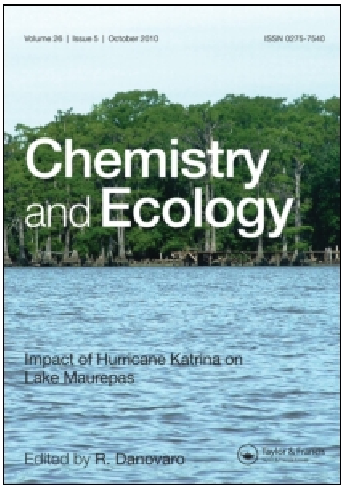

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BIOCHEMICAL CHANGES IN DECOMPOSING LEAVES OF MANGROVES

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Nylon bags containing yellow leaves of *Rhizophora apiculata* and *Avicennia marina*, were immersed for 80 days from August to October, 1996. The decomposing leaves were collected every 10 days and analysed for dry weight loss and six biochemical parameters: tannins, total amino acids, total sugars, total nitrogen, total lipids and fatty acid profile. The leaf weight initially decreased very rapidly by about 50% of the start in two species of mangroves within 10 days. Similar changes were observed with tannins, total amino acids and sugars. However, the concentration of nitrogen increased significantly with decomposition. There was no significant change in total lipid and fatty acid profile. The highest concentration of fatty acid in the decomposing leaves was palmitic acid (16:0). Unsaturated fatty acids such as, 18:1 w7c and 18:1 w9c were found to be present in decomposing leaves of both species.

Keywords: Leaf decomposition and changes; *Rhizophora apiculata*; *Avicennia marina*

INTRODUCTION

Mangrove litter is decomposed into detritus food material by microorganisms and small invertebrates and is eventually consumed by adjacent marine and estuarine fauna. The organic detritus and dissolved nutrients enrich the coastal sea and ultimately support the fishery resources (Golley *et al.*, 1962; Odum and Heald, 1972; Lugo and Snedaker, 1974; Teas, 1976). This concept is supported by several

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degradation studies of mangrove litter. These studies are related to degradation of mangrove leaf litter as influenced by season and exposure (Steinke and Ward, 1987) and leaching losses during decomposition (Steinke *et al.*, 1993). The rate of decomposition is largely influenced by the content of tannins present in the decomposing mangrove leaves (Steinke *et al.*, 1990). However, relatively little is known of the biochemical changes in decomposing leaf litter (Cundell *et al.*, 1979; Steinke *et al.*, 1983; D'Croz *et al.*, 1989), and the changes of total amino acids, lipids and fatty acids in decomposing mangrove leaves are not known. Hence, the present study has been made to trace the biochemical changes in decomposing leaves of two common mangrove species.

MATERIALS AND METHODS

Yellow leaves of *Avicennia marina* (Forssk.) Vierh and *Rhizophora apiculata* Blume were picked from the Pichavaram mangrove forest (Lat.11° 27′N; Long.79° 47′E) in the southeast coast of India. The leaves were brought to the laboratory and air-dried. To study the weight loss and biochemical changes during leaf decomposition, the litter bag method was employed. The litter bags (35 × 35 cm) were made of nylon having a mesh size of 2 mm.

About 500 g leaf litter of *Rhizophora apiculata* and *Avicennia marina*, were placed in litter bags and allowed to decompose for 80 days from August to October, 1996, in mangrove waters with temperature of 27–32°C, dissolved oxygen of 2.5–6.4 $ml\,l^{-1}$, tidal amplitude of 40–85 cm, nitrate of 0.9–3.0 $\mu g\,l^{-1}$, nitrite of 0.3–2.1 $\mu g\,l^{-1}$ and total phosphate of 2.2–8.2 $\mu g\,l^{-1}$ during the period of experiment. The litter bags (16) were maintained for each mangrove species. Every 10 days, approximately 5 g of decomposing leaves were sampled from each of eight bags for biochemical analyses and the leaves from one full bag for analysing the loss of dry weight. Concentration of tannins was determined by using ferric chloride reagent and is expressed as mg Wattle tannin equivalent per gram dry leaf tissue (Hagerman and Butler, 1978). Content of total amino acids was estimated by using ninhydrin as a reagent and is expressed as mg glycine equivalent per gram dry leaf tissue (Mahadevan and Sridhar, 1974). Content of total sugars was estimated by using phenol–sulphuric acid and is expressed in mg glucose equivalent per gram dry leaf tissue (Mahadevan and Sridhar, 1974). Air-dried leaf litter was digested and determined for total nitrogen in per cent of dry tissue, using Technicon Auto Analyser II (Gradko Industrial Ltd., UK). Content of lipids was analysed by using chloroform–methanol and is expressed as percentage of dry tissue (Johnson and Davenport, 1971). The leaf litter samples were analysed for fatty acid profile, by methyl esterification process followed by extraction in hexane and by injection into a Gas Chromatograph (Hewlett-Packard, Model HP 5890A, USA) coupled with a flame ionization detector and fitted with 5% phenylmethyl silicon column. All the data were statistically treated for analysis of variance and significant differences at 95% confidence level among the samples were tested.

RESULTS

Loss of Leaf Dry Weight

The loss in dry weight of mangrove leaves is shown in Figure 1. There was a significant difference in weight loss between all the days of decomposition. On the 10 days of decomposition, the leaves had lost

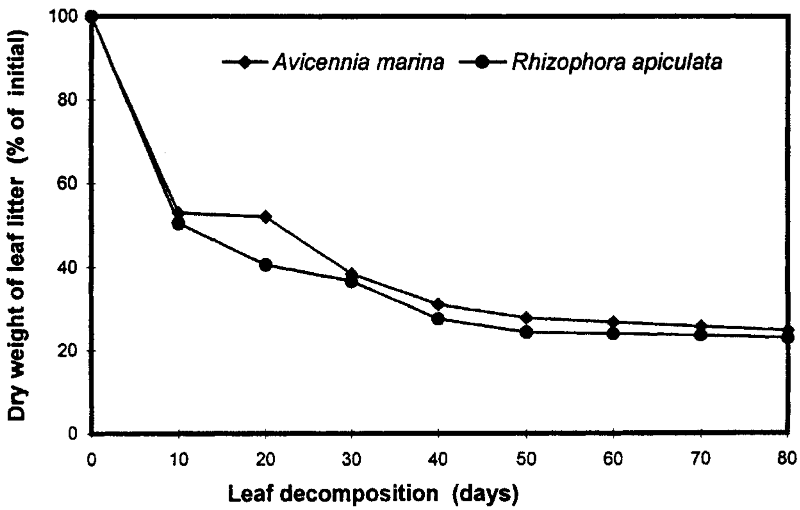

FIGURE 1 Dry weight (% of initial) during decomposition of mangrove leaves ($P < 0.05$ significant between all days; non-significant between species).

the dry weight by 49.4% and 47.0% in leaves of *R. apiculata* and *A. marina* respectively. On the 50 days the weight loss was by 75.6% in *R. apiculata* and by 72.2% in *A. marina.*

Tannins

Changes in the content of tannins in decomposing mangrove leaves are shown in Figure 2. There was a significant difference in the content of tannins between all the days of decomposition. The content of tannins decreased during leaf decomposition, from 36.7 $mg\,g^{-1}$ (100%) on the initial day to 1.9 $mg\,g^{-1}$ (5.2% of initial content) on the 80 days of decomposition in *Rhizophora apiculata*; also in *Avicennia marina*, the content of tannins reduced from 18.3 (100%) to 1.90 $mg\,g^{-1}$ (10.4% of initial content) on 80 days of decomposition. Thus there was 94.7% loss of tannins in the former and 89.6% in the latter, within 80 days of decomposition.

Total Amino Acids

Changes in the concentration of total amino acids in decomposing mangrove leaves are shown in Figure 3. There was a significant

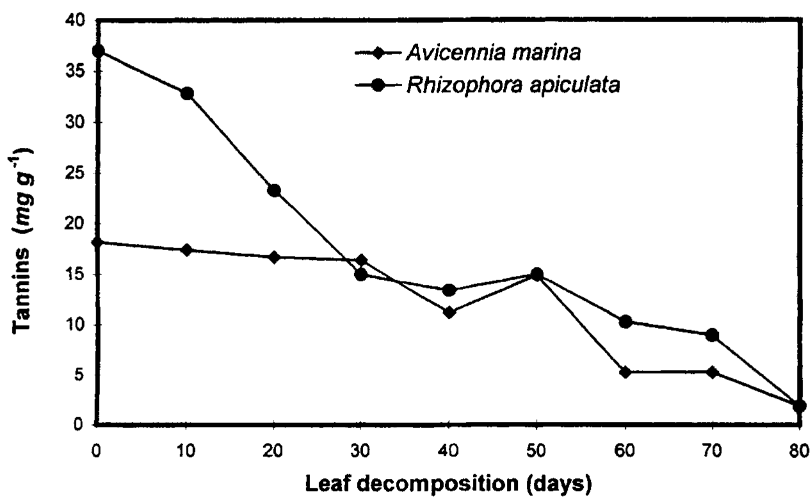

FIGURE 2 Content of tannins in the decomposing leaves of mangroves ($P < 0.05$ significant between all days; $P < 0.05$ significant between species).

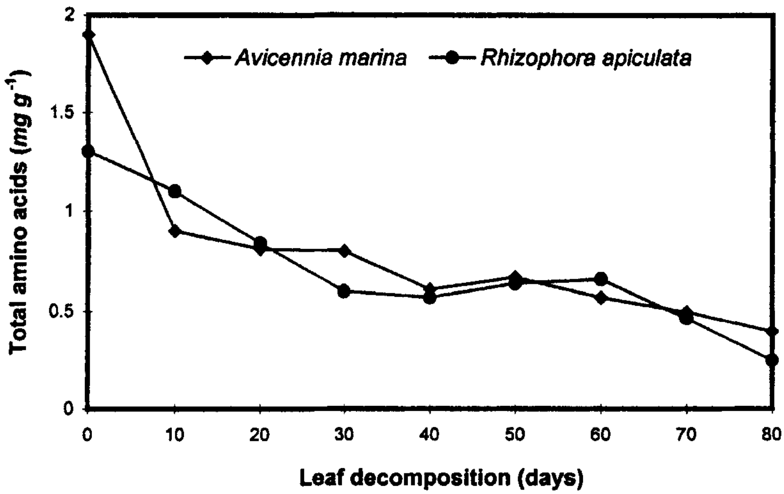

FIGURE 3 Content of total amino acids in the decomposing leaves of mangroves ($P < 0.05$ significant between all days; non-significant between species).

difference in the concentration of total amino acids between all the days of decomposition. The content of total amino acids decreased during leaf decomposition, from 1.9 mg g^{-1} (100%) to 0.4 mg g^{-1} (21.5% of initial) in *Avicennia marina* and from 1.4 mg g^{-1} (100%) to 0.3 mg g^{-1} (18.9%) in *Rhizophora apiculata* from the start of experiment to 80 days of decomposition. Thus, there was 81.1% leaching of total amino acids from leaf tissues of *R. apiculata* and 78.5% from *A. marina*, within 80 days of decomposition.

Total Sugars

Changes in the concentration of total sugars in decomposing mangrove leaves are shown in Figure 4. There was a significant difference in the content of sugars between all the days of decomposition. The content of sugars was 8.0 mg g^{-1} in *R. apiculata* and 7.6 mg g^{-1} in *A. marina* on the initial day of decomposition. The content of sugars decreased drastically until the 40 days of decomposition with virtually no change from 40 to 80 days of decomposition. The content reduced to 0.3 mg g^{-1} (4.3% of initial content) in *R. apiculata* and 0.5 mg g^{-1} (6.6%) in *A. marina* on the 80 days of

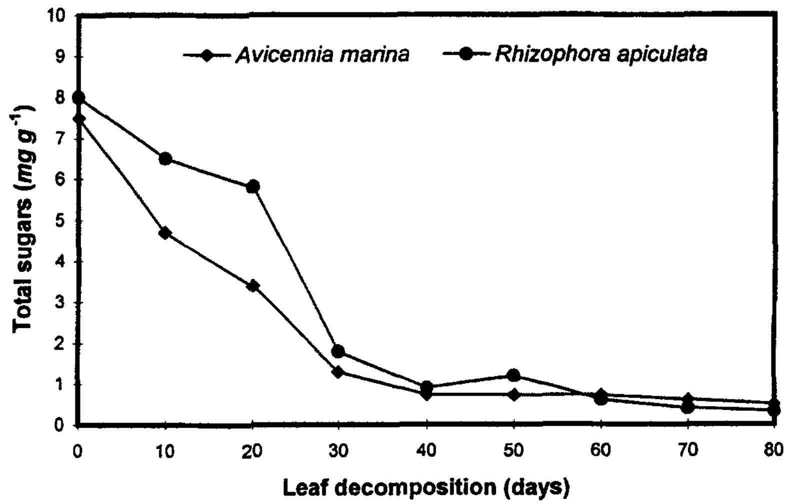

FIGURE 4 Content of total sugars in the decomposing mangrove leaves ($P < 0.05$ significant between all days; non-significant between species).

decomposition and thus the leaching of total sugars was 95.7% in *R. apiculata* and 93.4% in *A. marina*.

Total Nitrogen

Changes in the concentration of total nitrogen in decomposing mangrove leaves are shown in Figure 5. In general, the content of nitrogen was higher in decomposing leaves than in undecomposed ones. The level of nitrogen was $1.4\,mg\,g^{-1}$ (100%) in *Rhizophora apiculata* and $1.6\,mg\,g^{-1}$ (100%) in *Avicennia marina* on the initial day of decomposition. The content first increased on the 30 days onwards with a maximum level of $2.8\,mg\,g^{-1}$ (100% of initial content) in *R. apiculata* and $2.6\,mg\,g^{-1}$ (62.5%) in *A. marina* on 50 and 40 days of decomposition.

Total Lipids

There was no significant difference in the content of total lipids between all the days of decomposition. In general, total lipid content was higher in *Rhizophora apiculata* than in *Avicennia marina*.

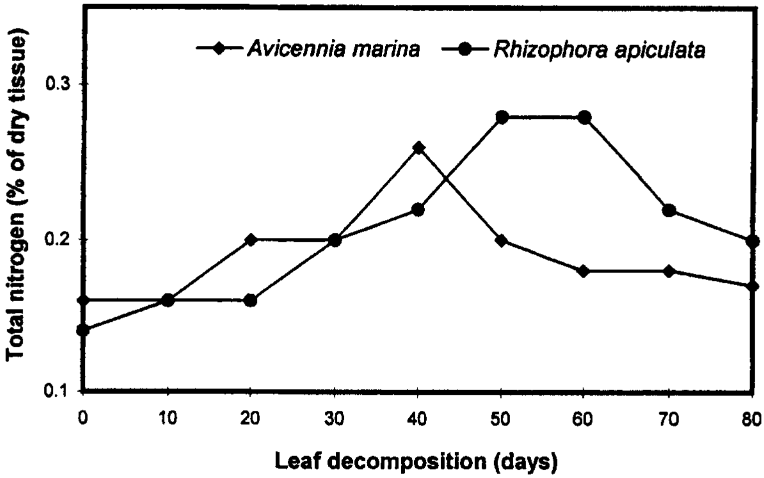

FIGURE 5 Nitrogen content in the decomposing leaves of mangroves ($P < 0.05$ significant between all days; non-significant between species).

TABLE I Percentage of fatty acids in decomposing leaves of *Rhizophora apiculata*

Name of fatty acid	*Fatty acid composition (% of total)* *Day of decomposition* 0	40*th*	80*th*
9:0	–	1.64	1.26
10:0 2OH	22.47	5.53	19.46
11:0 ANTEISO	–	4.22	15.45
12:0	2.58	2.52	2.32
14:0	8.77	8.73	7.86
15:0 ISO	1.61	–	2.18
15:0 ANTEISO	1.38	–	1.89
15:0	–	–	1.14
16:0	42.79	46.68	32.96
16:0 ANTEISO	–	2.57	–
17:0	–	1.43	1.23
17:0 ANTEISO	–	2.37	1.02
17:0 10 methyl	1.41	–	–
18:1 w9c	1.43	4.23	1.22
18:0	5.13	8.79	4.79
18:0 2OH	1.83	–	–
18:2 w6,9c	–	1.29	–
18:1 w7c	4.01	7.59	3.66
18:85	4.20	2.42	3.57
20:0	2.40	–	–
Total saturated	94.56	88.18	95.12
Total unsaturated	5.44	11.82	4.88

Non-significant among days of decomposition.

TABLE II Percentage of fatty acids in decomposing leaves *Avicennia marina*

Name of fatty acid	Fatty acid composition (% of total) Day of decomposition 0	40th	80th
9:0	2.35	3.08	4.01
10:0 2OH	2.21	3.54	–
12:0	2.93	4.62	1.93
14:0	7.49	8.04	9.76
15:0 ISO	–	2.18	4.56
15:0 ANTEISO	–	2.52	3.61
15:0 ISO 2OH	7.69	9.44	8.24
16:0	38.17	33.54	36.43
18:1 w7c	11.91	7.69	7.43
18:0	8.84	6.82	6.84
18:1 w9c	4.53	2.15	–
18:85	8.21	13.71	17.19
20:0	5.17	2.68	–
20:0 ISO	0.49	–	–
Total saturated	83.57	90.16	92.57
Total unsaturated	16.44	9.84	7.43

Non-significant among days of decomposition.

The content ranged from 4.1% to 10% in the former and 1.7% to 6.6% latter, during decomposition.

Fatty Acid Profile

The profile of fatty acids in decomposing leaves of *Rhizophora apiculata* and *Avicennia marina* is shown in Tables I and II. The content of fatty acids are not statistically significant between all the days of decomposition. The predominant fatty acids are the 1.6:0 ranging from 32.9 to 46.6% and the 10:0 20H varying from 5.5 to 22.4% in leaves of *R. apiculata* (Tab. I) and are the 16:0 ranging from 33.5 to 38.2% and the 18:1 w7c, varying from 7.4 to 11.9% in leaves of *A. marina* (Tab. II). Thus the palmitic acid 16:0 is predominantly common in both the species.

DISCUSSION

Dry Weight Loss in Decomposing Leaves

In general, the rate of leaf decomposition in the present study area of Pichavaram mangroves was faster (Fig. 1) than that in other places.

Rhizophora leaves showed a 50% weight loss after 27 days of immersion in the Bay of Panama (D'Croz *et al.*, 1989). *Avicennia* leaves were found to lose 57% weight in 21 days of decomposition, whereas *Bruguiera* leaves exhibited 27.4% weight loss, in South African waters (Steinke *et al.*, 1983). In the present study area, the weight loss was rapid by 49.4% in *R. apiculata* and 47% in *A. marina* within 10 days of decomposition (Fig. 1). This fast rate of leaf decomposition may be due to the rapid leaching of water soluble compounds such as tannins (Fig. 2), amino acids (Fig. 3), sugars (Fig. 4) *etc.*, the higher microbial activity (Ravikumar and Kathiresan, 1993; Kathiresan and Ravikumar, 1995) and the heavy grazing by invertebrates (Rajendran, 1997).

Changes in Tannins, Total Amino Acids and Total Sugars

The tannins have been reported to leach out from decomposing leaves of mangroves. Cundell *et al.* (1979) recorded that the content of tannins started to decrease on 27 days of decomposition. Steinke *et al.* (1993) reported that there was a decrease in the content of tannins after 14 days of decomposition and showed a total loss of 74–85% relative to the amount initially present. In the present study, the content of tannins reduced to 63.3% in *Rhizophora apiculata* and 38.8% in *Avicennia marina* after 40 days of decomposition relative to the amount initially present (Fig. 2). On the 80 days of decomposition, the loss of tannins was 94.8% in leaves of *R. apiculata* and 98.7% in *A. marina* (Fig. 2).

The content of total sugars decreased rapidly in the initial days of decomposition (Fig. 4). Alwar (1990) also found that a 50% of sugars was lost in *Lumnitzera racemosa* and 85% from *Avicennia marina* within 30 days of decomposition in the same study area.

Results reveal that contents of tannins, total amino acids and total sugars were reduced in the decomposing leaves of mangroves. This may be attributed to (i) the rapid leaching (Sumitra Vijayaraghavan *et al.*, 1980) (ii) the autolysis of leaf tissues (Cundell *et al.*, 1979) (iii) the utilization of the organic compounds by microbes (Ravikumar and Kathiresan, 1993; Kathiresan and Ravikumar, 1995).

It is interesting to note that the content of total nitrogen increased although the content of total amino acids decreased with decomposition. There was a relative increase of nitrogen by 142% in *Rhizophora apiculata* and 60% in *Avicennia marina*, in the 50 and 40 days of decomposition over the content of nitrogen in undecomposed leaves (Fig. 5). This higher content of nitrogen in decomposing leaves might be due to the microbial biomass that was built up on the surface of decomposing leaves, by utilizing the carbon and nitrogen sources of the leachates from the leaves (Rajendran, 1997).

Changes in Total Lipids and Fatty Acids in Decomposing Leaves

The content of total lipids did not change significantly during decomposition. Similar result was obtained by Vasantha (1989) in an adjoining area of the present study.

There was a common feature in composition of fatty acids in two mangrove species. The highest content of fatty acids which was found in leaves of *Rhizophora apiculata* and *Avicennia marina* was 16:0, palmitic acid (Tabs. I, II). Ackman *et al.* (1968) found that the photosynthetic organisms of Chrysophycean species also have relatively large amounts of C-16 acids, but differ from Bacillariophycean species which are rich in C-18 acids as well as C-20, C-22 acids. The unsaturated fatty acids found in both *R. apiculata* and *A. marina* were 18:1 w7c and 18:1 w9c. These omega fatty acids are very essential to metamorphosis of crustacean larvae to juveniles and to improve their resistance to stresses (Bell *et al.*, 1986).

The decomposition of mangrove leaves leached the amino acids (Fig. 3) and sugars (Fig. 4) which might have provided the source of nitrogen and carbon for microbes. The microbial load especially nitrogen fixing azotobacters increased the content of nitrogen in the decomposing leaves (Rajendran, 1997). The content of tannins, which have anti-feedant activity (Swain, 1977, 1979), was also low in the decomposing leaves (Fig. 2). Thus the decomposing mangrove leaves with high nitrogen (Fig. 5), low tannins (Fig. 2) and favourable fatty acid profile (Tabs. I, II), become nutritionally valuable food materials to detritivores, especially shrimps. This is evident by the shrimp juvenile resources which are shown to be attracted towards the decomposing mangrove leaves (Rajendran, 1997).

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