

Short Communication:

The relationship between content of particular metabolites of fallen mangrove leaves and the rate at which the leaves decompose over time

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Abstract. Ariyanto D, Bengen DG, Prartono T, Wardiatno Y. 2018. Short Communication: The relationship between content of particular metabolites of fallen mangrove leaves and the rate at which the leaves decompose over time. *Biodiversitas* 19: 780-785. Fallen mangrove leaves contain metabolites that play a role in their decomposition in coastal conditions. This research was conducted from September 2016 to February 2017 in Pasar Banggi, Rembang, Central Java, with the purpose of investigating the impact of the leaf metabolites of various mangrove species on the rate of decomposition of the leaves in exposed litter bags. The results suggested that secondary metabolites are closely involved in the decomposition of the mangrove leaves. The fastest rate of decomposition was found in *Avicennia marina*, and the slowest in *Rhizophora stylosa*. The leaves of *A. marina* required 10 days (half-life, t_{50}) to decompose by 50% and this was closely related to the phosphorus content of the leaves. On the other hand, *R. stylosa* required 24 days (half-life, t_{50}) to decompose by 50%.

Keywords: Decomposition, mangrove leaves, mass loss, Pasar Banggi coast, phosphorus, tannin

INTRODUCTION

The Pasar Banggi coast in Rembang, Central Java is fringed by various species of mangrove such as *Rhizophora mucronata* Lam., *Rhizophora apiculata* Blume, *Rhizophora stylosa* Griff., *Avicennia marina* (Forssk.) Vierh., and *Sonneratia alba* Sm. Such mangrove biomass contains both primary and secondary metabolic constituents. Mangroves are recorded as producing 100,000 to 200,000 types of secondary metabolites (Ralston et al. 2005). Secondary metabolites produced by plants are organic compounds with bioactive effects. The secondary metabolites of mangroves are produced in varying amounts determined by both genetic and environmental influences (Covelo et al. 2011). The secondary metabolic compounds of mangroves are particularly rich within the leaves (Covelo et al. 2011). Types of secondary metabolites in mangroves include tannins, sugars, free amino acids, and proteins among others (Yan and Guizhu 2007, Takemura et al. 2000). Their concentrations vary according to vegetation type (Hernes dan Hedges 2004), growing phase (Lin et al. 2006), and environment conditions (Northup et al. 1998). Sea-soaked leaves of mangrove released sugars, proteins, polyphenols, and inorganic nutrients to the water environment in a relatively short time.

Mangrove forest is a carbon-rich ecosystem of the tropical regions. It is highly productive, and its leaf fall decomposes readily in the coastal environment.

Decomposition is an important phase in the nutrient cycles of mangrove ecosystems. Decrease in weight of fallen mangrove leaves due to decomposition requires time and depends on the degree of washing to which the leaves are exposed (Mfilinge et al. 2005). Mangrove leaves decompose at different times and rate. The decomposition process starts with simple physical and chemical changes (Imgraben and Ditmann 2008) which drive the carbon and nutrient cycles in the mangrove ecosystem (Holguin et al. 2001; Hessen et al. 2004; Norris et al. 2012). The time rate of decomposition varies according to three main factors; the condition of the environment, the community of decomposers, and the substrate quality (Castanho and de Oliveira 2008). Tide promotes the shedding of leaves and the rate of microbial decomposition (Boulton and Boon 1991). Due to the activity of decomposers and currents and other transport processes, nutrients such as nitrogen and phosphorus become available for primary producers and higher organisms in the food chain (Wardle et al. 2004).

The decomposing process can be assessed by measuring the weight decrease due to loss of materials such as sugars and tannin compounds (Davis et al. 2003; Kristensen et al. 2008). Kandil et al. (2004) reported that decomposition is affected by tannins that act as defenses against herbivores. The products of the decomposing process can be utilized and consumed by benthic organisms (gastropod) (Kursar and Coley 1991; Ariyanto et al. 2018).

In the research described in this paper, we aimed to reveal the role of certain secondary metabolites in the decomposition of leaves of various mangrove species on the Pasar Banggi coast of Rembang, Central Java, Indonesia.

MATERIALS AND METHODS

Study area

This research was conducted from September 2016 to February 2017 along the Pasar Banggi coast, Rembang, Central Java, Indonesia (Figure 1). The sampling locations were five stations each with a different mangrove species: they were station 1 (*Rhizophora mucronata*); station 2 (*Rhizophora apiculata*); station 3 (*Sonneratia alba*); station 4 (*Rhizophora stylosa*); and station 5 (*Avicennia marina*). These stations were purposely selected to represent the typical mangrove population growing in each. Each station had three sub-stations.

The measurement of leaf decomposition

The rate of leaf decomposition at each station was measured for leaves freshly fallen from the mangrove trees. The decomposition rate was determined using the mesh bag technique with bags 16 cm by 21 cm in size and with a mesh size of 1 mm. This mesh size was used to prohibit mesofauna accessing the bags and thus affecting the extent of apparent microbial decomposition. The bags were placed up on 30 cm of sediment to prohibit predators (Figure 1.A), and were suspended to avoid direct contact with the sediment bed and above the level of the sea-water flux and reflux (Figure 1.B). Mangrove leaves typical of the species at each station on the Pasar Banggi coast -namely, *R. mucronata*, *R. apiculata*, *R. stylosa*, *S. alba*, and *A. marina* -were placed in the mesh bags, i.e., 50g of leaf in each bag.

Measurements of leaf dry weight in the bags were carried out on day 0, day 30, and day 60. Rates of leaf decomposition were then determined using the formula of Ashton et al. (1999): $X_t = X_0 e^{-kt}$. Where X_0 is the mass of the initial material, X_t is the mass remaining after time t (days) and k is a decay coefficient (days^{-1}). The half-life (t_{50}) is the time required for half of the initial mass to decay away and is determined as $t_{50} = \ln 2 / K$.

The measurement of leaf metabolite content

Before decomposition had started, collected leaves fresh from the field were divided into groups according to species of mangrove. For estimating metabolite content, the leaves were washed and then dried at 80°C temperature. The measurement of secondary metabolites was conducted in the Laboratory of Food Science and Technology in Bogor Agricultural University, Indonesia. The metabolites determined were tannins (Hagerman and Butler 1978), phosphorus (Anderson and Ingram 1989) and total sugar (Dubois et al. 1956) by using a spectrophotometer. Meanwhile, total amino acids were determined using used an HPLC (Moore and Stein 1948).

Data analysis

The relationship between the content of secondary metabolites in the various types of mangrove leaves and the rate of decomposition of the leaves was investigated by using Correspondence Analysis (CA). The analysis on row data matrix (mangrove species; decomposition rate) and column (metabolites content; tannins, total sugar, phosphorus, and total amino acids) purposed to discover the relationship between the metabolites compounds and decomposition rate of mangrove leaves). The analysis was conducted with XLstat 2016 software.

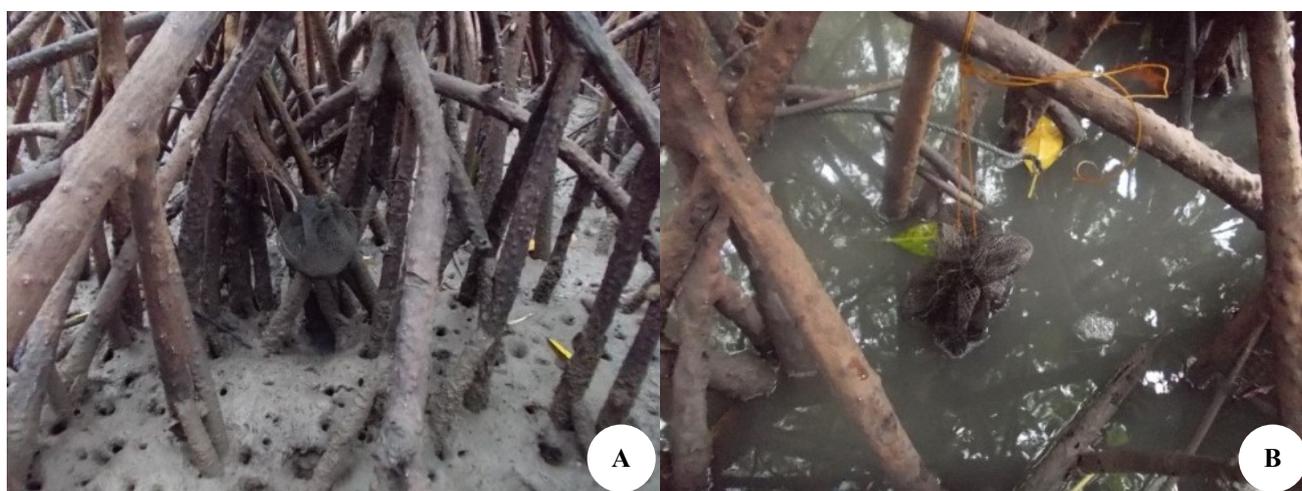


Figure 1. The decomposition measurement conditions at low tide (A) and high tide (B)

RESULTS AND DISCUSSION

Metabolite compounds

The research showed that the five mangrove species varied in the tannin, total sugar and phosphorus contents of their leaves. Leaves of *A. marina* had the lowest content of tannin and *S. alba* leaves had the highest content of tannins out of the five species; leaves of *A. marina* had the highest and *R. apiculata* the lowest content of total sugars (Table 1). The total amino acid content of mangrove leaves on the Banggi Coast was 4.52 to 5.55 mg/g. *R. mucronata* leaves contained the lowest content of amino acid out of the five mangrove species. The amino acid content of the leaves in our study ranged from highest to lowest as follows: *R. apiculata* > *A. marina* > *R. stylosa* > *S. alba* > *R. mucronata*.

Decomposition of leaves over time

The dry weight of the leaves in the mesh bags declined by 31-100% over the research period of 60 days (Figure 2). Observation after 30 days showed that leaves of *S. alba* had experienced the slowest rate of decomposition, having declined in dry weight from 50 g to 35.6±9.9 g; while leaves of *A. marina* had experienced the steepest decline in dry weight, down to 6.3±2.3 g at day 30. Observation after 60 days showed that leaves of *A. marina* had experienced the greatest decline in dry weight during the decomposing process, with 0 g remaining in the mesh bags; while *R. stylosa* had experienced the least decline in weight, down to 9.5±2.8 g at day 60. At day 60, the decline in leaf dry weight, ranked from greatest decline to least, was as follows: *A. marina* > *S. alba* > *R. mucronata* > *R. apiculata* > *R. stylosa*.

There were observed physical differences between the mangrove leaves samples placed in the bags. Leaves of *A. marina* were observed to be the thinnest of the mangrove

species compared in this study. This was probably an important factor in their high rate of decomposition. Observation suggested that the thicker the leaves were the slower was the extent of decomposition over the 60 day period.

Calculation of the decomposition rate constant (*k*) revealed differences between the species; the values for *k* varied from 0.028 to 0.065 across the species (Table 2). The *k* value (0.028) for *S. alba* was the lowest which indicated that *S. alba* had the slowest rate of leaf decomposition of the five species. Therefore it required longer time than the others to decompose. Meanwhile, *R. stylosa* and *R. apiculata* have the constant value of 0.079 and 0.041, higher than the others. For *A. marina* there was a more rapid initial rate of decomposition with the weight of remaining leaf falling close to zero well before the 60th day. The decomposition rate constant for the species ranked from highest to lowest as follows *A. marina* > *S. alba* > *R. apiculata* > *R. mucronata* > *R. stylosa*.

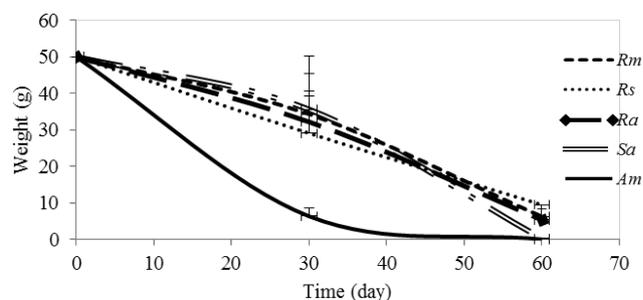


Figure 2. Decomposition in mangrove leaves on the Pasar Banggi Coast of Rembang, Central Java, Indonesia. Note: Rm = *Rhizophora mucronata*, Rs = *Rhizophora stylosa*, Ra = *Rhizophora apiculata*, Sa = *Sonneratia alba*, Am = *Avicennia marina*

Table 1. The content of tannin, phosphorus, total sugar, and total amino acids in leaves of various species of mangrove on the Pasar Banggi coast of Rembang, Central Java, Indonesia

Mangrove sp.	Tannin (mg/g)		Total sugar (mg/g)		Phosphorus (mg/g)		Amino acid (mg/g)	
	Study	Comparison	Study	Comparison	Study	Comparison	Study	Comparison
<i>R. mucronata</i>	4.39	1.231-5.71 ^a	0.44	0.06-1.231 ^a	17.08	0.98-4.93 ^a	4.52	5.71-9.49 ^a
<i>R. apiculata</i>	1.07	0.4-1.23 ^b	0.35	0.3 ^e	4.64	7.12 ^h	6.05	3.2 ^l ; 1.4 ^e
<i>R. stylosa</i>	2.69	9.32-9.74 ^c	0.52	0.04-0.06 ^f	9.36	4.82±2.09 ⁱ	5.42	1.9 ^k
<i>S. alba</i>	7.09	7.60-8.17 ^c	0.85	0.05-11 ^f	15.12	6 ^j	5.21	4.7 ^k ; 1 ^l
<i>A. marina</i>	0.85	3.73 ^d	0.9	0.85-0.99; 0.5 ^{g,e}	27.18	31.71±6.56 ^d	5.55	1.9 ^k ; 1.5 ^e

Note: Balakrishnan et al. 2016^a, Ravi and Kathiresan 1990^b, Suh et al. 2014^c, Zhou et al. 2010^d, Rajendran and Kathiresan 2000^e, Yan and Guizhu 2007^f, Fukushima et al. 1997^g, Gong and Ong 1990^h, Lin and Wang 2001ⁱ, Telave 2015^j, Popp et al. 1983^k, Telave 2015^l

Table 2. Value of decomposition rate constant (*k*) for mangrove leaves on the Pasar Banggi coast of Rembang, Central Java, Indonesia.

Mangrove	Present study				Comparison study		
	Day	<i>k</i>	<i>t</i> ₅₀	<i>R</i> ²	Day	<i>K</i>	Reference
<i>R. mucronata</i>	60	0.035	19	0.79	47	0.10	Bosire et al. 2005
<i>R. apiculata</i>	60	0.040	17	0.78	43	0.016	Ashton et al. 1999
<i>S. alba</i>	60	0.041	17	0.77	31	0.16	Bosire et al. 2005
<i>R. stylosa</i>	60	0.028	24	0.88	63	0.010	Irma 2010
<i>A. marina</i>	60	0.065	10	0.96	21	0.014	Fernando and Bandeira 2009

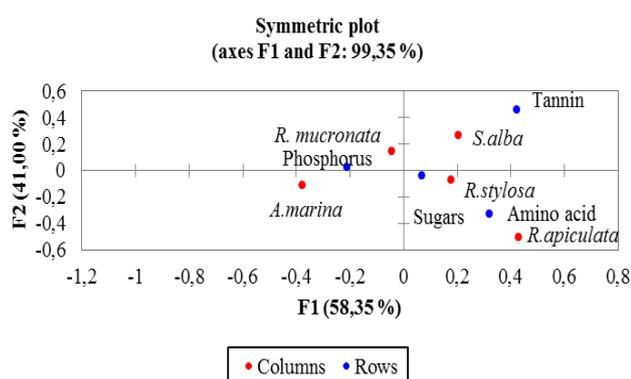


Figure 3. The correlation between content of metabolites and the decomposition rates of decomposition of leaves across five mangrove species based on Correspondence Analysis (CA). F1 is the first axis of the Correspondence Analysis and F2 is the second axis

The relationship between decomposition rate and the metabolites content of mangrove leaves

The leaf dry weight measurements from which decomposition rates were calculated were taken on three occasions; day 0, day 30, and day 60. The measurement of secondary metabolite content of the mangrove leaves was conducted on a single occasion at the beginning, before the decomposition process began. Figure 3 shows the relationship between rate of decomposition and secondary metabolite contents in the mangrove leaves as depicted on the first two axes of a Correspondence Analysis plot. The result of the Correspondence Analysis showed that 71.5% of the total variation was accounted for by the first axis (F1) and 25.6% was accounted for by the second axis (F2), the two axes together accounting for 97.1% of the total variation. The Correspondence Analysis suggested that there was a close relationship between particular secondary metabolites and the rate of leaf decomposition of the different mangrove species. Tannin content was inversely proportional to the decomposition rate (-0.615) and phosphorus content was directly proportional to the decomposition rate (0.51). It showed that the lower the content of tannin is, the faster the decomposing rate will be.

Discussion

This research was designed to determine the amino acid, tannin, total sugar, and phosphorus contents of leaves of the mangrove species *Rhizophora mucronata*, *Rhizophora apiculata*, *Sonneratia alba*, *Rhizophora stylosa*, and *Avicennia marina*, and to see if these chemical constituents influenced the rate at which the leaves decomposed in a controlled experiment on the Pasar Banggi coast of Rembang in Central Java. In this study, the main metabolites that were found to apparently influence leaf decomposition rate were tannin and phosphorus. In other studies, high concentration of tannin has been found to play a role in inhibiting the activity of detritivores and microbial decomposers (Robertson 1988). Differences in leaf tannin concentration have been reported to lead to

differences in decomposition rate and microbial activity (Ellison and Farnsworth 1997; Tam et al. 1998). The rate of leaf decomposition is influenced by leaching of water-soluble compounds such as tannins, amino acids, and sugar (Rajendran and Kathiresan 2000). A slower rate of decomposition results from higher concentrations of lignin and hydrolyzed-tannins.

In our study, leaves of *A. marina* on the Pasar Banggi coast, of Rembang, Central Java had a faster rate of decomposition than leaves of the other mangrove species assessed. This was also reported by Robertson (1988) who found in Australia that *A. marina* contained lower levels of hydrolyzed-tannin and degraded faster than *R. stylosa*. In India, Rajendran and Kathiresan (2000) reported that the tannin concentration declined to 63.3% in *R. apiculata* and 38.8% in *A. marina* after 40 days of decomposition. Similarly, Rajendran and Kathiresan (2007) reported lower tannin concentration in *A. marina* than in *R. apiculata* during the first three weeks of decomposing, after which, the concentration of tannin was similar in both species. Cundell et al. (1979) also noted declining tannin concentration after 27 days of the decomposing process.

Steinke et al. (1993) reported that in the early stages of leaf decomposition, soluble organic compounds such as sugars are washed out of the leaves, while more durable materials, represented in the dry-weight of the leaves, break down at a slower rate (Steinke et al. 1990). The degradation and decomposition of mangrove leaves can be affected by the frequency of sea flux and reflux (Dick and Osunkoya 2000; Mfilinge et al. 2002; Bosire et al. 2005). The level of decomposition is higher in the sub-tidal area than in the intertidal area, as a result of sea water submersion and washing away of materials. In our study, leaves of *A. marina* decomposed faster than leaves of *R. mucronata*. Differences in the morphology and texture of the leaves could be factors along with chemical constituents such as tannins in the differences in decomposition rate (Alongi et al. 2000). Damage to ecosystems of mangrove could cause differences in rates of mangrove decomposition, with roll-on effects on microbiological activity, aerobic condition of the bottom sediments and on dependent fauna communities (Clough et al. 2000; Morrissey et al. 2003; Ye et al. 2013). Our research revealed that the decomposition of *R. mucronata*, *R. stylosa*, and *R. apiculata* leaves required a longer time than leaves of *A. marina* a result that confirmed the findings of Wafar et al. (1997) and Hoosain et al. (2014).

Robertson (1998) reported that the decomposition of mangrove leaf litter in tropical area required 40 days to decompose 50% of the dry matter. Ashton et al. (1999) reported a half-life of 43 days for leaves of *R. apiculata* in a conservation mangrove forest on the Malaysian Peninsula. When the decomposition process is slow the nutrient loss from the leaves and consequent nutrient enrichment of the environment declines (Lacerda et al. 1986).

The decomposition rate (k) on the Pasar Banggi coast of Rembang ranged between 0.028 and 0.079 in our study. The value for k of *R. stylosa* (0.079) was higher than the k value for *S. alba* (0.028). In general, the k values in our

study can be regarded as high, since according to the classification of Ananda et al. (2008), values of $k > 0.01$ reflect fast decaying leaves, values of k between 0.005 and 0.01 are obtained from leaves that decay at medium rates, and slow decaying leaves have values of $k < 0.005$.

The tannin content of mangroves plays a role in several ecological processes (Hernes et al. 2001, Kraus et al. 2003). Tannins have an impact on growth, development, and reproduction, and act as defensive agents against biotic and abiotic pressures (Achakzai et al. 2009). High tannin levels can slow down the cycling of nutrients (Madritch and Lindroth 2015). Tannins leached from the leaves during initial breakdown eventually decompose and are transformed by biotic and abiotic processes in the watery environment (Hattenschwiler and Vitousek 2000; Kraus et al. 2003; Maie et al. 2008).

In conclusion, the rate of decomposition of mangrove leaves in our study ranked from the highest to lowest the lowest rate was as follows: *A. marina* > *S. alba* > *R. mucronata* > *R. apiculata* > *R. stylosa*. The fastest decomposition was *A. marina* ($k=0.065$), and the slowest one was *R. stylosa* ($k=0.0282$). The relationship of the faster decomposition of mangrove leaves affected by the high phosphorus and the low tannin in *A. marina*.

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