Decomposition of aquatic macrophytes from Cantá stream (Roraima, Brazil): kinetics approach

Decomposição de macrófitas aquáticas do Igarapé do Cantá (Roraima, Brasil): aspectos cinéticos

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Abstract: Aim: This study aimed at describing and comparing the kinetics of aerobic and anaerobic decomposition of *Eleocharis interstincta, Nymphaea* sp. and *Montrichardia arborescens*; **Methods:** The samples of aquatic macrophytes and water were collected in the Cantá Stream (02° 49' 11" N and 60° 40' 24" W), Cantá, Roraima, Brazil. The plant material was dried and triturated and for each experimental condition (aerobic and anaerobic) mineralization chambers were prepared with plant fragments and stream water. The volume of evolved gases in anaerobic mineralization was monitored during 78 days, while the oxygen consumption was measured for 121 days; **Results:** The results of aerobic and anaerobic decomposition were fitted to first-order kinetics model. The oxygen consumption varied from 195.36 mg g^{-1} (DM) for *E. interstincta* to 629.46 mg g^{-1} (DM) for *Nymphaea* sp. The deoxygenation rate derived from mineralization of *M. arborescens* was higher (k_D: 0.049 day^{-1}), followed by *E. interstincta* (k_D: 0.038 day^{-1}) and *Nymphaea* sp. (k_D: 0.027 day^{-1}). For the anaerobic condition the evolution of gases presented two phases: the consumption and formation. According to temporal variations of mineralized carbon, the anaerobic decomposition of *M. arborescens* presents the higher mineralization coefficient (0.0047 day^{-1}); followed by *Nymphaea* sp. (0.0035 d^{-1}) and *E. interstincta* (0.0017 day^{-1}); **Conclusion:** Based on these results we conclude that during the aerobic decomposition of these macrophytes, the *Nymphaea* sp. was responsible for the higher oxygen demand and *M. arborescens* generated the highest amounts of gases during the anaerobic mineralization. On average, the aerobic decay processes were 11-fold faster than anaerobic. Regarding to the materials fluxes in freshwater ecosystems, low rate of decomposition observed in anaerobic process when comparing to aerobic rates reflect that the sediment represent a very efficient sink of carbon in the organic matter cycling.

Keywords: *Eleocharis interstincta, Nymphaea* sp., *Montrichardia arborescens*, aerobic and anaerobic process, aquatic macrophytes.

Resumo: Objetivos: Este artigo descreve e compara a cinética de decomposição aeróbia e anaeróbia de *Eleocharis interstincta*, *Nymphaea* sp. e *Montrichardia arborescens*; **Métodos:** Amostras de água e de macrófitas aquáticas foram coletadas no Igarapé do Cantá (02° 49' 11" N e 60° 40' 24" W), Cantá, Roraima, Brasil. O material foi seco e triturado e para cada condição experimental (aeróbia e anaeróbia), foram preparadas câmaras de mineralização contendo fragmentos de planta e água do igarapé. O volume de gases na mineralização anaeróbia foi monitorado durante 78 dias e consumo de oxigênio durante 121 dias; **Resultados:** Os resultados da decomposição aeróbia e anaeróbia foram ajustados a um modelo cinético de 1ª ordem. O consumo de oxigênio variou de 195,36 mg.g^{-1} (PS) para *E. interstincta* a 629,46 mg g^{-1} (PS) para *Nymphaea* sp. A mineralização de *M. arborescens* apresentou o coeficiente de desoxigenação mais elevado (0,049 dia^{-1}), seguida por *E. interstincta* (0,038 dia^{-1}) e *Nymphaea* sp. (0,027 dia^{-1}). Na condição anaeróbia, a evolução de gases apresentou duas fases: consumo e formação. De acordo com a variação temporal do carbono mineralizado, a decomposição anaeróbia de *M. arborescens* apresentou o coeficiente de mineralização mais elevado (0,0047 dia^{-1}); seguido por *Nymphaea* sp. (0,0035 dia^{-1}) e de *E. interstincta* (0,0017 dia^{-1}); **Conclusão:** Baseado nestes resultados foi possível concluir que durante a decomposição aeróbia dessas

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macrófitas aquáticas, *Nymphaea* sp. foi responsável pela maior demanda de oxigênio e *M. arborescens* gerou as maiores produções de gases durante a mineralização anaeróbia. Em média, o processo aeróbio foi 11 vezes maior que o anaeróbio. Em relação aos fluxos de materiais em ecossistemas de água doce, as baixas taxas de decomposição observadas no processo anaeróbio, quando comparado com as taxas do decaimento aeróbio permite refletir que os sedimentos atuam como um compartimento eficiente de sumidouro de carbono na ciclagem de matéria orgânica.

Palavras-chave: *Eleocharis interstincta, Nymphaea* sp., *Montrichardia arborescens*, processo aeróbio e anaeróbio, macrófitas aquáticas.

1. Introduction

In freshwater aquatic environments, the detritus (e.g. exudates and tissues) derived from primary producers as aquatic macrophytes is often the main energy source for microorganisms (Boschker et al., 1999) that require pre-synthesized organic matter as a source of carbon and energy (Anesio et al., 2003). Macrophytes are conspicuous components of rivers backwater and littoral zone of lentic environment contributing with large quantities of dissolved (DOC) and particulate organic matter (POM) to the detritus food chain. The hydrosoluble compounds from tissues enter to the DOM pool and degradation process occurs within water column (e.g. through microbial loop). Since POM is deposited in sediments, detritus are degraded initially on the oxic surface before being buried into the anoxic layers where anaerobic decomposition takes place (Bryant et al., 2010).

During decomposition the predominant type of catabolic process are driven by environmental conditions (e.g. redox potential and oxygen availability) that select organisms. Dissolved oxygen availability is one of the most critical ecological forcing function affecting aquatic systems metabolism. Usually, anaerobic metabolism predominates in sediment and aerobic metabolism prevails in water column and in the upper layers of sediments. The oxygen uptake is a function of both dissolved oxygen diffusion to the sediment and oxygen consumption processes (e.g. respiration, oxidation). In general, sediment tends to present greater amounts of recalcitrant organic matter (mainly as POM) when comparing to water column (e.g. labile DOM and low concentration of dissolved carbon ranging from 2 to 10 mg.L^{-1}; Thurman, 1985).

Decomposition of aquatic plants is an important process for the input of carbon and energy and therefore the microbial metabolism associated with dead plant biomass could represent a major route for ecological recovery of organic matter in these environments. Heterotrophic microorganisms

use a variety of organic compounds under diverse environmental conditions, extracting energy from these compounds both anaerobically by fermentation and anaerobic respiration and aerobically by aerobic respiration (Madigan et al., 2000). The availability of electrons acceptors will determine the metabolic routes of organic compounds and also the final products of decomposition (Kristensen et al., 2000). Regardless of the oxygen availability in the environment, decomposition processes encompass three distinct mechanisms: leaching, catabolism and fragmentation (Cárcamo et al., 2000). Leaching is an abiotic process by which soluble material from particulate is removed by water (Carpenter, 1980). Catabolism consists in the transformation of complex organic matter into compounds with simple, small molecules and takes place through biochemical reactions (Reddy and DeLaune, 2008). In the fragmentation process, the size of particulate detritus is reduced by macroinvertebrates action within plant fragments (Abelho, 2008). It differs from catabolism because of its physical nature, being generally related to feeding activities - ingestion as well as digestion by decomposing agents.

Considering that decomposition occurs simultaneously both in water column and sediments and the abiotic characteristics of these compartments drive the metabolic route of heterotrophic microorganism, as just outlined, we aimed at describing the kinetics of aerobic and anaerobic decomposition of *Eleocharis interstincta, Nymphaea* sp. and *Montrichardia arborescens*, focusing essentially on distinct catabolic microbial process that occurs within to aquatic systems that are essential to organic matter cycling. Our purpose was also to determine the relative speed of aerobic and anaerobic decomposition processes, once degradation rates reflects the residence of organic matter cycling within aquatic compartment. To accomplish this, we conducted two experiments presenting different dissolved oxygen availability, i.e. oxygen uptake assay simulates aerobic decomposition

in water column and gases production simulates anaerobic decomposition in sediment.

2. Material and Methods

2.1. Plant and water sampling

Water samples and leaves and stems of *Eleocharis interstincta*, *Montrichardia arborescens* and *Nymphaea* sp. were collected in January/2000 (beginning of flood period) in a macrophyte stand within the Cantá stream in the river backwater zone (2° 49' 11" N and 60° 40' 24" W), State of Roraima, Brazil. The plant samples were washed with tap water to remove periphyton, sediment particles and coarse material (Ogburn et al., 1987). After washing, the plant material was oven-dried (50 °C), grounded (0.2 cm > diameter < 0.6 cm) and homogenized. The water samples were filtered (Millipore 1.2 μm) to remove large organisms and coarse detritus.

2.2. Aerobic assays

The plant fragments (200 mg.L^{-1} DM) were placed in duplicate in acid-washed 1-L flasks with stream water samples. The incubations were maintained under aerobic conditions in the dark at 22.5 ± 2.3 °C. In order to maintain the solutions under aerobic conditions, the incubations were oxygenated in the beginning of experiment during 1 hour, to keep dissolved O$_2$ near saturation. Afterwards, the dissolved oxygen (DO) was measured with an ODmeter (YSI model 58; Yellow Spring Instruments; precision: 0.03 mg.L^{-1}). When concentrations of DO had decreased to approximately 2.0 mg L^{-1} the solutions were aerated; this procedure was adopted to ensure aerobic condition. The oxygen consumption was estimated during 121 days. To remove the background DO consumption, two blank flasks (with sample of stream water) were also incubated. During the aerobic mineralization, it is usually assumed that the consumed oxygen is proportional to the CO$_2$ formed (e.g. O/C stoichiometry = 2.66; Chapra and Reckhow, 1983). We considered, therefore, that consumption of oxygen was directly related to the oxidation of the organic resource, and that first-order kinetics model can represent this process. Using a non-linear method (Levenberg-Marquardt iterative algorithm; Press et al., 1993) the results were fitted to 1st order kinetics model (Equation 1; Peret and Bianchini Jr., 2004) where the deoxygenation coefficient (k$_D$) and the total amount of consumed oxygen were estimated (OC$_{max}$).

$$\frac{dDO_t}{dt} = -k_D DO_t \qquad (1)$$

where: DO = change per unit time in the amount of dissolved oxygen, mg.L^{-1}; k$_D$ = deoxygenation rate constant (day^{-1}).

The results of accumulated dissolved oxygen from aerobic decay of macrophytes were analyzed individually using the Kruskal-Wallis test (KW) test followed by Dunn's multiple comparison to detect possible significant differences between treatments (p < 0.05).

2.3. Anaerobic assays

For each species of aquatic macrophyte, two chambers were prepared to monitor the formation of gases from anaerobic decomposition processes. These incubations were prepared by the addition of 10.0 g (DM) of plant fragments in one liter of stream water. The chambers were incubated for 78 days at 28.6 ± 1.1 °C, in the dark and under anaerobic conditions. In these chambers, the temperature and the volumes of gases were recorded daily, with a mercury thermometer and a low-pressure manometer (Bianchini Jr. et al., 1997), respectively. After each measurement the flasks were depressurized. At the end of experiment the remaining material was fractionated into particulate (POM) and dissolved (DOM) organic matter by filtration (pore size: 0.45 μm; Millipore). POM samples were oven-dried (45 °C) until constant weight, and their final masses were determined with a gravimetric method (Wetzel and Likens, 1991). The carbon contents of particulate detritus were quantified using a Carlo Erba CHN elemental analyzer (model EA1110), calibrated with external standards (L-cystine, sulphalamine and 2,5-bis[tert-butyl-2-benzoxazolyl]thiophene). The organic carbon concentrations of DOM were measured by Pt-catalyzed non-dispersive combustion and detection in infrared gas analysis (Shimadzu, TOC-5000A analyzer). The consumed organic matter (on carbon basis) was calculated by the difference between the initial and final concentrations of dissolved organic carbon and the contents of carbon in the plant fragments. The mineralized carbon (MC) was related to the final value of accumulated volume (obtained from manometric method) by linear regression (volume (mL) = 81.31 × MC(g); r^2: 0.84); according to this regression, the kinetics of organic carbon decay were estimated. The organic carbon (dissolved + particulate) decay curves were fitted to 1st order kinetics model (Equation 2; Carvalho et al., 2005) using a non-

linear method (Levenberg-Marquardt iterative algorithm; Press et al., 1993).

$$\frac{dMC_t}{dt} = -k_M MC_t \qquad (2)$$

where: MC = change per unit time in the amount of carbon mineralized; k_M = mineralization rate constant (day^{-1}).

The results of accumulated gases were analyzed individually using the Kruskal-Wallis test (KW) test followed by Dunn's multiple comparison to detect possible significant differences between treatments ($p < 0.05$).

3. Results

The kinetics of oxygen uptake from the aerobic mineralization of aquatic macrophytes is shown in Figure 1, from which the oxygen uptake deriving from water samples from Cantá Stream (control) was subtracted. OC_{max} for the whole 121 days of experiment ranged from 195.36 mg.g^{-1} (DM) for *E. interstincta* to 629.46 mg.g^{-1} (DM) for *Nymphaea* sp. (Table 1). The mineralization of *M. arborescens* showed the higher constant rate (k_D: 0.049 day^{-1}), followed by mineralization of *E. interstincta* (k_D: 0.038 day^{-1}) and *Nymphaea* sp. (k_D: 0.027 day^{-1}), as shown in Table 1.

The KW test showed that oxygen uptake during decomposition of E. *interstincta* was different statically than *M. arborescens* ($p < 0.001$) and *Nymphaea* sp. ($p < 0.001$).

For all anaerobic incubations, gases were predominantly released in the beginning of the experiments (2 to 6 days), with the following maximum daily rates: *E. interstincta* (16.2 mL, day: 0.75), *Nymphaea* sp. (10.0 mL, day: 0.5); *M. arborescens* 11.5 mL; day: 0.5). Then, the consumption processes (negative rates) prevailed (*E. interstincta*: 6th to 11th day, *Nymphaea* sp.: 4th
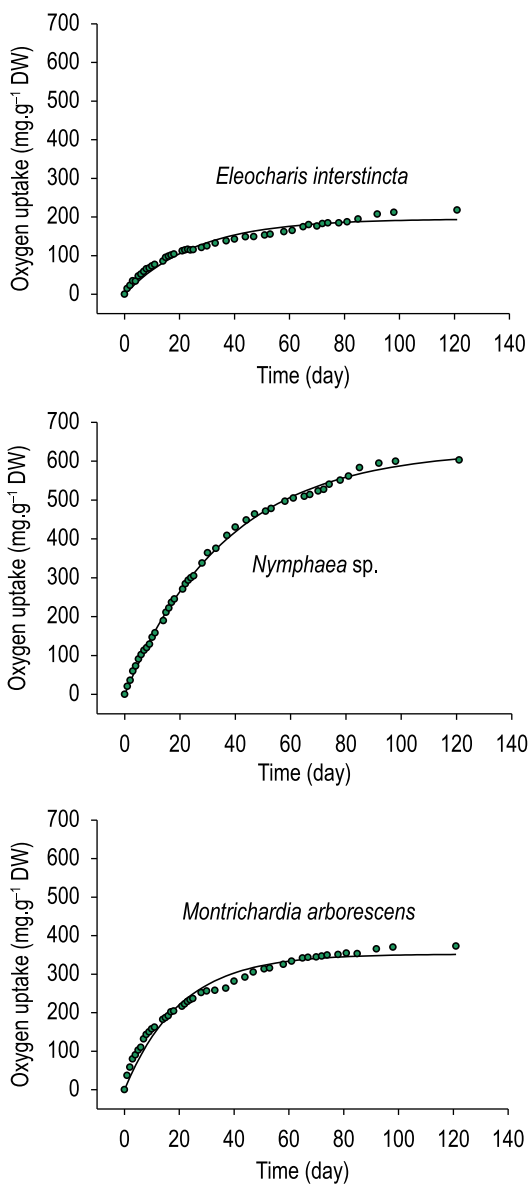

Figure 1. Oxygen uptake kinetics during aerobic decomposition of *E. interstincta*, *Nymphaea* sp. and *M. arborescens*.

Table 1. Carbon budget and kinetics parameters related with anaerobic and aerobic mineralization of aquatic plants.

Anaerobic	Ci (mg)	Cf (mg)	MC (mg)	Vol (mL)	k_M (d^{-1})	error (d^{-1})	$t_{1/2}$ (d)	r^2
Eleocharis interstincta	4.42	4.03	0.39	59.70	0.0017	0.0001	398	0.82
Nymphaea sp.	4.70	3.73	0.97	92.40	0.0036	0.0001	195	0.94
Montrichardia arborescens	4.96	3.37	1.59	114.25	0.0047	0.0001	148	0.97

Aerobic	OC_{max} (mg.g^{-1})	error (mg.g^{-1})	k_D (d^{-1})	error (d^{-1})	$t_{1/2}$ (d)	r^2
Eleocharis interstincta	195.36	4.21	0.038	0.002	18	0.97
Nymphaea sp.	629.46	4.84	0.027	0.005	25	0.99
Montrichardia arborescens	352.17	5.47	0.049	0.003	14	0.98

to 11th day; *M. arborescens*: 2nd to 11th day). In a third stage, as illustrated in Figure 2, the rates of gases formation increased, with these processes being maintained until the end (Figure 2). In this second stage of gases formation, the incubations with *M. arborescens* displayed the highest average rate (2.43 mL.day⁻¹) followed by incubation with *Nymphaea* sp. (1.63 mL.day⁻¹) and *E. interstincta* (0.66 mL.day⁻¹). After 78 days, the incubations with *M. arborescens* showed the highest gases formation (114.25 mL), while for *Nymphaea* sp. and *E. interstincta*, the amount of gases was 92.40 mL and 59.70 mL, respectively. The consumption of gases was 16.7, 21.3 and 20.1 mL, respectively (Figure 2).

Regardless to anaerobic decomposition, the KW test showed that gases formation were not significant statically among the three species ($p > 0.05$; KW = 2.454).

According to the changes of MC (Figure 3) the anaerobic decomposition of *M. arborescens* presents the highest mineralization coefficient (0.0047 day⁻¹); followed by decomposition of *Nymphaea* sp. (0.0035 day⁻¹) and *E. interstincta* (0.0017 d⁻¹). These constants rates lead to the following mineralization half-times: *M. arborescens*: 151 days; *Nymphaea* sp.: 198 days and *E. interstincta*: 408 days.

4. Discussion

The total amount of OC_{max}, obtained in the dark, is usually employed as a measure of total heterotrophic activity in samples of lake water, soils and sediments (Hantush, 2007; Chomicki and Schiff, 2008; Bond-Lamberty and Thomson, 2010), and it is therefore reasonable to use OC_{max} to follow the process of a microbial reaction in aerobic environments (Characklis, 1990). The long-term BOD tests are the experimental procedure to obtain this variable (Cunha-Santino and Bianchini Jr., 2003). Considering the high determination coefficients (r^2: from 0.97 to 0.99) obtained from the fittings using the kinetics model (Figure 1) it was possible to verify that the proposed model (Equation 1) was robust to represent the kinetics of oxygen uptake.

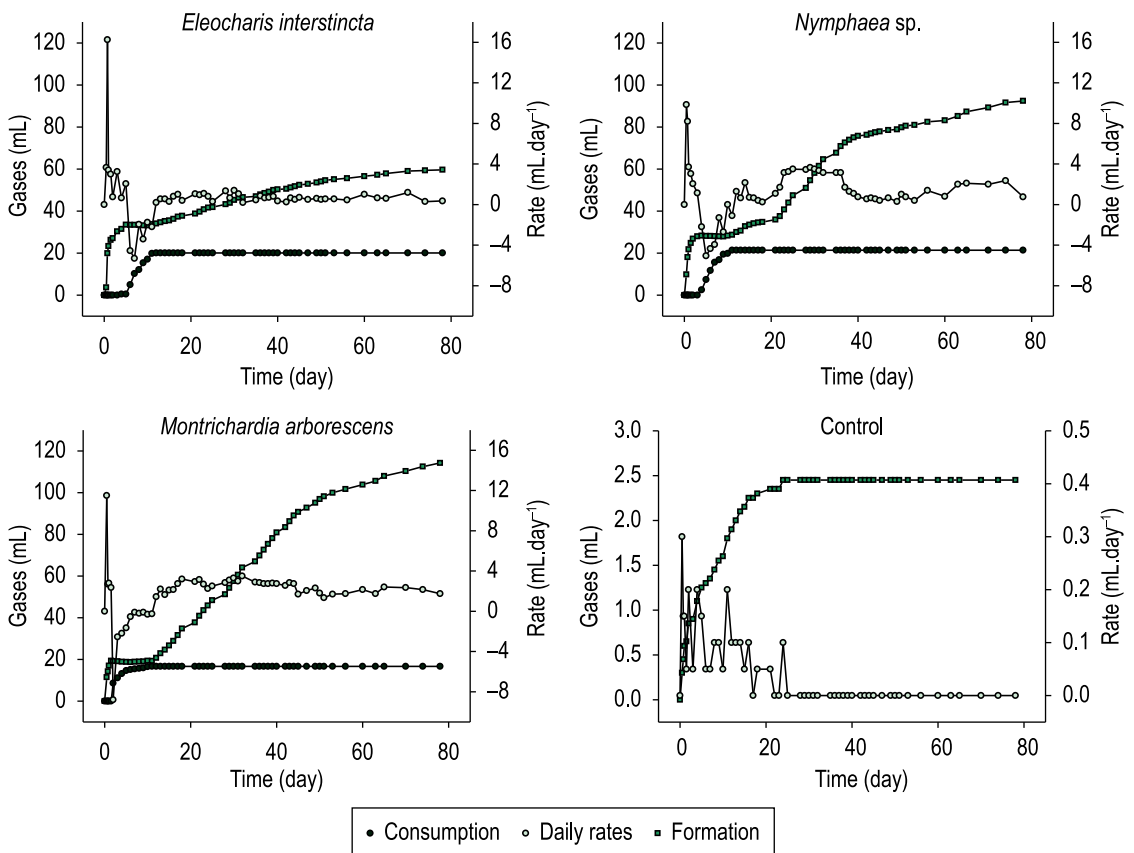From the kinetics point of view, the oxygen consumption was similar to that observed by

Figure 2. Gases formation and consumption during anaerobic decomposition of *E. interstincta*, *Nymphaea* sp. and *M. arborescens*.
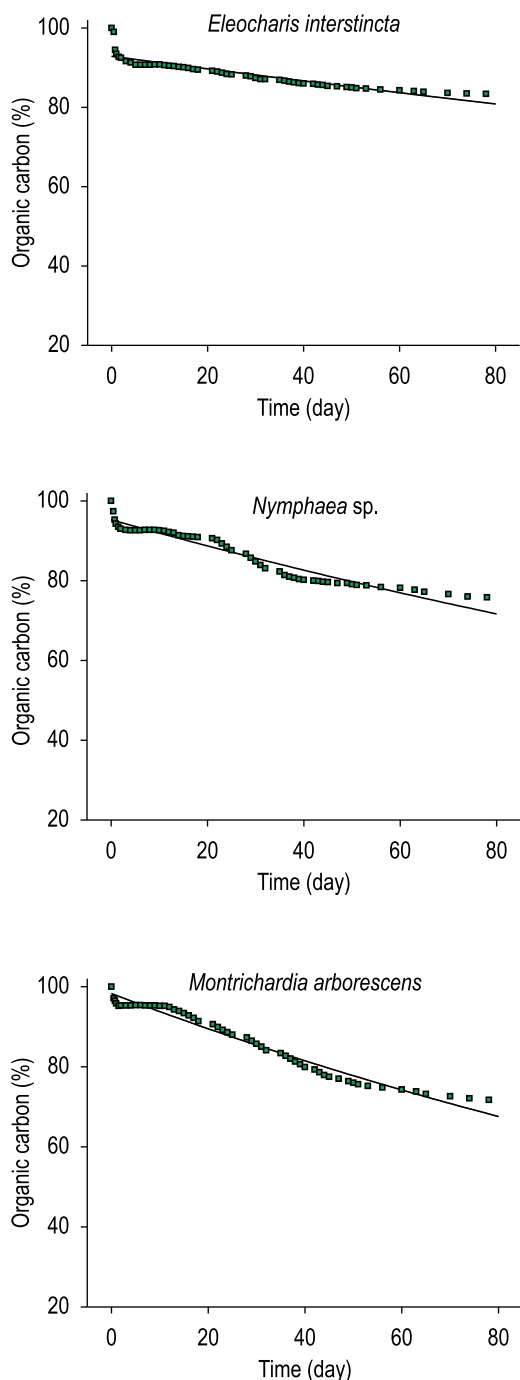
Figure 3. Organic carbon decay during anaerobic mineralization of *E. interstincta*, *Nymphaea* sp. and *M. arborescens*.

Santos et al. (2009). There was a strong increase in oxygen demand in the beginning of the experiment, followed by a decrease in oxidation, tending to stabilization of the process (Figure 1). Considering that aquatic macrophyte detritus is a heterogeneous source of organic matter with labile and refractory compounds, the oxygen uptake was probably related to the labile fractions. On the other hand, the reduction on oxygen uptake was

associated with the mineralization of refractory fractions (fibers tissue, e.g. cellulose, lignin and hemicellulose). Decomposition experiments with *Eleocharis interstincta* showed a labile fraction of 17.3%, to be contrasted with 27.2% for *Nymphaea ampla* (Brum and Esteves, 2001); for this specie Bianchini Jr. (1982) observed a labile fraction of 50.2%. The kinetic model for decomposition of *Montrichardia arborescens* pointed to a labile fraction of 29.3% (Bianchini Jr. et al., 2002).

Comparing the OC_{max} obtained in the present study with similar experiments (Table 2), *Nymphaea* sp. showed the highest values (629.5 mg $^{-1}$ DM); in fact aerobic mineralization of *Nymphaea ampla* presented OC_{max} values varying from 258.0 to 450.0 mg.g^{-1} DM (Brum et al., 1999; Farjalla et al., 1999). Furthermore, the *Egeria najas* generated the higher oxygen demand (mg) per g (DM) (699.9 mg.g^{-1} DM; Bianchini Jr. et al., 2008). The lower values of OC_{max} obtained in long-term BOD experiments were 32.5 mg.g^{-1} DM during decomposition of *Typha domingensis* and 60.0 mg.g^{-1} DM for *Eleocharis fistulosa* (Farjalla et al., 1999). For the decomposition of *Eleocharis interstincta* we found that OC_{max} value was 195.4 mg.g^{-1} DM; although these values were about 3.3 times that of *Eleocharis fistulosa,* it was close to other Cyperaceae, such as *Oxycaryum cubense*: 144.0 and 160.9 mg.g^{-1} DM (Bitar and Bianchini Jr., 2002; Lemos and Bianchini Jr., 1998). On average, considering all experiments listed in Table 2 the mean OC_{max} is 278.9 mg.g^{-1} DM; the OC_{max} in the present study was 392.4 mg.g^{-1} DM. According to Bianchini Jr. (2003), in the aerobic decay of different types of aquatic plants, the OC_{max} from mineralization of free-floating and submerged macrophytes was similar (354.4 mg.g^{-1} DM), for emergent aquatic macrophytes this value was 178.8 mg.g^{-1} DM.

A compilation on oxygen uptake from aquatic plants resources (Bianchini Jr. et al., 2007) showed that, overall, the average of OC_{max} from aquatic macrophytes (n = 33 taxons) were 607 mg.g^{-1} DM and k_D was 0.106 day^{-1}. Considering the life style of macrophytes: the emergent present an OC_{max} 456 mg.g^{-1} DM (k_D = 0.121 day^{-1}), for submerged macrophytes these values were 895 mg.g^{-1} DM and 0.071 day^{-1}. Floating-leaves showed an OC_{max} of 753 mg.g^{-1} DM (k_D = 0.124 day^{-1}). Considering only the macrophytes fibers (ca. cellulose, lignin and hemicelluloses) the OC_{max} were 351 mg.g^{-1} DM (k_D = 0.011 day^{-1}) and for macrophytes leachates these values were 1253 mg.g^{-1} DM and 0.030 day^{-1}, respectively.

Table 2. Parameters derived from oxygen uptake model during aerobic decomposition of aquatic macrophytes. Where: OC_{max} = total amount of consumed oxygen and k_D = the deoxygenation constant rate.

Resource	OC_{max} (mg.g^{-1})	K_D (day^{-1})	Reference
Cabomba sp.	342.0	0.093	Bitar, 1995
Cabomba piauhyensis	339.0	0.097	Cunha and Bianchini Jr., 1998
Cabomba piauhyensis	384.1	0.045	Bianchini et al., 2008
Cyperus giganteus	316.7	0.025	Bianchini et al., 2008
Eichhornia azurea	140.0	0.199	Bitar, 1995
Eichhornia azurea	279.2	0.027	Bianchini et al., 2008
Eleocharis interstincta	195.4	0.038	This study
Eleocharis fistulosa	60.0	0.040	Farjalla et al., 1999
Egeria najas	699.9	0.014	Bianchini et al., 2008
Lemna sp.	230.0	0.230	Bitar, 1995
Ludwigia inclinata	393.6	0.022	Romeiro, 2005
Montrichardia arborescens	235.2	0.044	Cunha-Santino et al., 2004
M. arborescens	352.2	0.049	This study
Myriophyllum aquaticum	599.9	0.018	Santos et al., 2009
Nymphaea sp	629.5	0.027	This study
Nymphaea ampla	258.0	0.136	Brum et al.,1999
N. ampla	450.0	0.112	Farjalla et al., 1999
Oxycaryum cubense	144.0	0.166	Bitar, 1995
Oxycaryum cubense	160.9	0.011	Lemos and Bianchini Jr., 1998
Oxycaryum cubense	274.9	0.038	Bianchini et al., 2008
Potamogeton stenostachys	377.0	0.054	Brum et al., 1999
P. stenostachys	360.0	0.070	Farjalla et al., 1999
Salvinia sp.	185.0	0.079	Bitar, 1995
Salvinia auriculata	166.3	0.041	Bianchini et al., 2008
Typha domingensis	139.0	0.147	Brum et al., 1999
T. domingensis	32.5	0.014	Farjalla et al., 1999
Utricularia breviscapa	260.0	0.045	Cunha-Santino, 2003
Utricularia breviscapa	469.7	0.023	Bianchini et al., 2008
Wolffia sp.	573.5	0.079	Bitar, 1995
Average of this study	392.4	0.038	
Average of all experiments	312.0	0.068	

The results indicated that during aerobic decomposition in the Cantá Stream the dissolved oxygen availability is most affected by *Nymphaea* sp. > *M. arborescens* > *E. interstincta*. The detritus with higher content of fibers is responsible for the benthic demand of oxygen, since these aquatic macrophytes debris tended to accumulate on the sediment.

The value of deoxygenation coefficient (k_D: 0.027 to 0.049 day^{-1}) determined for the aerobic mineralization of *Nymphaea* sp., *M. arborescens*, *E. interstincta* was lower than the mean value (0.068 day^{-1}; n = 21) in similar experiments (Table 2).

The accumulated gases generated during the anaerobic decay of *Nymphaea* sp., *M. arborescens* and *E. interstincta* (Figure 2) result from fermentation and methanogenesis (Bitar, 2003). The time evolution of CM was associated with the evolved

gases. Through its relation with the final mass balance a methodological equivalence of oxidation of the consumed organic matter (on C basis) and the formation of gases could be established. The relation between these results presented a high determination coefficient (r^2: 0.84). From the potential function the daily rates of mineralization of organic matter (CM) could be estimated on a carbon basis (Figure 3).

The anaerobic decomposition of *Nymphaea* sp., *M. arborescens* and *E. interstincta*, present two stages. In the first, from 2nd to the 11th day, referred to the consumption processes, there were negative rates, which means that gas consumption by assimilation or solubilization prevailed over gas formation via mineralization. The second stage occurred when the gases probably reached their saturation concentrations and the processes of gas

formation supplanted the generation of dissolved inorganic compounds (e.g. carbonate ions). This second stage was characterized by intense release of gases with strong increase in daily rates. These higher rates are probably due to the mineralization of labile dissolved compounds, formation of CH_4, denitrification, formation of H_2S and the adaptation of the heterotrophic community.

Comparing the gas production of *Nymphaea* sp., *M. arborescens* and *E. interstincta*, in 78 days of decomposition, *M. arborescens* generated the highest amount of gases (1.3 fold for *Nymphaea* sp. and 1.9 fold for *E. interstincta*). Studying the decomposition of *Eichhornia azurea* and *Egeria najas*, Bitar (2003) observed in 120 days of anaerobic mineralization that the production of gases from *E. azurea* (44.9 mL) was smaller than *E. najas* (199.2 mL). According to the author, this difference was probably related to the structural composition of the plants (cellulose contents and labile fraction of carbon). During 213 days of anaerobic decomposition, in vitro assays of *Eichhornia azurea* in a eutrophic reservoir water produced 94.18 mL of gases (Cunha-Santino and Bianchini Jr., in press). In the anaerobic decomposition of *Cabomba piahuyensis* and *Oxycaryum cubense,* the volume of evolved gases (during 120 days) was, respectively, 213.1 and 36.0 mL (Cunha and Bianchini Jr., 1998). The aerobic mineralization of *M. arborescens* presented a gaseous yield of 236.9 mL (127 days). According to Ballester and Santos (2001), in anaerobic environment the gases emissions are mainly CO_2, whose origin is organic matter oxidation, denitrification and sulphate reduction; methane arising from methanogenesis; and N_2 from denitrification. For an oxbow lake Ballester and Santos (2001) reported maximum rates of gas formation between the 80º and 90º days of incubation, with formation of CO_2 and CH_4 and, in general, prevalence of gas production over consumption. Assays on anaerobic decomposition of *Ludwigia sedoides* in different temperatures indicated that CO_2 formation were produced from the first day of decomposition; in relation to methanogenesis, this gases formation presented different genesis periods: 15th day at 29.9 °C and 99th at 15.0 °C (Romeiro and Bianchini Jr., 2008).

The higher mineralization coefficient (k_M = 0.0047 day^{-1}) was observed in the anaerobic decomposition of *M. arborescens,* which means that under such conditions these detritus undergo a faster mineralization process than *Nymphaea* sp. (1.4 times) and *E. interstincta* (2.8 times). The debris

of *E. interstincta* will probably remain in sediments for long periods; according to a revision made by Little (1979) this genus presented ca. 30% of DM of crude fibers. The genera *Nymphaea* presents ca. 16% of crude fibers (DM) but higher content of phenolic compounds (e.g. *Nymphaea alba*: 235 mg.g^{-1} DM; Smolders et al., 2000) and these substances influenced the decomposition process (Kok et al., 1992). *M. arborescens* presented less phenolic compounds than *Nymphaea* (ca. 105.8 mg.g^{-1} DM; Cunha-Santino et al., 2003).

The results indicate that in the Cantá stream, the cycling of *Nymphaea* sp., *M. arborescens* and *E. interstincta* is more efficient with regard to oxygen uptake (i.e. oxidation of labile organic matter). In this context, according to k_D and k_M; on average, the aerobic processes were 11-fold faster than anaerobic ones. The effect of the microbial degradation in the regulation of organic matter content of detritus is related with k_D. It is assumed that the fractions responsible for the high k_D have reduced periods of half-time, and therefore do not accumulate in the ecosystems. The aerobic decay of labile fraction of aquatic macrophytes can promote great depletion in the dissolved oxygen budget in water column; *Nymphaea* sp. is the genera that can generate the largest short-term pressures on the dissolved oxygen availability and *M. arborescens is* the aquatic plant detritus that enhanced the gas adduction within this environment. Owning to the time scale of k_M ($t_{1/2}$: 151 to 408 days), the fibrous debris of these plants (POM - refractory fractions), associated with the appropriate values of pH and oxi-reduction potential, will contributed to the dynamics of gas production and storage of particulate organic matter in sediments of the Cantá Stream. Regarding to the materials fluxes in freshwater ecosystems, low rate of decomposition observed in anaerobic process when comparing to aerobic rates reflect that the sediment represent a very efficient sink in the organic matter cycling.

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