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Kinetics of the aerobic decomposition of *Talauma ovata* and *Saccharum officinarum*

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ABSTRACT. The aim of this study is to evaluate the kinetics of aerobic decomposition of *Saccharum officinarum* and *Talauma ovata* leaves. For each species, decomposition chambers (leaves and water) were set up, which were maintained under controlled conditions. Each sampling day (1, 7, 15, 30, 39, 58, 72 and 90 days), the concentrations of total organic carbon, pH and electrical conductivity (EC) were determined in the dissolved fraction, while the mass and cell wall fractions (CWF) were determined in the particulate fraction. The pH stabilization of the chambers with *T. ovata* and *S. officinarum* leaves occurred in alkaline (ca. 8 - 8.5) and close to the neutrality (ca. 7 - 7.5) environment, respectively. The EC values were on average 1.6 times higher in incubations with *T. ovata* leaves. The mass loss did not differ between the species (mean = 53.85%), however the decay coefficient was higher for *S. officinarum* (k_4 = 0.007 day^{-1}) than for *T. ovata* (k_4 = 0.005 day^{-1}) leaves. The CWF mass loss (mean = 50.16%) and their coefficient (0.0090 day^{-1}) were similar. *S. officinarum* decomposed faster due to its high concentrations of energetic compounds of interest to the microbiota. The slower decomposition of *T. ovata* may have occurred due to the presence of secondary compounds with negative effects to the microorganisms.

Keywords: riparian zone, mass loss, mineralization, dissolved organic carbon, particulate organic carbon.

Cinéticas da decomposição aeróbia de *Talauma ovata* e *Saccharum officinarum*

RESUMO. O objetivo deste estudo foi avaliar as cinéticas da decomposição aeróbia de folhas de *Talauma ovata* e *Saccharum officinarum*. Para cada espécie foram montadas câmaras de decomposição (folhas e água) que foram mantidas sob condições controladas. A cada dia amostral (1, 7, 15, 30, 39, 58, 72 e 90 dias), as concentrações de carbono orgânico total, pH e condutividade elétrica (CE) foram determinadas na fração dissolvida, enquanto a massa e as frações de parede celular (FPC) foram determinadas na fração particulada. A estabilização do pH das câmaras com folhas de *T. ovata* e *S. officinarum* ocorreram em meio básico (ca. 8 - 8,5) e próximo à neutralidade (ca. 7 - 7,5), respectivamente. Os valores de CE foram em média 1,6 vezes maiores nas incubações com folhas de *T. ovata*. A perda de massa não diferiu entre as espécies (média = 53,85%). No entanto, o coeficiente de decaimento foi maior para as folhas de *S. officinarum* (k_4 = 0,007 dia^{-1}) que para *T. ovata* (k_4 = 0,005 dia^{-1}). As perdas de massa da FPC (média = 50,16%) e seus respectivos coeficientes (0,0090 dia^{-1}) foram similares. *S. officinarum* decompôs mais rapidamente devido às elevadas concentrações de compostos energéticos de interesse para a microbiota. A decomposição mais lenta de *T. ovata* pode ter ocorrido pela presença de compostos secundários com efeitos negativos sobre os micro-organismos.

Palavras-chave: zona ripária, perda de massa, mineralização, carbono orgânico dissolvido, carbono orgânico particulado.

Introduction

Riparian vegetation is the transition zone between the terrestrial and aquatic ecosystem (RICHARDSON et al., 2007). This zone has functions of great importance to the environment: (i) avoiding the erosion of stream banks and the consequent widening of the channel; (ii) shaping the channel morphology by the heterogeneity introduced via plants or large woody debris that change the water flow direction; (iii) altering channel hydraulics, also by large woody debris structures, reducing or increasing water velocity and changing its residence time; (iv) impacting water quality, either by acting as filters, reducing nutrients and pesticide movements into rivers by taking and storing them, or even by releasing nutrients through decomposition or exuding components; (v) controlling the streams microclimate via shading and evapotranspiration; (vi) working as ecological corridors, enabling biological connections through

environmental gradient and (vii) providing habitat, refuge and food for the fauna (NAIMAN; DÉCAMPS, 1997; RICHARDSON et al., 2007; TABACCHI et al., 2000). However, one of the most relevant functions is the supply of organic matter into the water. In low order forested streams, allochthonous matter is the most important source of energy to support the biotic communities inhabiting the site (ABELHO, 2001). This occurs because the dense canopies shade the stream, reducing the penetration of solar radiation, promoting low temperatures and consequently limiting primary production (ABELHO, 2001). In many cases, leaves are the most abundant fraction of the allochthonous particulate organic matter (e.g., GONÇALVES JUNIOR et al., 2006a). Thus, leaf litter breakdown is a fundamental function performed in streams (PASCOAL et al., 2005). It depends on both litter quality (e.g., leaf chemistry such as secondary compounds - tannins and lignins for example - and nutrient concentrations) and stream characteristics (e.g., temperature, pH, specific conductivity, salinity, total dissolved solids and nutrient concentrations), which affect biofilm formation, microbial decomposition and invertebrate colonization (LEROY; MARKS, 2006; TREVISAN; HEPP, 2007; WRIGHT; COVICH, 2005).

The leaf litter breakdown in streams is characterized by three distinct phases, which act simultaneously: leaching, conditioning and fragmentation (GESSNER et al., 1999). Leaching is the release of soluble leaf constituents, which is generally quick, accounting for a substantial reduction in initial mass (ABELHO, 2001; GESSNER et al., 1999). Conditioning is the colonization of leaf litter by microorganisms that enhance breakdown by grinding, metabolizing and incorporating leaves into secondary production (ABELHO, 2001). Microorganisms also increase detritus palatability for invertebrate shredders, although leaf decomposition does not necessarily end up in the feeding of shredders (GESSNER et al., 1999). The microbial community is basically composed by fungi and bacteria (GONÇALVES JUNIOR et al., 2006b). However, fungi, especially aquatic hyphomycetes, are of greater importance than bacteria in this process in terms of biomass and activity (ABELHO et al., 2005; GULIS; SUBERKROPP, 2003; HIEBER; GESSNER, 2002; PASCOAL; CÁSSIO, 2004). Finally, fragmentation can occur in two distinct ways: (i) physical fragmentation occurs by abrasion and shear stress carried by the flowing water and (ii) biotic fragmentation occurs by microbial enzymatic degradation and feeding of shredders, which transform coarse into fine particulate organic matter (ABELHO, 2001; GESSNER et al., 1999; GRAÇA, 2001). Subsequently, the dissolved and fine particulate organic carbon is converted into CO_2 and other inorganic compounds (mineralization) by oxidation (CUNHA-SANTINO; BIANCHINI JUNIOR, 2000; GESSNER et al., 1999).

Although riparian and riverine systems have always played a fundamental role in human life, providing the most diverse ecosystem services, these systems are subject to antrophic degradation all over the world (KYLE; LEISHMAN, 2009). Inappropriate agricultural practices, for example, have led to the loss of riparian vegetation, with its replacement by monoculture that has great economic interest, such as sugar-cane (*Saccharum officinarum*). This replacement modifies the quality and quantity of matter entering stream, consequently affecting its communities and functional processes (e.g. BELTRÃO et al., 2009; CORBI; TRIVINHO-STRIXINO, 2008). Brazil is the largest sugar-cane producer in the world, which is cultivated in the southeastern and northeastern parts of the country (MORIYA et al., 2007). In São Paulo State, particularly in recent years, this plant has been extensively cultivated and usually replaces the original riparian forest. *Talauma ovata* is among the species threatened by this process. This is a late secondary or climax plant particularly found in the Atlantic Rain Forest, with substantial representation in the gallery forests of Brazilian Savanna or the wetland environments (LORENZI, 2002).

We hypothesized that the decomposition of *T. ovata* leaves is slower than *S. officinarum* leaves, since *T. ovata* is rich in secondary compounds (STEFANELLO et al., 2005) which can present anti microbial action. Taking this into account, the aim of this study is to describe the kinetics of the aerobic decomposition of *Talauma ovata* and *Saccharum officinarum* leaves. This was done by analyzing the particulate organic carbon decay, the carbon balance and the release of hydrosoluble compounds from leaves in controlled conditions.

Material and methods

Experimental procedures

Talauma ovata (Magnoliaceae) is a perennial species (ANTUNES; RIBEIRO, 1999) whit glabrous leaves and reticulate nervure, simple blades with entire margins and an acute apex and base. Its leaves were collected on the banks of the Espraiado stream at the beginning of flowering, i.e. in the dry

season. Leaves at the senescence stage were taken directly from the adult plant, just before abscission. *Saccharum officinarum* (Poaceae) has hairy leaves (silica) with parallel nervure, simple blades with ciliate margins, an invaginating base and acute apex. Its leaves were collected in a plantation located between the cities of Araraquara and Ibaté (21°52'S and 48°0.5'W), also in the dry season, when the plant was in the ripening period (i.e. moments before harvest). After collecting, the leaves of both species were washed in running water in order to remove any material that interferes in the gravimetric method (e.g. inorganic material, small organisms, animal feces). Afterwards, they were dried in an oven at 45°C, until they obtained a constant mass, and fragmented (Ø = 4.01 ± 1.21 cm).

Water samples were collected at the Espraiado stream (21°53'S and 47°52'W), located in the city of São Carlos (São Paulo State, Brazil) next to the campus of the São Carlos Federal University, on the borders of São Carlos Ecological Park. Espraiado is a first order stream with preserved riparian vegetation (CORBI; TRIVINHO-STRIXINO, 2008). Its waters has limnological variables ranging in the following intervals: dissolved oxygen 2.08 – 5.00 mg L^{-1}; pH 4.51 - 5.65; electrical conductivity 11 - 35 μS cm^{-1} (DORNFELD; FONSECA-GESSNER, 2005); total nitrogen 190-310 μg L^{-1} and total phosphorus 0.2 - 0.7 μg L^{-1} (CORBI; TRIVINHO-STRIXINO, 2008).

For each species, chambers of decomposition (n = 24) were set up, with ca. 0.5 g of leaf fragments and 50 mL of water sample from the Espraiado stream. This water was previously filtered using a cellulose acetate membrane (pore Ø = 0.45 μm; Millipore) to remove all particulate organic material. The chambers were maintained in the dark under aerobic conditions at 22.6ºC, for 90 days. Every sampling day (1, 7, 15, 30, 39, 58, 72 and 90 days), three chambers of each resource were fractionated into particulate and dissolved fractions through a nylon mesh (Ø = 400 μm). In the dissolved fraction the following was determined: (i) the concentrations of total organic carbon (TOC) by combustion and infrared detection (Shimadzu TOC-5000A); (ii) the pH values, using the potentiometric method (Qualxtron, model 8010); and (iii) the electrical conductivity (EC) values, also using the potentiometric method (Digimed, model DM3). The remaining particulate organic matter (POM) was dried at 45°C to obtain a constant weight and its mass was determined by gravimetry (WETZEL; LIKENS, 1991). The cell wall fraction (CWF; lignin, cellulose and hemicellulose) of POM was determined by the modified method proposed by Van Soest and Wine (1967). The POM was converted into carbon bases (POC) by a factor of 0.40. This value represents the mean obtained by a compilation of 45 studies of different species conducted by Bianchini Junior and Cunha-Santino (2008).

Data treatment

The temporal variations of pH, EC and mass loss of the two species were tested using the Shapiro-Wilk normality test. For the data that presented normal distribution (mass loss), the Student t test was applied later. For the data with non-normal distribution (pH and EC), the Kruskal-Wallis test was applied.

Considering the carbon mass balance of incubation, the evolution of the carbon mineralization process from the aerobic decomposition of *T. ovata* and *S. officinarum* leaves were obtained from the kinetic model described in Equations 1 to 4 (BIANCHINI JUNIOR, 2003). For the parameterization of the model (Equations 1 to 4), the temporal variations of POC and DOC were fitted using the Levenberg-Marquardt iterative algorithm (PRESS et al., 1993).

$$IN_1 = \frac{k_1}{k_T} POC_{LS}(1 - e^{-k_T t}) \quad (1)$$

$$IN_2 = \frac{k_2}{k_T} POC_{LS}(1 + \frac{k_3}{k_T - k_3} e^{-k_T t} + \frac{k_T}{k_3 - k_T} e^{-k_3 t}) \quad (2)$$

$$IN_3 = POC_R(1 - e^{-k_4 t}) \quad (3)$$

$$MC = \sum_{i=1}^{3} IN_i \quad (4)$$

where:

POC_{LS} = labile/soluble particulate organic carbon (%);

POC_R = refractory particulate organic carbon (%);

POC_L: labile particulate organic carbon (%);

$POC_L = (k_1 k_T^{-1}) \times POC_{LS}$;

DOC = dissolved organic carbon (%) derived from leaching;

$DOC = (k_2 k_T^{-1}) \times POC_{LS}$;

MC = mineralized carbon (%);

e = natural logarithm base;

t = time (day);

k_T = global decay coefficient of POC_{LS} ($k_1 + k_2$) (day^{-1});

k_1 = mineralization coefficient from POC_L (day^{-1});

k_2 = leaching coefficient from POC_{LS} (equal to the rate of DOC formation; day^{-1});

k_3 = DOC mineralization coefficient (day^{-1});

k_4 = POC_R mineralization coefficient (day^{-1});

IN_{1-3}: inorganic compounds produced by the 3 mineralization pathways (%).

The half-life times ($t_{1/2}$) of the decomposition process of *T. ovata* and *S. officinarum* were calculated by the Equation 5.

$$t_{1/2} = 0{,}693/k_{(1-4)} \quad (5)$$

For the temporal variations of CWF a first-order kinetic model (single exponential) was applied.

Results

The pH of incubations with *T. ovata* leaves did not differ statistically from that with *S. officinarum* leaves (Kruskal-Wallis test, p = 0.0934). Initially the dissolved fraction of both species showed acidic character (5.18). Then, the pH of the chambers with *T. ovata* leaves increased, reaching its maximum value (8.53) on the 39th day of decomposition and then tended to stabilize in a basic pH medium (mean = 8.28). The pH of the chambers with *S. officinarum* leaves tended to stabilize from the 30th day at close to the neutrality environment (mean = 7.37), reaching its maximum value (7.49) on the 72nd day of decomposition (Figure 1).

The electrical conductivity (EC) of the incubation with *T. ovata* and *S. officinarum* leaves differed statistically (Kruskal-Wallis test, p = 0.004718), and the values obtained for *T. ovata* were 1.6 times higher than those obtained for *S. officinarum*. The initial water EC value was 19.18 µS cm^{-1} for both species. After the first day, this value increased dramatically, reaching 797 and 559 µS cm^{-1} in the incubations with *T. ovata* and *S. officinarum* leaves, respectively. The EC of incubation with *T. ovata* leaves increased progressively, reaching its maximum value (1134 µS cm^{-1}) on the 30th day and, subsequently began to decrease gradually arriving at 888 µS cm^{-1} at the end of the experiment (90th day). In the decomposition of *S. officinarum* leaves, the maximum EC value (718 µS cm^{-1}) was found on the 58th day, decreasing from then and reaching 532 µS cm^{-1} at the end of the experiment (90th day) (Figure 1).

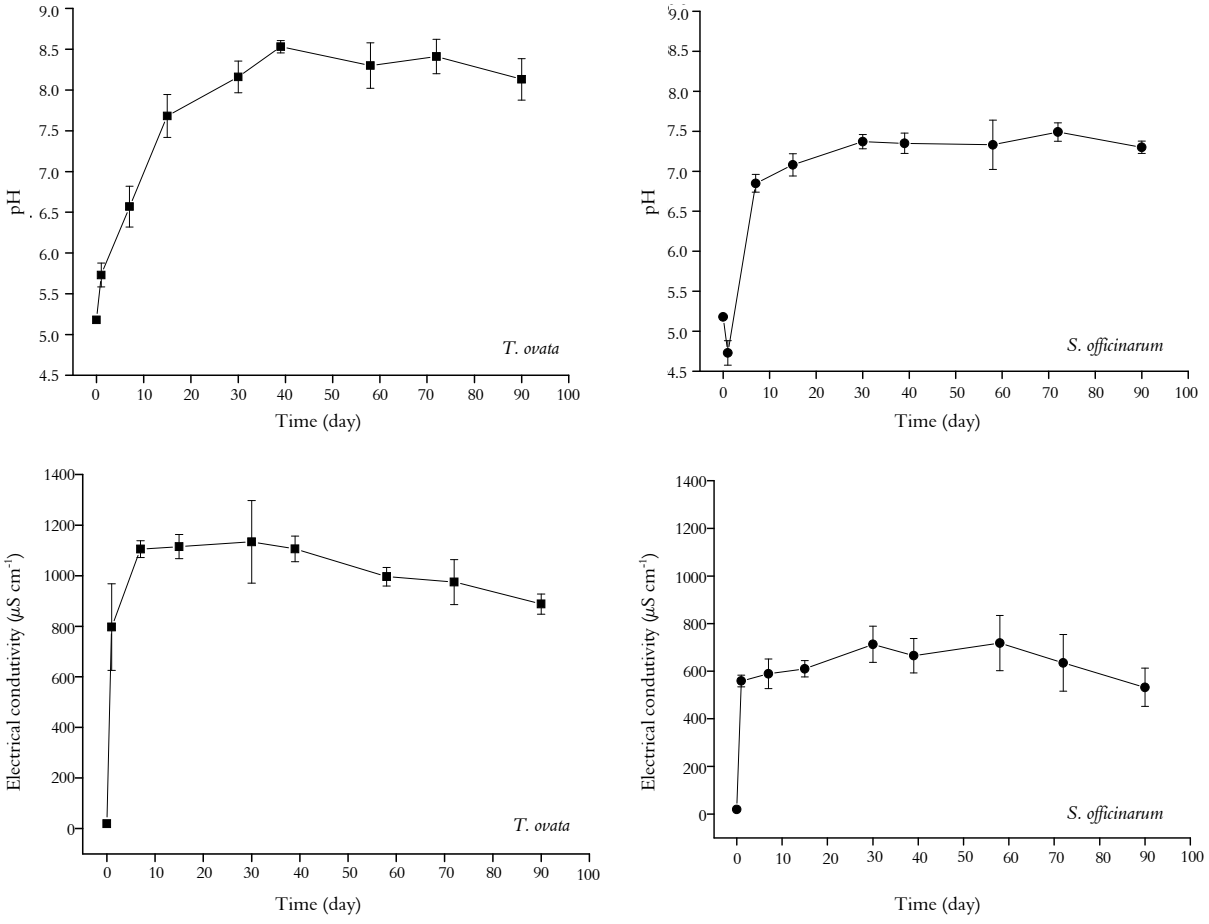

Figure 1. Mean values and standard deviations (n = 3) of pH and electrical conductivity temporal variations of the incubations with *Talauma ovata* and *Saccharum officinarum* leaves.

The DOC presented an increase of 15.69% in the incubation with *T. ovata* leaves and of 9.16% in that with the *S. officinarum* leaves after the first day, which are the maximum values recorded. Since then, the DOC concentrations decreased gradually reaching the minimum value on the 90th day of the experiment (1.22% for incubations with *T. ovata* leaves and 1.59% for that with *S. officinarum* leaves) (Figure 2). *T. ovata* leaves showed a loss of 54.63% of their initial mass after the 90 days of the experiment. This value was very close to that lost by *S. officinarum* leaves in the same period (53.07%). The POC decay (mass loss) was not statistically different between the two species (t-test, F = 1062 and P = 0.4671) (Figure 2).

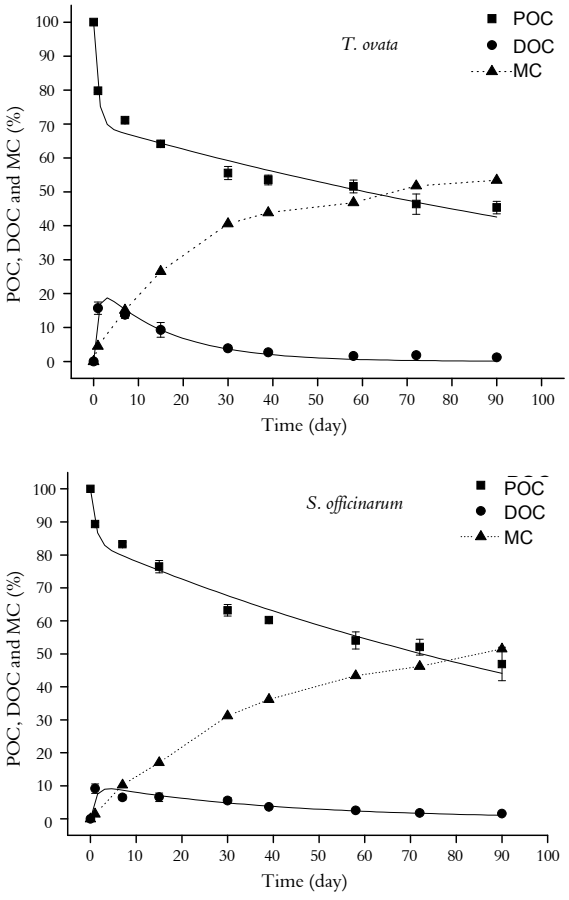

Figure 2. Mean values and standard deviations (n = 3) of the temporal variations during the decomposition of particulate organic carbon (POC), dissolved organic carbon (DOC) and mineralized carbon (MC) of detritus from *Talauma ovata* and *Saccharum officinarum* leaves.

In general, the kinetic model suggests that the particulate organic carbon (POC) from selected resources had two fractions: a labile and/or soluble (POC_{LS}), and a refractory (POC_R). The POC_{LS} is represented by the fast mass loss during the first days of decomposition through a leaching process, while the POC_R had a slower decomposition. *T. ovata* leaves showed a POC_{LS} content of 30.11%, almost twice the *S. officinarum* leaves values (16.15%). Due to the greater labile character of *T. ovata* leaves, 20.23% of its initial mass was lost after the first day of decomposition, double the amount lost by *S. officinarum* (10.63%). A higher content of POC_R was, consequently shown by *S. officinarum* (83.82% compared to 69.88% of *T. ovata* leaves). The percentage of POC_R was 53.75, on average, higher than the POC_{LS} fraction. The parameter values obtained for the kinetic model are shown in Table 1.

The values of the global decay coefficients of POC_{LS} (k_T) of *T. ovata* (1.071 day^{-1}) and *S. officinarum* (0.954 day^{-1}) leaves were high and very close, and the value of *T. ovata* leaves slightly higher. The corresponding $t_{1/2}$ was 0.6 and 0.7 day, respectively. The POC_R mineralization coefficients (k_4) were low, and in this case, the mass loss of *S. officinarum* leaves (0.007 day^{-1}) was slightly faster than that of the *T. ovata* leaves (0.005 day^{-1}). Thus, the process $t_{1/2}$ was lower for *S. officinarum* leaves (97 days) than for *T. ovata* leaves (126 days).

The dissolved organic carbon (DOC), formed due to the mass loss of POC_{LS}, corresponded to 74.29% of the leachate for *T. ovata* leaves (k_2 = 0.796 day^{-1}). For *S. officinarum* leaves, this value was 11.95% lower (k_2 = 0.594 $days^{-1}$). The rest of the POC_{LS} was immediately mineralized by direct oxidation at a rate (k_1) corresponding to 0.275 day^{-1} for *T. ovata* leaves. For *S. officinarum* leaves, this value was 30% higher (0.359 day^{-1}).

Table 1. Values of the parameters obtained from the kinetic model used for *T. ovata* and *S. officinarum* leaves. Where: POC_{LS} = labile/soluble particulate organic carbon; POC_R = refractory particulate organic carbon; DOC = dissolved organic carbon; IN_1 = content of organic carbon easily oxidized and mineralized according to k_T; k_T = global decay coefficient of POC_{LS} ($k_T = k_1 + k_2$); k_1 = mineralization coefficient from POC_L; k_2 = leaching coefficient from POC_{LS}; k_3 = DOC mineralization coefficient; k_4 = POC_R mineralization coefficient; $t_{1/2(1\text{-}4)}$ = coefficients ($k_{1\text{-}4}$) half-life time.

Parameter	*T. ovata*	*S. officinarum*
POC_{LS} (%)	30.11	16.15
POC_R (%)	69.88	83.82
k_T (day^{-1})	1.071	0.954
k_4 (day^{-1})	0.005	0.007
r^2	0.98	0.98
DOC (%)	22.36	10.07
k_3 (day^{-1})	0.062	0.025
r^2	0.96	0.78
IN_1 (%) ⋆	7.74	6.08
k_1 (day^{-1}) ⋆⋆	0.275	0.359
k_2 (day^{-1}) ⋆⋆	0.796	0.594
$t_{1/2\ (kT)}$ (day)	0.647	0.727
$t_{1/2\ (k1)}$ (day)	2.515	1.929
$t_{1/2\ (k2)}$ (day)	0.871	1.166
$t_{1/2\ (k3)}$ (day)	11.124	27.326
$t_{1/2\ (k4)}$ (day)	125.798	97.059

(⋆)Values proportional to the formation of IN_1; (⋆⋆)Values estimated by the difference between POC_{LS} and DOC.

The direct mineralization from POC_{LS} (IN_1) of *T. ovata* leaves accounted for 7.74% of the total particulate organic carbon, while the DOC mineralization (IN_2) corresponded to 22.36% and the POC_R (IN_3) to 69.88%. *S. officinarum* leaves showed lower percentages of POC_{LS} mineralization, 6.08 and 10.07% respectively, and consequently a higher percentage of carbon presented mineralization from POC_R, 83.82%. The total mineralized carbon curve from the three pathways is shown in Figure 2.

The initial cell wall fraction (CWF) was 88.19% and 59.14% total mass to *S. officinarum* and *T. ovata* leaves, respectively. After the first day of incubation, the CWF of *T. ovata* was enriched by 12%, it was followed by a gradual decrease, reaching 52.14% of the initial value at 90 days of the experiment. *S. officinarum* leaves presented a slightly higher reduction, reaching 48.19% in the same period (Figure 3). According to the kinetic model adopted, there was no difference between the CWF decay coefficients of both species (0.0090 day^{-1}).

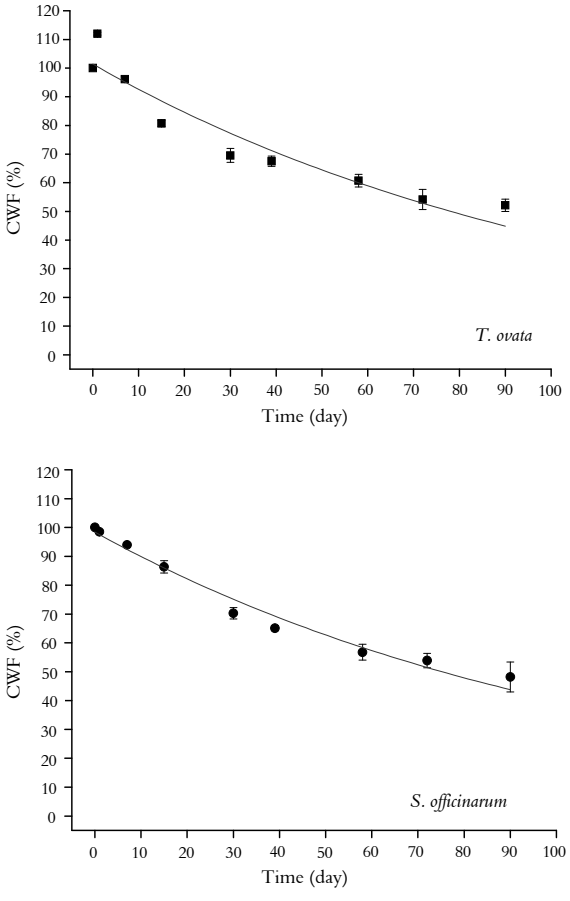

Figure 3. Mean values and standard deviations (n = 3) of the temporal cell wall fraction (CWF) variations of detritus from *Talauma ovata* and *Saccharum officinarum* during the decomposition process.

Discussion

The leaching process that occurred in the early stages of decomposition in this experiment was responsible for the rapid release of organic and inorganic compounds present in the protoplasm and hydrosoluble fractions of detritus (DAVIS III et al., 2003). This led to chemical changes in the environment, among them the increase of pH values observed at the beginning of the process. The subsequent stabilization of the pH occurred, according to Cunha-Santino and Bianchini Junior (2004), as a result of humic substances formation, which behaved as buffers. The pH probably did not present any negative effect on the decomposition, since stabilizations occurred in a circumneutral and basic environment, not in acid. The acidity presents negative effects on the decomposition (WEBSTER; BENFIELD, 1986), reducing the microbial metabolism, the richness and abundance of invertebrates and making the leaf breakdown substantially slower, as demonstrated by numerous studies in acid natural systems (e.g. DANGLES; GUÉROLD, 1998; DANGLES; CHAUVET, 2003; DANGLES et al., 2004; SUBERKROPP, 1995). On the other hand, Suberkropp (2001) analyzed leaf breakdown in a circumneutral stream and in a basic one (pH 6.7 and 8.0, respectively) and observed higher rates of decomposition and fungal production in the basic stream. Considering that the decay rate is correlated with pH, once the degradation process involves hydrolytic microbial enzymes that depend on pH, then it is possible that this factor has contributed in some way to the faster decomposition of *S. officinarum* in relation to *T. ovata* leaves.

The release of hydrosoluble compounds, including ions, was also responsible for the abrupt increase of EC in the environment observed after the first day of incubation (PAGIORO; THOMAZ, 1999). The carbonic acid dissociation deriving from oxidation of labile compounds is another factor that may have contributed to the increase in EC. On the other hand, the decrease in EC values observed at the end of the experiment can be attributed to the assimilation of ions by the microorganisms (CUNHA-SANTINO; BIANCHINI JUNIOR, 2004). Leaching also explains the peak of DOC observed after the first day of incubation. According to Wetzel (1995), more than 40% of total organic carbon of detritus is often leached during the first 24 hours of decomposition. The gradual decrease showed since then, can also be attributed to the mineralization of DOC, which justifies the gradual increase of the MC, and the formation of microbial biomass. The high values of EC and DOC observed

in incubations with *T. ovata* indicate the more labile character of its leaves, when compared to *S. officinarum* leaves. This is confirmed by the higher content of POC_{LS} from *T. ovata*.

The mass loss observed at the beginning of the experiment (also due to the leaching process) was high for both species. However, this loss may be over estimated. The leaves that fall naturally in streams are usually fresh, while those used in experiments are usually previously dried, whether at room temperature or in an oven (BÄRLOCHER, 1997). This procedure is designed to homogenize the samples and make the quantification of initial mass more accurate (BÄRLOCHER, 1997; TAYLOR; BÄRLOCHER, 1996). However, the drying of the leaves causes death and loss of tissue integrity, thus accelerating the leaching process (GESSNER et al., 1999).

The higher percentages of POC_R in relation to POC_{LS}, as well as the higher values of k_T in relation to k_4 obtained for *T. ovata* and *S. officinarum*, indicate the predominance of the slow process of decomposition. This tendency was also observed by Bianchini Junior (1999), who calculated, from data presented by different references, the content of labile and refractory fractions, as well as their respective decay coefficients (k_T and k_4), of 118 resources decomposed in different environmental conditions. The author obtained a variation of the labile particulate organic matter from 0 to 71.6% and of the refractory between 28.4 and 100%, with average values equal to 26.6 and 73.4%, respectively. The k_T values observed by the author were about 118 times, on average, higher than k4. In the present study, the k_T/k_4 ratios were 214 and 136 for the leaves of *T. ovata* and *S. officinarum*, respectively. This confirmed the fact that the labile fraction of the detritus is generally smaller and is lost faster than the refractory one. The *S. officinarum* k_T was slightly higher than for *T. ovata*. Other values of k found in the literature can be seen in Table 2. The values found ranged between 0.0002 day^{-1} for *Fagus sylvatica* (DANGLES; GUÉROLD, 1998) and 0.0672 day^{-1} for *Hura crepitans* (ABELHO et al., 2005) with an average of 0.01226 day^{-1}. It is important to highlight that the k values presented in the table are comparable to k_4 of this study as these authors did not evaluate separately the decay of labile and refractory organic matter. The large differences in decay rates can be attributed to numerous factors, including the structural differences of each species (hardness) and its content of nutrients (MUN et al., 2001), the environmental conditions imposed on decomposition and methodological limitations (BIANCHINI JUNIOR, 1999).

Table 2. Values of the decomposition coefficient (k) obtained from various studies for different tree leaves decomposed in streams in different environmental conditions.

Resource (leaves)	k (dia^{-1})	Reference
Acer rubrum	0.0048	Gulis and Suberkropp (2003)
Acer rubrum	0.0089	Gulis and Suberkropp (2003)
Acer Saccharum	0.0090	Das et al. (2007)
Ailanthus altissima	0.0080	Alonso et al. (2010)
Almus oblongifolia	0.0199	Leroy and Marks (2006)
Almus oblongifolia	0.0173	Leroy and Marks (2006)
Almus oblongifolia	0.0149	Leroy and Marks (2006)
Alnus glutinosa	0.0352	Hieber and Gessner (2002)
Alnus glutinosa	0.0220	Pascoal and Cássio (2004)
Alnus glutinosa	0.0200	Pascoal and Cássio (2004)
Alnus glutinosa	0.0130	Pascoal and Cássio (2004)
Alnus glutinosa	0.0420	Pascoal and Cássio (2004)
Alnus glutinosa	0.0295	Gonçalves Junior et al. (2006c)
Alnus glutinosa	0.0166	Gonçalves Junior et al. (2006c)
Alnus glutinosa	0.0137	Gonçalves Junior et al. (2006c)
Alnus glutinosa	0.0093	Gonçalves Junior et al. (2006c)
Alnus glutinosa	0.0136	Gonçalves Junior et al. (2006c)
Alnus glutinosa	0.0143	Gonçalves Junior et al. (2006c)
Alnus glutinosa	0.0117	Sampaio et al. (2008)
Alnus glutinosa	0.0338	Sampaio et al. (2008)
Cecropia schreberiana	0.0375	Wright and Covich (2005)
Cecropia schreberiana	0.0159	Wright and Covich (2005)
Dacryodes excelsa	0.0395	Wright and Covich (2005)
Dacryodes excelsa	0.0266	Wright and Covich (2005)
Eucalyptus grandis	0.0050	Trevisan and Hepp (2007)
Eucalyptus grandis	0.0050	Hepp et al. (2009)
Fagus sylvatica	0.0008	Dangles and Chauvet (2003)
Fagus sylvatica	0.0010	Dangles and Chauvet (2003)
Fagus sylvatica	0.0010	Dangles and Chauvet (2003)
Fagus sylvatica	0.0017	Dangles and Chauvet (2003)
Fagus sylvatica	0.0036	Dangles and Chauvet (2003)
Fagus sylvatica	0.0018	Dangles and Guérold (1998)
Fagus sylvatica	0.0002	Dangles and Guérold (1998)
Fraxinus angustifolia	0.0090	Alonso et al. (2010)
Fraxinus velutina	0.0172	Leroy and Marks (2006)
Fraxinus velutina	0.0151	Leroy and Marks (2006)
Fraxinus velutina	0.0138	Leroy and Marks (2006)
Hura crepitans	0.0672	Abelho et al. (2005)
Liriodendron tulipifera	0.0100	Suberkropp (2001)
Liriodendron tulipifera	0.0050	Suberkropp (2001)
Miconia chartacea	0.0033	Moretti et al. (2007)
Miconia chartacea	0.0051	Moretti et al. (2007)
Myrcia guyanensis	0.0063	Moretti et al. (2007)
Myrcia guyanensis	0.0053	Moretti et al. (2007)
Nothofagus pumilio	0.0033	Albariño and Balseiro (2002)
Ocotea sp.	0.0043	Moretti et al. (2007)
Ocotea sp.	0.0088	Moretti et al. (2007)
Pinus ponderosa	0.0017	Albariño and Balseiro (2002)
Platanus wrightii	0.0121	Leroy and Marks (2006)
Platanus wrightii	0.0081	Leroy and Marks (2006)
Platanus wrightii	0.0069	Leroy and Marks (2006)
Populus fremontii	0.0206	Leroy and Marks (2006)
Populus fremontii	0.0186	Leroy and Marks (2006)
Populus fremontii	0.0176	Leroy and Marks (2006)
Protium brasiliense	0.0020	Moretti et al. (2007)
Protium brasiliense	0.0042	Moretti et al. (2007)
Protium brasiliense	0.0057	Gonçalves Junior et al. (2007)
Protium brasiliense	0.0047	Gonçalves Junior et al. (2007)
Protium brasiliense	0.0055	Gonçalves Junior et al. (2007)
Protium brasiliense	0.0046	Gonçalves Junior et al. (2007)
Protium brasiliense	0.0021	Gonçalves Junior et al. (2007)

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Resource (leaves)	k (dia^{-1})	Reference
Protium brasiliense	0.0016	Gonçalves Junior et al. (2007)
Protium heptaphyllum	0.0019	Moretti et al. (2007)
Protium heptaphyllum	0.0040	Moretti et al. (2007)
Quercus alba	0.0070	Suberkropp (2001)
Quercus alba	0.0040	Suberkropp (2001)
Quercus gambelii	0.0138	Leroy and Marks (2006)
Quercus gambelii	0.0076	Leroy and Marks (2006)
Quercus gambelii	0.0073	Leroy and Marks (2006)
Querus alba	0.0030	Das et al. (2007)
Rhododendron maximum	0.0018	Gulis and Suberkropp (2003)
Rhododendron maximum	0.0065	Gulis and Suberkropp (2003)
Robinia pseudoacacia	0.0050	Alonso et al. (2010)
Salix atrocinerea	0.0154	Sampaio et al. (2008)
Salix atrocinerea	0.0170	Sampaio et al. (2008)
Salix fragilis	0.0270	Hieber and Gessner (2002)
Sebastiana commersoniana	0.0240	Trevisan and Hepp (2007)
Sebastiana commersoniana	0.0280	Hepp et al. (2009)
Ulmus minor	0.0080	Alonso et al. (2010)

The enrichment of CWF observed for *T. ovata* leaves after the first day of incubation occurred due to soluble organic matter leaching, as in the initial material the soluble fraction was still present, reducing the overall percentage of CWF. The initial CWF found for *S. officinarum* in this study was higher than other values found in the literature. Azevêdo et al. (2003), by analyzing three different varieties of sugar cane found an average CWF of 46.7%, a value 41.3% lower than that found here. Bakshi and Wadhwa (2007) determined the CWF of nine tree species leaves and obtained values ranging between 35% (*Melia azedarach* and *Morus Alba*) and 60% (*Ficus glomerate*). The authors also obtained the value of 58% for *Albizzia lebbock*, a value similar to those obtained for *T. ovata* leaves in this experiment. Abdulrazak et al. (2000) determined the CWF of six Acacia tree leaves and obtained values ranging between 15.4% (*A. nubica*) and 31.2% (*A. nilotica*; about half the value obtained for *T. ovata*). It can be noted that, although *T. ovata* leaves presented a CWF content considerably lower than *S. officinarum*, this value is quite high when compared to other tree species. These high percentages of CWF of both species investigated here can result in a great contribution for the particulate organic matter accumulation in lotic ecosystems. This occurs due to the difficult decomposition of structural compounds.

Conclusion

In conclusion, *T. ovata* showed a great content POC_{LS}, while *S. officinarum* showed higher percentages of POC_R. Although there have been no significant differences between the mass loss from the leaves of both species, the decomposition of *S. officinarum* was relatively faster, even with its high content of CWF. This may be due to the high concentrations of energetic compounds in the biomass, mono and polysaccharides, for example, which is of great interest to the decomposing microorganisms. *T. ovata*, as expected, presented a lower decomposition, probably due to the high content of secondary compounds (e. g. terpenoids; STEFANELLO et al., 2005) which may have negatively affected the decomposing organisms.

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