

Caloric content of leaves of five tree species from the riparian vegetation in a forest fragment from South Brazil

Conteúdo calórico de folhas de cinco espécies de árvores da vegetação ripária em um fragmento florestal do Sul do Brasil

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Abstract: Aim: The measurement of the caloric content evidences the amount of energy that remains in the leaf and that can be released to the aquatic trophic chain. We assessed the energy content of leaves from five riparian tree species of a forest fragment in south Brazil and analyzed whether leaf caloric content varied between leaf species and between seasons (dry and wet). The studied sites are located in Northwest of Paraná State, inside a Semi-Deciduous Forest fragment beside two headwater streams. **Methods:** Sampling sites were located along the riparian vegetation of these two water bodies, and due to its proximity and absence of statistical differences of caloric values, analyzed as one compartment. **Results:** Caloric content varied significantly among species and among all pairs of species, with exception of *Nectandra cuspidata* Ness and *Calophyllum brasiliensis* Cambess. Two species presented significant differences between seasons, *Sloanea guianensis* (Aubl.) Ben and *Calophyllum brasiliensis* Cambess. **Conclusions:** The absence of significant seasonal differences of energy content for some species may be due to the characteristics of the tropical forest, in which temperature did not varied dramatically between seasons. However, the energy differed between species and seasons for some species, emphasizing the necessity of a preliminary inspection of energy content, before tracing energy fluxes instead of using a single value to all species from riparian vegetation.

Keywords: leaf litter; energy; allochthonous organic matter; headwater stream; Atlantic Forest.

Resumo: Objetivo: O conteúdo calórico evidencia a quantidade de energia que permanece na folha e que pode ser libertado para a cadeia trófica aquática. O presente estudo teve como objetivo investigar o conteúdo calórico de folhas de cinco espécies de árvores de vegetação ripária e avaliar sua variação interespecífica e sazonal (seca e chuva). **Métodos:** As coletas foram realizadas trimestralmente durante um ano, na área de vegetação ripária de um fragmento florestal no sul do Brasil. Os locais de amostragem foram localizados ao longo da vegetação ripária desses dois corpos de água, e devido à sua proximidade e ausência de diferenças estatísticas significativas do conteúdo calórico, analisados em conjunto. **Resultados:** O conteúdo calórico variou significativamente entre as espécies e entre todos os pares de espécies, com exceção de *Nectandra cuspidata* Ness e *Calophyllum brasiliensis* Cambess. Duas espécies apresentaram diferenças significativas entre estações, *Sloanea guianensis* (Aubl.) Ben e *Calophyllum brasiliensis* Cambess. **Conclusões:** A ausência de diferenças significativas sazonais no teor energético de algumas espécies pode ser devido às características da floresta tropical, em que a temperatura não variou significativamente entre as estações do ano. No entanto, a diferença de energia entre as espécies e de sazonalidade para algumas espécies, enfatiza a necessidade de uma inspeção preliminar no teor energético, antes de traçar fluxos de energia, em detrimento do uso de um único valor para toda a vegetação ripária.

Palavras-chave: serapilheira; energia; matéria orgânica alóctone; riacho de cabeceira; Mata Atlântica.

1. Introduction

Food webs of small streams in forested watersheds are based almost entirely on detritus (Trevisan & Hepp, 2007; Sánchez-Carmona et al., 2012) and detritus can be any form of non-living organic matter, including different types of plant tissues, such as leaves (Moore et al., 2004). Leaves represents up to 70% of the allochthonous organic matter biomass provided by riparian vegetation to streams (Gonçalves Junior & Callisto, 2013) and litter fall dynamics on the tropics is composed of a few species that contribute with high values of leaf biomass (Gonçalves Junior et al., 2014). These leaves are accumulated, processed and transported downstream, providing energy supply to the aquatic system (Moore et al., 2004).

The energy supplied by leaves can be expressed by their caloric content, which measure the combustion heat of specific dry mass and can describe energy patterns in ecological process (Lindeman, 1942). Caloric value can be used as a coefficient index when biomass is converted into equivalent energy and it is the primary energy storage available to high trophic levels, constituting a helpful tool to study energy transfer (Yajing et al., 2007; Lin & Cao, 2008). It is directly related to leaves biodegradability, which is influenced by the presence of low energetic inorganic compounds (Costa, 1982), or dependent on the presence of high energetic and organic compounds such as sugar and fatty acids (Francisco & Pinotti, 2000). Such energetic content of leaves may be detected by grazers, which enhance the consumption rates of high quality plants (Prado & Heck, 2011).

The effective amount of caloric content provided by leaves can change according to the species, climatic conditions, water supply and dissolved mineral salt concentration (Dourado et al., 2004). High light intensity can improve caloric gain in plants growth and season variability changes energy transfer and storage of plant parts (Meletiou-Christou et al., 1994; Núñez-Regueira et al., 2004). Caloric content can be a function of the plants' nutritive status and life history (Yajing et al., 2007). For mangrove plant species such as *Avicennia marina* and *Aegiceras corniculatum*, authors recorded values of 19.25 kJ g⁻¹ and 21 kJ g⁻¹, respectively (Lin et al., 2007; Zhou et al., 2010), while for freshwater systems, riparian vegetation and macrophytes leaves reached up to 19.5 kJ g⁻¹ (Dourado et al., 2004).

The measurement of the caloric content as a surrogate for energy content evidences the amount of energy that remains in the leaf and that can be released to the aquatic trophic chain. We assessed the energy content of leaves from five riparian tree species of a forest fragment in south Brazil and analyzed whether leaf energy content varied between leaf species and between seasons (dry and wet).

2. Material and Methods

2.1. Study area

The studied sites are located in Northwest of Paraná State (Figure 1), inside a Semi deciduous forest fragment from Atlantic Forest called Caiuá Ecological Station (CES). Inside CES drains two headwater streams, 900 meters apart, named Conceição and Scherer. Sampling sites were located along the riparian vegetation of these two water bodies, and due to its proximity, analyzed as one compartment – CES riparian areas. Statistical analyzes were performed prior to grouping these areas, no differences were detected between species along both riparian areas. CES has an area of 1.427,30 ha, with high variety of native species in the riparian vegetation areas, along with rare and endangered species. Families with high richness are Leguminosae, Myrtaceae e Lauraceae.

Conceição stream (22°35'15.0" S 052°53'29.0" W) banks are well protected by a dense riparian cover, with a diversity of vegetation layers such as herbaceous, shrubs and trees with different heights and thickness. Leaf litter accumulates on the banks and margins, protecting the soil and are promptly available to reach the stream channel, which catches up to 450 m length. Scherer stream (22°36'06,7" S 052°53'02,0" W) banks presents dense riparian cover along with clear-cut areas for tracks, along a 1600 m longitudinal length. There are high accumulation leaf litter over the banks and immediate margin, some can readily reach stream' channel, while other are frequently buried by bank displacement due to erosion.

2.2. Sampling

Leaves were sampled in July 2008, October 2008, January 2009 and April 2009 (which are representative of annual seasons: July and April – dry season; October and January – wet season) with the help of twelve nets (1 m², 5 mm mesh size). The nets were displayed randomly six at each margin of the streams – riparian vegetation areas, which represents the potential stock that can be transported to the stream. All nets were kept in

the field for a month before sampling. The species with high and constant biomass input through all the sampling period were chosen for identification and caloric content analysis. Leaf samples were dried up in a lamp greenhouse, at approximately

60°C and weighted repeatedly until reaching a constant weight. Species were: *Nectandra cuspidata* Ness (Lauraceae), *Calophyllum brasiliensis* Cambess (Clusiaceae), *Alchornea triplinervia* (Spreng.) Müll. Arg. (Euphorbiaceae) and *Sloanea guianensis* (Aubl.)

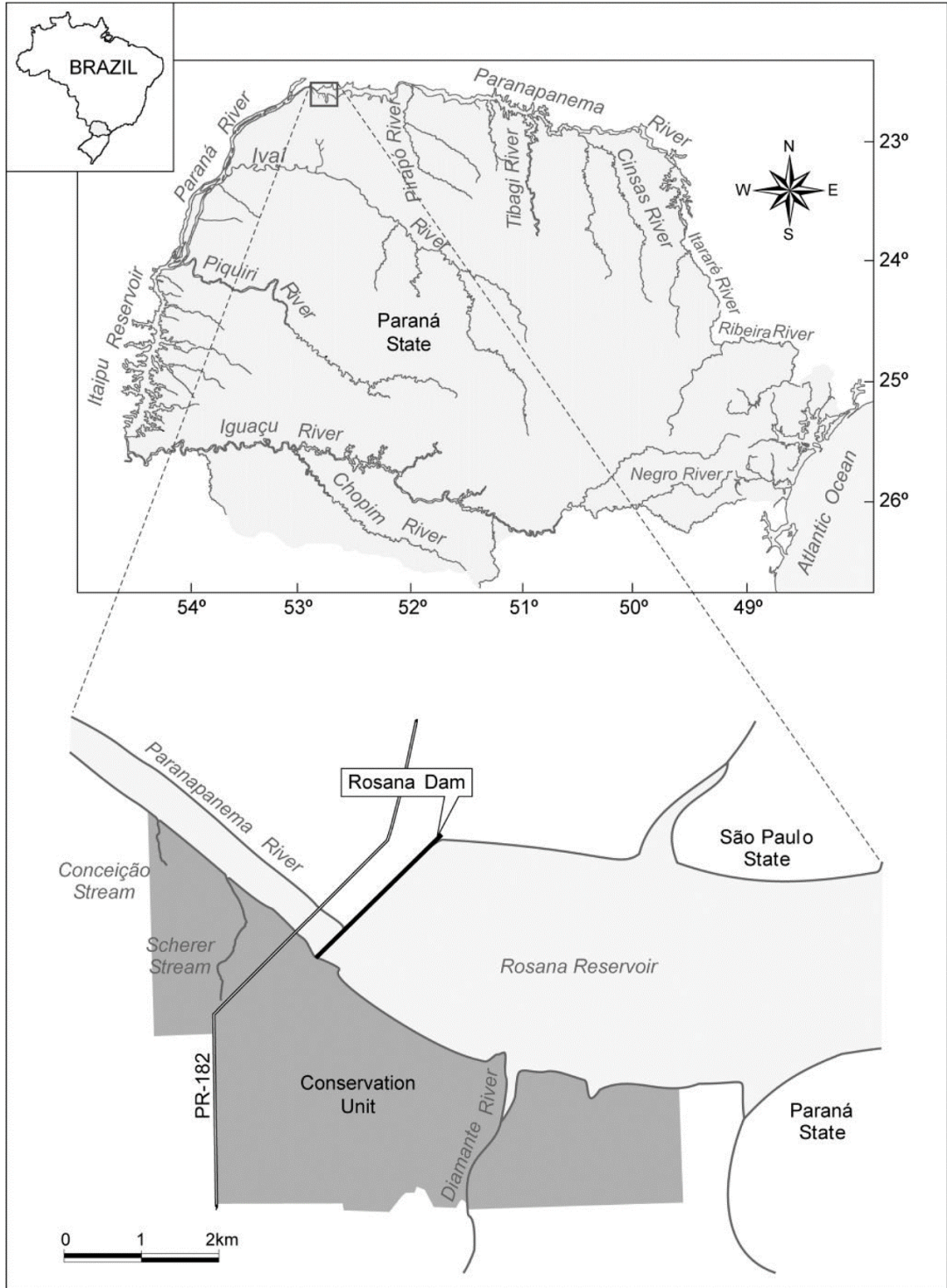


Figure 1. Sampling stations in Caiuá Ecological Station riparian areas along Conceição and Scherer streams, Northwest Paraná State.

Ben (Elaeocarpaceae). The fifth specie belong to the Bignoniaceae family and it was not possible to identify to species level. Due to its high biomass input through the months, it was considered for analyzes and called *sp. B*.

Sub-sampling was conducted after leaf retrieval from the field. One sub-sample consisted of four randomly peaked leafs of a specific species (Table 1). Each sub-sample was dried and macerated to powder material which was combusted using a calorimeter PARR 1620 (Automatic Isoperibol Bomb Calorimeter - Parr Instrument Company) for caloric content determination, expressed as KJ.g^{-1} of dry weight. Leaves were selected in similar decomposition stages, avoiding extreme ones (young green leaves, or in an advanced decomposition stage), searching for similar sizes and coloration.

2.3. Data analysis

There were no significant differences in the caloric content between leaf samples of the same species, which occurred in both riparian areas (Conceição and Scherer), so we analyzed the caloric content of leaves from CES riparian areas as one.

Table 1. Number of sub-samples (N) and mean \pm standard deviation (Mean \pm SD) of caloric content (KJ.g^{-1}) of each species and months from CES riparian areas.

Species / Period	N	Mean \pm SD
<i>Nectandra cuspidata</i>		
Jul-08	10	18.52 \pm 0.33
Oct-08	10	18.81 \pm 0.69
Jan-09	10	19.37 \pm 1.78
Apr-09	10	19.44 \pm 1.08
<i>Calophyllum brasiliensis</i>		
Jul-08	5	18.85 \pm 0.75
Oct-08	5	18.13 \pm 0.33
Jan-09	5	18.37 \pm 0.33
Apr-09	5	18.90 \pm 0.26
<i>Alchornea triplinervia</i>		
Jul-08	5	16.79 \pm 0.17
Oct-08	5	16.97 \pm 1.88
Jan-09	5	17.26 \pm 0.26
Apr-09	5	17.06 \pm 0.16
<i>Sloanea guianensis</i>		
Jul-08	10	16.18 \pm 0.63
Oct-08	10	15.98 \pm 0.38
Jan-09	10	15.39 \pm 1.05
Apr-09	10	17.09 \pm 2.02
<i>sp. B</i>		
Jul-08	10	13.88 \pm 1.80
Oct-08	10	13.12 \pm 1.59
Jan-09	10	12.85 \pm 0.64
Apr-09	10	12.86 \pm 0.92

sp. B = specie of the Bignoniaceae family.

In order to verify differences in the average caloric content between species it was applied a one-way ANOVA test. To investigate for seasonal differences in the caloric content of species, a one-way ANOVA was applied separately for each species. For significant differences, post-hoc Tukey HSD test was used to determine which pair of observations differed from each other. Analyses were conducted in the software Statistica 7.1® (Statsoft, 2005) with a level of significance of 5%.

3. Results

Caloric content varied significantly among species ($F_{4,157} = 157.52$; $p < 0.050$) and among all pairs of species (Post-hoc Tukey HSD test, $p < 0.050$), with exception of *N. cuspidata* and *C. brasiliensis* (Post-hoc Tukey HSD test, $p = 0.685$) (Figure 2).

The largest caloric content was observed for *Nectandra cuspidata*, varying from 17.84 to 23.68 KJ.g^{-1} , and lower caloric content for *sp. B*, varying from 9.27 to 18.52 KJ.g^{-1} . Two species presented significant differences between seasons (Table 2), *S. guianensis* and *C. brasiliensis* ($F_{3,40} = 4.612$; $p < 0.050$ and $F_{3,15} = 5.15$; $p = 0.020$, respectively). Especially between January and April for *S. guianensis* (Post-hoc Tukey HSD test, $p < 0.050$), and October and April for *C. brasiliensis*

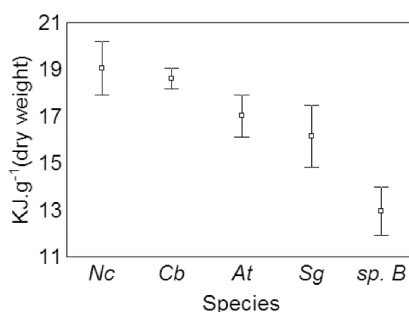


Figure 2. Mean (box) and standard deviation (line) in caloric content of leaves from tree species from CES riparian areas. *Sg* = *Sloanea guianensis*; *Nc* = *Nectandra cuspidata*; *Cb* = *Calophyllum brasiliensis*; *At* = *Alchornea triplinervia*; *sp. B* = specie of the Bignoniaceae family.

Table 2. ANOVA test for seasonal variation of caloric content (KJ.g^{-1}) for each species of CES riparian area.

Species	df	F	p
<i>Nectandra cuspidata</i>	3	1.500	0.232
<i>Calophyllum brasiliensis</i>	3	5.150	0.016
<i>Alchornea triplinervia</i>	3	0.216	0.884
<i>Sloanea guianensis</i>	3	4.612	0.008
<i>sp. B</i>	3	1.044	0.386

sp. B = specie of the Bignoniaceae family.

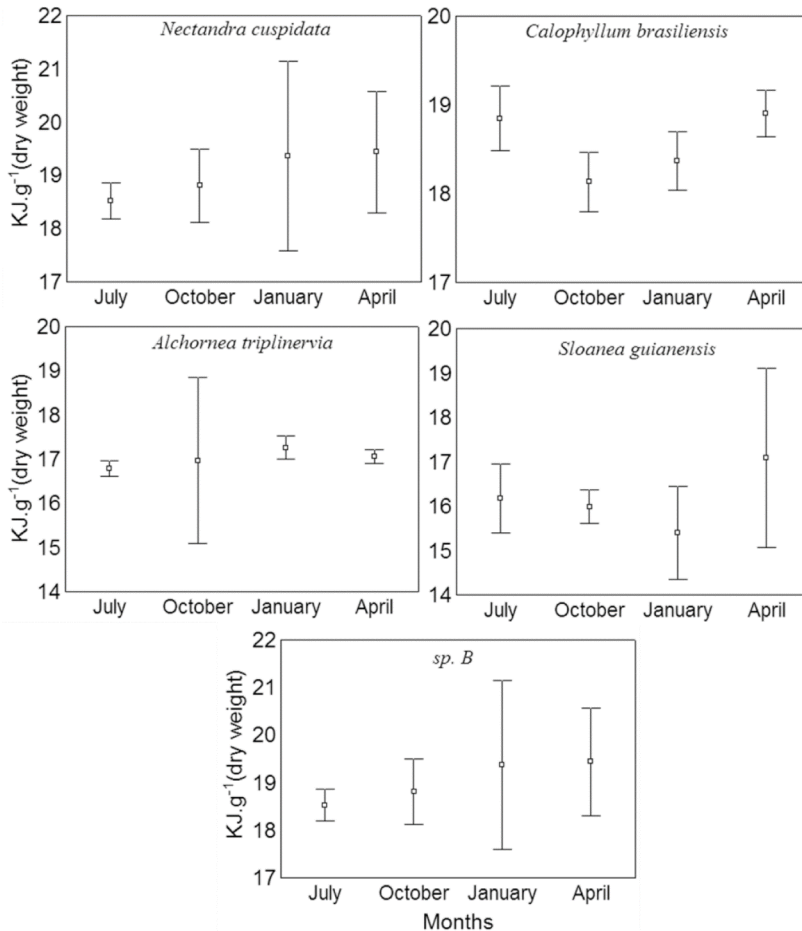


Figure 3. Temporal variation in the caloric content of tree leaves from CES riparian area. Mean (box) and standard deviation (line). Please note that graphics have different Y-axis scales, in order to better visualize the results. sp. B = specie of the Bignoniaceae family.

(Post-hoc Tukey HSD test, $p = 0.030$). For all other species no seasonal differences were detected (Figure 3).

4. Discussion

Caloric content of the most dominant leaf species in the riparian area of CES vegetation ranged from 9.3 to 23.7 KJ.g⁻¹ dry weight. Semi deciduous leaf species presents high energetic amplitude and are available to aquatic ecosystems once it reaches the water bodies. The reported species presented higher amplitude than the 11.7 to 19.2 KJ.g⁻¹ reported for riparian vegetation specimens from the upper Paraná river basin (Dourado et al., 2004), and aquatic macrophytes from the same basin (7.9 to 19.5 KJ.g⁻¹) (Lopes et al., 2006). The caloric content of vascular plants from Semi deciduous forest vary greatly and highlights the importance of leaf diversity as energy input to aquatic systems. Caloric content amplitude varied less for herbaceous species on a grassland ecosystem ranging from

13.2 to 18.1 KJ.g⁻¹ (Yajing et al., 2007), much lower than those reported for tree leaves in our study.

Caloric content differed between pairs of species with exception of *N. cuspidata* and *C. brasiliensis*. Yang et al. (2003) reported that caloric values varies among plant species and within species in different environments, due to chemical composition of the organic substances (Lin et al., 2007). It is noteworthy that plants that grow better and can achieve higher biomass presents higher caloric content (Yajing et al., 2007). Major caloric content was recorded for *Nectandra cuspidata* (17.8 KJ.g⁻¹ to 23.7 KJ.g⁻¹ dry weight). Some studies registered the presence of cyanogenic glycosides to species of the genus *Nectandra* (Francisco & Pinotti, 2000), that when hydrolyzed by enzymes, produce sugar, fatty acids, aldehyde or ketone and hydrocyanic acid (Buhrmester et al., 2000) that contribute directly to the energetic potential of the species. Yajing et al. (2007) reported that plants with high caloric values are better competitors than those with low caloric

content. Minor caloric content was observed for *sp. B* (9.3 KJ.g⁻¹), which had high inorganic compounds concentration after combustion on the calorimeter. Inorganic compounds can consist in carbonate, chloride and other oxides that have been found in other Bignoniaceae species (Costa, 1982; Alves et al., 2010).

The caloric content of *S. guianensis* and *C. brasiliensis* varied seasonally with higher caloric values in the dry month (April). Some studies found strong seasonality of litter fall in the driest months (Selva et al., 2007) with low temperatures (Lin & Cao, 2008). During our study the temperature did not varied dramatically between seasons, however, the driest months corresponded to colder ones. During colder seasons plants accumulate more energy to reduce heat lose, energy is condensed and the caloric content increase (Lin & Cao, 2008). Caloric difference between species and seasons, for some species, emphasize the necessity of a preliminary inspection of energy content before tracing energy fluxes instead of using a single value to each species.

The amount of energy provided by leaves from CES riparian vegetation to aquatic ecosystems are highly variable and reaches high amplitude, due to species specific characteristics and seasonality. Knowledge about energetic content of leaves can help elucidating fish trophic behavior, since they depend on food resources derived from the adjacent vegetation (Uieda & Kikuchi, 1995). Higher caloric content values have been registered for detritivorous fishes from aquatic environments with preserved vegetation (Pazianoto et al., 2013), since allochthonous source availability inside water bodies are proportional to vegetation coverage (Sarragiotto et al., 2014). Overall, the maintenance of riparian vegetation represents one of the most important features for headwaters equilibrium since it propitiates sources of energy for different organisms.

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