture system for White shrimp *Litopenaeus vannamei*. **Aquaculture**, v. 258: p. 396-403, 2006.