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Dynamics of calorific values and energy during the decomposition of *Kandelia candel* litter leaves in different estuary mangrove habitats dominated by salinity

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Abstract

The aim of this study was to determine if some factors, especially salinity, have any impact on the decomposition of mangrove leaves. Three study sites where chosen in the Jiulongjiang Estuary near Caoputou Village, Longhai County, Zhangzhou City, Fujian Province, China. The salinity level in the different sites is the main difference between the three sites. In the first, second and third site the salinity is 0%, 0.5% respectively 1%. At every site 15 bags where filled with 30g of *Kandelia candel* leaves. After 1,2,3,5 and 7 weeks three bags from each site were brought to the laboratory. Then the dry mass, calorific value and content of soluble sugar were determined. From analyzes the energy content and mean rate of decomposition could be calculated. No connection between salinity and calorific value could be seen from the results. The calorific value first increases and after three to five weeks the highest calorific values are measured, thereafter there will be a decrease of the calorific value. During the three first weeks there is a difference in loss of mass between the different salinities.

Key words: Mangrove, calorific values, energy

Introduction

The mangrove forest is important in many ways, since the trees prevent the shore from erosion, instead soil can fasten in the roots of the mangrove trees and enlarge the shore. (NE) The mangrove ecosystem has a relative high diversity of wildlife (Ashtong et al, 1999), and is important for many marine species reproduction. (NE) The decomposition of mangrove litter is an important function in the mangrove ecosystem since the breakdown releases nutrients and organic matter. (Ashtong et al, 1999) The primary production in a mangrove ecosystem is performed by the mangrove and the secondary and tertiary yield is performed by the aquatic heterotrophs. The ecosystem survives due to the essential energy and nutrient flux from the terrestrial part of the system to the aquatic part. (Wafar et al, 1996)

There are several kinds of litter from the mangrove tree. More than half of the litter amounts consist of leaves, often yellow leaves. (Wafar et al, 1996) During a year the mangrove produce 800-1000 g dry weight litter per m^2. (Nielsen & Andersen, 2003) The mangrove has a high litter return. Less than a tenth of the mangrove leaves are consumed alive (Bosire et al, 2004), this enhances the importance of knowing the energy flux created from the mangrove litter leaves.

Half decomposition phase of the following leaves from terrestrial forest such as *Betula allegheniensis, Acer saccharum, Fagus grandijolia* will be 0.8, 1.4 respectively 1.9. (Gosz et al., 1973) The mangrove ecosystems have a higher litter decomposition rate since the half decomposition phase is just some days. (Lin, 1992)

When the leaves fall directly from the mangroves into the water, there is a large leach of organic carbon (e.g. sugars and starch), tannins and nitrogen, which occur within 3 to 28 days. The percent of the loss differs among different mangrove species, general 14 – 40 % of the initial dry mass of the mangrove leaves. (Ashtong et al, 1999) Ashton *et al.* (1999) had in one litterbag mangrove leaves from different species, *Rhizophora apiculata, Rhizophora mucronata, Bruguiera parviflora and Sonneratia alba,* in the air. The leaves were never flooded, resulting in a loss rate only based on leaching by rainwater. Meaning that the decomposition never progresses further then a certain point, approximately 55 % of the mangrove leaves initial dry weight, without the faunal components. Mangrove leaves that are beneath the water surface decompose more rapid, due to leaching, higher microbial activity and physical effect from the tide. (Ashtong et al, 1999, Bosire et al, 2004)

High levels of sodium and chloride could inhibit enzymes activity in microbes. (Roache et al, 2005) Salinity is an osmotic stress factor for microbes. An adoption to the salinity is based on equalizing the concentration gradient inside and outside the cell. These activities results in a lower effective decomposition of mangrove litter. (Wichern et al, 2006) The decomposition rate of the freshwater *Triglochin procerum* decreases with increasing salinity. Microbes those not are adapted to salt conditions, have an even poorer decomposition rate. A contributory cause to the lower decomposition rates with increased salinity is the less dissolved oxygen level. (Roache et al, 2005)

The decomposition rate is also dependent of temperature, geographical location (Ashtong et al, 1999), humidity and oxygen availability. (Nielsen & Andersen, 2003) The technique most common used to find the decomposition rates is commonly the litterbag technique. This method gives a lower decomposition rate than the actual natural rate since there is no access for larger decomposers e.g. invertebrates and crabs. Neither is the leaves exposed for mechanical forces. (Bosire et al, 2004)

This study focus on the tidal water salinity and variations of calorific value of decomposed *Kandelia candel* plants growing in different salinity habitats along Jiulong River Estuary,Fujian Province. At the same time, some other indicators such as pH and enzyme activity were studied with the aim to elucidate the relationship between salinity and energy of mangrove plants under special habitat, and to provide scientific basis for induction, acclimatization and utilization of mangrove plants.

Materials and methods

Study site

The study site was located in a mangrove forest in Jiulongjiang Estuary near Caoputou Village, Longhai County, Zhangzhou City, Fujian Province, China, *see figure 1*. The mangrove forest was planted in 1962 as a part of a costal restoration project. Now the forest has canopy coverage of 90% and the adult trees are 5-6m high with a trunk diameter at breast height of 7-8 cm. The most dominant mangrove species is *Kandelia candel*, and the forest also include the species *Aegiceras corniculatum*, *Bruguiera gymnorrhiza* and *Rhizophora stylosa*.

The region were the mangrove forest is located have a subtropical climate with a mean temperature of 21°C and an average precipitation of 1284 mm/year mostly origin from summer typhoons. Tides are semi-diurnal with an average range of 4m. The mean salinity in the open water is 1.71%.

Figure 1. A map showing the location of the mangrove forest in Jiulongjiang Estuary near Caoputou Village, Longhai County, Zhangzhou City, Fujian Province.

*Figure 2.*The study sites are marked on the map over the Jiulongjiang Estuary. The first site is the red mark which is "in the river", then the second site is marked and the third site is the one which is in the most open water.

Sampling

Mangrove leaves, *Kandelia candel*, have been sampled from three different sites in a mangrove forest in Jiulongjiang Estuary near Caoputou Village, Longhai County, Zhangzhou City, Fujian Province, China, *see figure 1*. The three sites are located with an interval of several kilometers, *see figure 2*The mangrove trunks where shaken to represent wind. From the leaves which fell down from the tree, 30 g of fresh leaves where collected and put in a bag. At every site 15 bags where tied to the root of the mangrove tree. The leaves in the bags begun to decompose and after 1, 2, 3, 5 and 7 weeks three bags from each site where brought to the laboratory for analyses.

Analyzes

Before the analyses were carried out the leaves were washed in distilled water. Then the leaves where dried and weighted, to determine the dry weight and water content. From the dry weight the mean rate of decomposition where calculated, *see equation 1*. The calorific value, in calories per gram, where determined by burning the sample in a XRY-IB bomb calorimeter at Mangrove Wetland Ecology Lab at Xiamen University. The energy content in each bag could then be calculated by multiplying the calorific value with the dry weight. The anthrone colorimetric method where used to determine the soluble sugar in the decomposed mangrove leaves.

(1) $MRD = (m0 - mt)/(m0 \cdot t) \cdot 1000$

Salinity, enzyme activity and pH in the soil where determined. The salinity where determined with a portable refractometer by diluting the soil with 25 mL distilled water. The enzyme activity where determined by using the methods potassium permanganate titration, ninhydrin colorimetric for respectively catalase and protease activity. pH where determined with the potentiometry method.

There where three samples for each time and site, an average were calculated and used in the analyses. One exception was the soluble sugar when there was two samples for each time and site. All the data results where analyzed with the computer software *Stastitcal Program for Social Science*. The software were used to calculate a one-way analyze of variance to see if there were a significance different between the data sets. Both between each week and for the whole time where compared with each other.

Results

Mangrove habitats dominated by salinity

Salinity of sea water

Because of the tidal flow there is a variation of salinity at the different sites. In the first site the salinity is 0% during low tide and 0.5% during high tide. For the second site the salinity is 0.5% respectively 1% and for the third site the salinity is 1.0% respectively 2.5%.

Soil pH, salinity and enzymes

Salinity and pH in the sediment at the different sites are presented in *figure 8* and the enzyme, protease and catalase, activity is presented in *figure 9*. The enzyme catalase is negative correlated with both salinity in the sediment and the salinity in the seawater during both low and high tide. The correlation coefficient is -0.814 and the significance is 0.008 for the soil salinity. For the salinity in the seawater during low tide there is a correlation coefficient of -0.978 and the significance is 0. During high tide the correlation coefficient is -9.84 with a significance of 0. There is also a negative correlation between the protease and the seawater salinity during low tide, the correlation coefficient is -0.739 and the significance is 0.0023. Finally there is also a positive correlation between the concentration of protease and catalase, the correlation coefficient is 0.722 with the significance of 0.0028.

Site	**Salinity (%)**	**pH**
1	0±0	6.86±0.05
2	0.467±1.5275	7.01±0.07
3	0.5±0	6.75±0.065574

Figure 8. A table presenting the salinity and pH in the sediment at the three studied sites.

Site	Protease (NH$_2$-N mg/ g dry weight)	Catalase (0.1mol·L^{-1}KMnO$_4$ mL·g^{-1})
1	0.61444±0.08097	2.8073±0.00962
2	0.60089±0.04116	2.5137±0.03930
3	0.45426±0.10019	2.125±0.05017

Figure 9. A table presenting the concentration of the enzymes protease and catalase in the sediment in the different studied sites.

Biomass loss of litter leaves

During decomposition there is a loose in weight of litter leaves, *see figure* 3. After seven weeks 59% of the weights have been lost in the second site and 71% of the weights have been lost in the first and third site. The mean rate of decomposition is highest, at 32.9 - 44.8 · 10^{-3} d^{-1} (m/m) in the first week, in the beginning of the decomposition and the rate will then decrease, *see figure* 4. During the seventh week the mean rate of decomposition is 12.1-14.5 · 10^{-3} d^{-1} (m/m), which is a decrease of 20.8-30.4 · 10^{-3} d^{-1} (m/m). For the first three weeks there is a significant difference between the samples from site 2 and 3 in both the MRD and for the loose of weight. In the last four weeks of decomposition there is no significant difference between any of the sites.

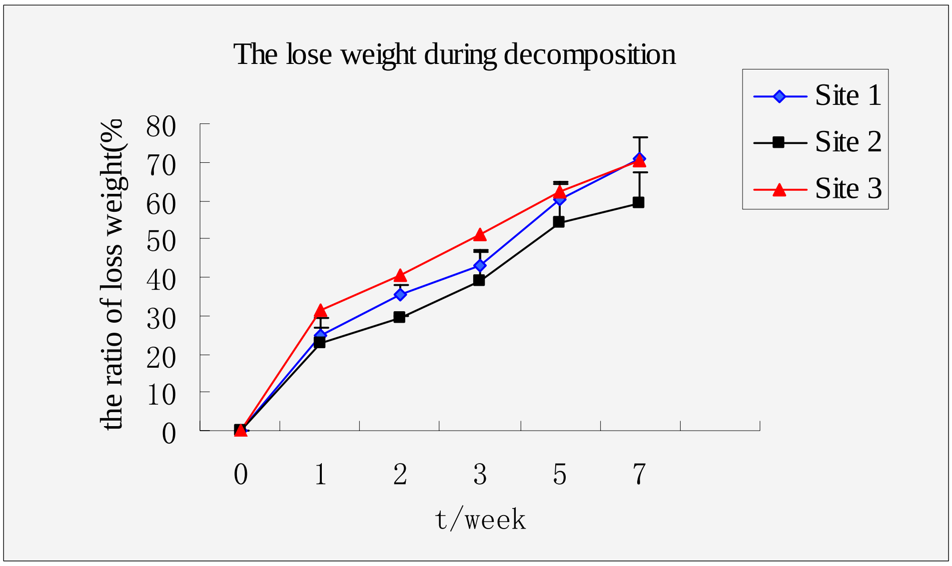

Figure 3. During the decomposition process the mangrove leaves will lose weight and after seven weeks about 59-71% of the weight have been lost.

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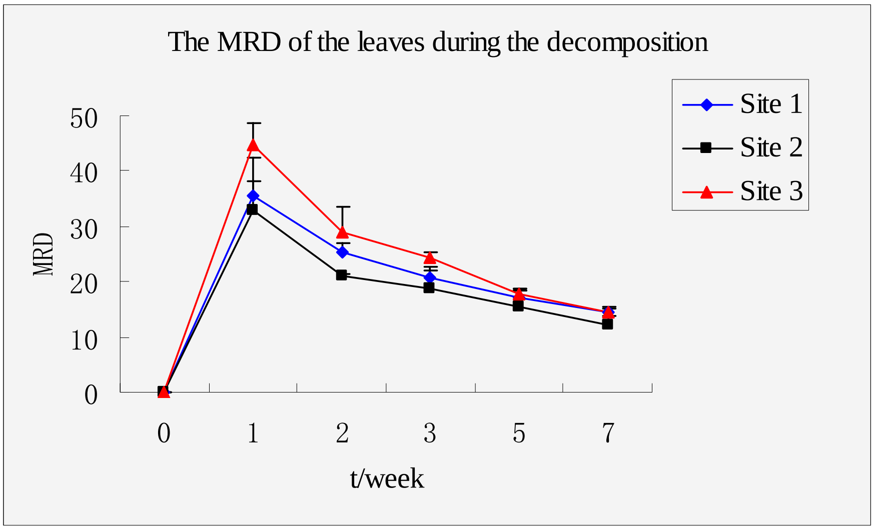

Figure 4. The mean rate of decomposition is highest during the first week and will thereafter the rate will decrease.

Dynamic of calorific values of litter leaves

The samples which have not begun the decomposition have a calorific value of 17881 J/g dry weight. During the first stage of the decomposition there is an increase in calorific value. At the third week there is a peak noticed for all the three sites. The first site has the highest value of 20727.67 J/g dry weight and the lowest value has the second site with 19734.67 J/g dry weight. There between is the third sites value of 20396.33 J/g dry weight Thereafter there is a decrease in calorific value. The trend could be seen in *figure 5*. First in the third week there is a significant difference between the sites, the difference is between the first and the second site. In the fifth week there is a significant difference between the first site compared to the second and third sites but there is no significant difference between the second and third sites.

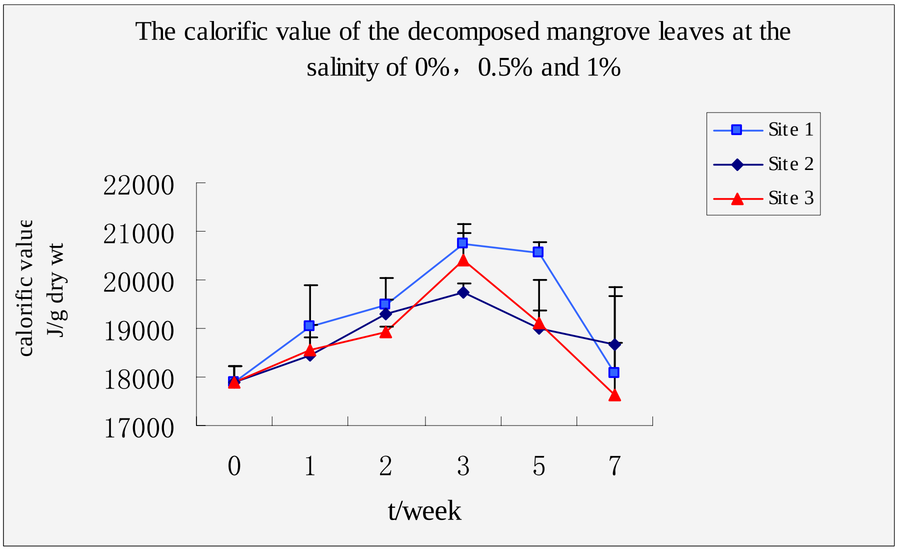

Figure 5. The calorific value is first increasing and during the 3-5 week there is a peak before the calorific value begin to decrease.

Energy loss of litter leaves

The energy content in the leaves before decomposition is 187.5 kJ. Then there is a decrease of the energy content during the decomposition of the mangrove litter. Only in the last week there is a significant difference between the first and the other two sites. After seven weeks the energy content has decrease to 52.2 kJ, 78.9 kJ and 54.9 kJ for the first, second respectively third site.

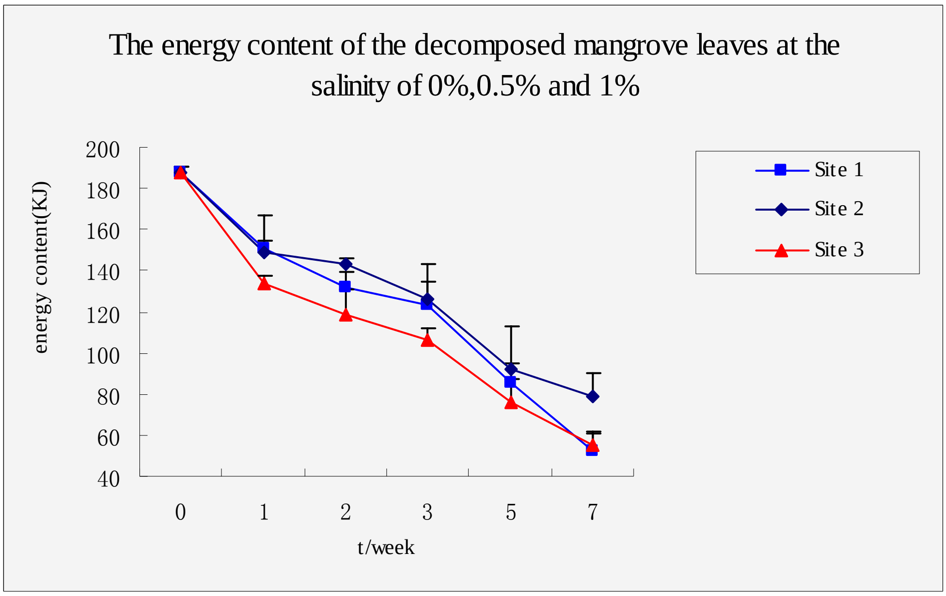

Figure 6. The energy content is decreasing during decomposition of mangrove litter.

Dynamic of Soluble sugar of litter leaves

The soluble sugar content is 3.5 % before the decomposition and after only one week there are a content of 1.15%, 1.65% and 1.22% for the first, second respectively the third site. Thereafter there will continue to be a decrease in content of soluble sugar, but the rate will be lesser then during the first week, *see figure 7*. During the whole decomposition there is only significance difference in the second and seventh weeks. In both the weeks the difference is between the second and third sites. During the seventh week there is also a significant difference between the first and second site, but not between the first and third sites.

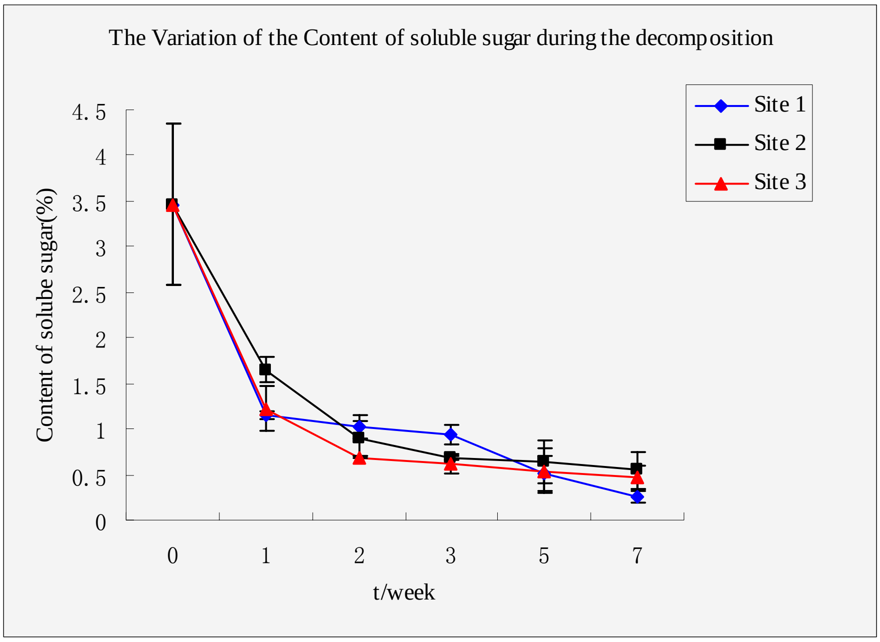

Figure 7. During the first week the loss of soluble sugar content is much higher then the rest of the weeks.

Discussion

There is significant difference in biomass loss. By analyzes, we find that the correlation coefficient of the rate of biomass loss and the decomposition rate is -0.649 and the p-value is 0.000. Hence, there is significant difference between them and they are negatively related. We also find that the correlation coefficient of the rate of biomass loss and the energy is -0.986, and the p-value is 0.000. That is, there is significant different between them and they are highly and negatively related. This can reflect that in the ecosystem the energy flow goes with the circulation and transformation of materials.

Through analyses, we find that there are no significant difference in calorific value, energy loss, and soluble sugar of litter leaves as a whole, but there are a few times where there are significant differences. The difference in calorific value can be explained by the different decomposition rates for different compounds and their components.

Firstly, all of the three sites have a trend of first increase to reach the peak value in the third week and then decrease. During the decomposition, the calorific value first increases probably because the loss of carbohydrates is faster than the nitrogen and phosphorus, which are tied to the tissues of microorganism. Besides, the increase of the calorific value is also probably due to the increases of microorganism and its biological nitrogen fixation and the adhesion of marine macro fauna.

Secondly, the hard-decomposed compounds will need to be transformed into other compounds before they are able to be decomposed, and the new compounds will then have a higher calorific value. Hence, there is no significant difference in the calorific value at the beginning because the soil leaching is almost the same. This can be seen from the variation of the content of soluble sugar during decomposition. In the first and second week, it is probably that salinity has no much impact on them whereas it does impact the leaching thus there is significant difference in the third week.

Besides, the significant difference in a few times is probably related to the special habitat in each site for example microbial activity. The correlation coefficient of the salinity and the catalase is -0.814 and the p-value is 0.008. That is to say, there is significant difference between them and they are highly and negatively related. So we think that it depends on the different habitats and different kind of enzymes and their activity.

Further studies will be needed to be able to determine if there is a relationship between salinity and the calorific value during the decomposition of mangrove litter.

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