CALORIC VALUES OF ORGANIC MATTER IN WOODLAND, SWAMP, AND LAKE SOILS[1]

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Abstract. Caloric values were determined on an ash-free dry-weight basis for organic matter in woodland, swamp, and lake soils and in certain plants. Mean values in kilocalories per gram are: 11 woodland soils, 5.04; 20 swamp soils, 4.87; 9 lake sediments, 5.24; 10 tree-leaf samples, 5.22; 9 samples of aboveground parts of the ground flora, 4.65; 4 aquatic algae, 5.23; and 4 aquatic macrophytes, 4.31.

Measurement of the energy content of organic matter in different parts of the biosphere is becoming increasingly important as the study of ecology lays greater emphasis upon energy flow in ecosystems. This paper presents caloric values for organic matter in surface soils from woodland, swamp, and aquatic sites. Some data are also provided for plants that are important sources of soil organic matter in these sites.

METHODS

Shallow soil cores were collected during summer along a 250-m transect from mixed upland forest through coniferous swamp forest to a small pond, Cedar Bog Lake, on the Anoka sand plain. A few samples were also collected from woodlands and lakes in the vicinity. More detailed decriptions of the main site are given by Gorham and Sanger (1964), who provide transect data for soil pH and water and organic content. Conway (1949) and Lindeman (1941) have also worked in the area. Depth of sampling was 10 cm in the aquatic sediments and most swamp peats, but it was less in some swamp hummocks matted with tree roots and in the organic horizons of the woodland soils, which were about 3–7 cm thick and usually quite distinct from the mineral soil beneath. The approximate depth of summer water table above or below the soil surface was measured at the time of sampling.

The energy content of the organic material was determined on 1-g samples in a Parr oxygen-bomb calorimeter (with plain jacket), after grinding to pass a 40-mesh screen in a Wiley mill, and drying at about 80°C. Appropriate acid and fuse-wire corrections were made for each sample, and the ash remaining in the calorimeter cup was weighed to allow expression of results on the basis of ash-free dry weight (= ignition loss). Caloric values are expressed in kilogram calories, i.e., the amount of heat required to raise the temperature of 1 kg of water by 1°C. All samples were analyzed in duplicate, the average difference being 0.031 kcal for plant samples and 0.046 kcal for soils.

Because some samples contained considerable mineral matter (up to a maximum of 70% in one woodland sample), tests were made on several samples (mostly 1 g) in which various amounts of ashed soil were mixed with benzoic acid or finely ground plant tissue. The variations in caloric value were minimal (Table 1).

In these non-calcareous and rather organic soils, ash-free dry weight is closely equivalent to organic content and is the most satisfactory basis for expression of caloric values. In the plants, also, no precipitates of calcium carbonate were observed, so that ignition loss is an accurate measure of organic matter.

TABLE 1. Caloric values of organic materials combined with varying amounts of added mineral material[a]

Benzoic acid		Oak leaves		Sphagnum	
Organic matter (% dry wt)	Kcal/g ash-free dry wt	Organic matter (% dry wt)	Kcal/g ash-free dry wt	Organic matter (% dry wt)	Kcal/g ash-free dry wt
100	6.32	98	5.20	93	4.27
100	6.32	78	5.20	90	4.11
100	6.33	67	5.29	82	4.32
79	6.32	57	5.26	74	4.21
60	6.32	48	5.15	62	4.24
50	6.32	38	5.23	53	4.31
42	6.32	29	5.23	47	4.15
41	6.31			35	4.17
30	6.31	Mean	5.22	31	4.15
29	6.31			19	4.15
Mean	6.32			Mean	4.21

[a]Mineral material is a leached fine sand, almost wholly lacking in clay, from the Anoka sand plain.

TABLE 2. Caloric values of organic matter in woodland, swamp, and aquatic soils (± standard deviation of the mean)

Soil type	Kcal/g ash-free dry wt	Ignition loss % dry wt
11 woodland humus layers	5.04±0.04	57.5±5.7
20 swamp soils	4.87±0.04	77.3±1.5
9 lake and pond muds	5.24±0.05	59.3±3.6

RESULTS AND DISCUSSION

The energy content of soil organic matter is distinctly different in the three types of habitat, with aquatic soils highest (5.24 kcal/g) and swamp soils lowest (4.87 kcal/g) (Table 2). In these two categories there is a definite relation between energy content and the level of the summer water table (Fig. 1). The organic matter of the woodland soils is intermediate in energy content (5.04 kcal/g) and shows some variation related to percentage organic matter in the soil. Samples with less than 50% organic matter, collected along the Cedar Bog

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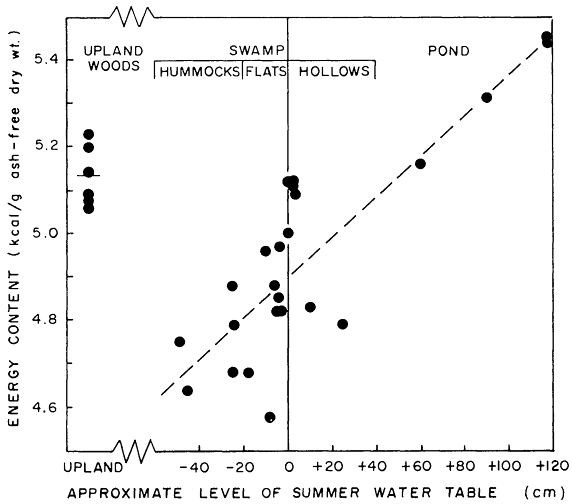

FIG. 1. Caloric values of soil organic matter in relation to approximate levels of summer water table.

Lake transect, average 5.11 kcal/g, while the remaining samples, with more than 60% organic matter, average 4.97 kcal/g.

No conclusive explanations can be given for the differences mentioned above, but some possibilities deserve examination. For example, the organic layers of the woodland soils derive mainly from tree leaves, while in the swamp the extremely luxuriant ground flora probably outweighs the trees in the supply of litter. Table 3 indicates a much lower energy content for the aboveground parts of ground flora in both woodland (4.67 kcal/g) and swamp (4.64 kcal/g) than for the leaves of trees in woodland (5.12 kcal/g) and swamp (5.31 kcal/g). Because of the preponderance of ground flora in the swamp, a lower energy content would be expected in soil organic matter from this habitat.

The influence of root material in these samples is difficult to assess. Roots were excluded as far as possible from the samples, but they did comprise an appreciable fraction in some of the swamp hummocks, where low energy contents were observed (Fig. 1). Roots were also important in one sample beneath *Decodon* at the edge of the swamp next to the pond. The energy content of this sample (4.79 kcal/g) was distinctly low relative to that of samples from swamp hollows (up to 5.12 kcal/g), in which most of the organic matter was highly decomposed.

The influence of root content upon the caloric value of soil organic matter was investigated by analyzing three swamp peats with an abundance of interwoven roots and two well-decomposed swamp peats with very few roots. All samples came from hummocks. Contrary to expectation, the samples with abundant roots showed slightly higher caloric values (5.04, 4.98, 4.96 kcal/g) than those with few roots (4.95, 4.94 kcal/g).

In a further attempt to examine different fractions of the organic debris in soils, two whole woodland humus layers with appreciable root and bark material were sorted on sieves and analyzed (Table 4). The 2-mm sieve fractions gave the highest caloric values, but in one case the finest fraction exhibited a lower energy content than the coarsest roots, and in the other case its energy content was distinctly higher.

TABLE 3. Caloric values of plants from woodland, swamp, and aquatic sites

Description of sample	Kcal/g ash-free dry wt
Woodland trees	
Living *Quercus* leaves	4.93
Dead " "	5.07
Living *Pinus strobus* needles	5.29
Dead " " "	5.37
Mixed dead tree leaves	4.96
Mean	5.12
Woodland ground flora (aboveground parts)	
Living ground flora, mixed	4.68
Dead " " "	4.63
Dead " " "	4.69
Mean	4.67
Swamp trees	
Living *Thuja occidentalis* twigs	5.25
Dead " " "	5.30
Dead " " "	5.51
Living *Larix laricina* needles	5.26
Dead " " "	5.21
Mean	5.31
Swamp ground flora (aboveground parts)	
Living ground flora, mixed	4.62
" " " "	4.80
" " " "	4.88
" " " "	4.73
" *Decodon verticillatus*	4.65
" *Sphagnum*	4.16
Mean	4.64
Phytoplankton	
Melosira sp.	5.15
Mixed blue-green algae	5.00
" " "	5.35
Anabaena solitaria	5.41
Mean	5.23
Aquatic macrophytes	
Ceratophyllum demersum	4.26
Nuphar	4.48
Potamogeton (broad-leaved)	4.28
Elodea canadensis	4.20
Mean	4.31

TABLE 4. Caloric values of fractions sieved from whole humus layers (Kcal/g ash-free dry wt)

Fraction	Cedar hummock	Oak wood
Large roots......	—	4.88
5-mm screen.....	4.87 (roots)	5.21 (bark)
2-mm screen.....	5.01 (mostly roots)	5.29 (bark, roots)
1-mm screen.....	4.87 (mostly roots)	5.18
0.5-mm screen...	4.76	5.16
Remainder......	4.72	5.15

The degree of decomposition might also be expected to influence caloric values of soil organic matter. For Finnish peat samples Salmi (1954) has recorded a striking positive correlation between caloric value and degree of decomposition, which may explain at least partially the relatively high caloric values of the well-decayed peats from swamp hollows as contrasted with the less-decayed peats from hummocks.

Whether the correlation observed by Salmi is dependent upon anaerobic decay, or is evident also under aerobic conditions, remains to be established. We analyzed litter (L) and moderately decomposed (F) humus layers in three sites and found very little difference (5.19 kcal/g for the L and 5.12 kcal/g for the F layers). Moreover, in the one site where a moderately organic and well-decomposed (H) humus layer could be sampled, a caloric value of only 4.82 kcal/g was recorded. These data therefore provide no evidence for a parallel increase of caloric value with degree of decay in well-aerated soils.

The organic matter of the anerobic lake muds is highly comminuted and decomposed, and this condition may be partly responsible for its high energy content. However, the role of source material is not easily evaluated for the aquatic sites, because little is known of the balance between algae and macrophytes in supplying organic matter to the sediments. If algae are important the sediments will receive much organic matter of relatively high caloric value (Table 3). Muds from the deepest part of Cedar Bog Lake (Fig. 1) exhibited higher caloric values than did a marginal sample beneath a dense mat of *Ceratophyllum,* which has a low energy content (4.26 kcal /g).

In conclusion, this study has demonstrated distinct differences in the energy content of soil organic matter from different natural habitats and has indicated certain lines of approach to the explanation of these differences.

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SEED GERMINATION AND ESTABLISHMENT AS AFFECTED BY NON-WETTABLE SOILS AND WETTING AGENTS

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Abstract. To study the effects of soil wettability and wetting agents on seed germination and establishment, three substrates (naturally occurring non-wettable soil, wettable soil, and a wettable quartz sand) were placed in small plastic containers and received applications of wetting agent in liquid, wetting agent on perlite, and no treatment as a control. The containers were seeded to wimmera ryegrass and were placed both on a 30° slope and on the level in a controlled temperature chamber (70°F). Seed placed on non-wettable soil which received no wetting agent treatment failed to germinate in those containers placed on the slope. Good germination occurred on soil which was treated with a wetting agent and on wettable sand. The same relationships occurred for the plants which were allowed to become established. Differences are primarily due to water relations; water ran off the sloping non-wettable soils. Wetting agent treatment on the wettable sand reduced both germination and establishment of the tested plants.

Introduction

Hydrophobic, or non-wettable properties have been observed in many soils (Jamison 1945, 1946, Bond 1964), including several in Southern California watersheds (Letey, Osborn, and Pelishek 1962, Pillsbury et al. 1963). Krammes and DeBano (1965) indicated that 60% of a previously burned watershed in Southern California was non-wettable, and in another Southern California burn all areas tested were hydrophobic.

Letey et al. (1961, 1962) and Pelishek et al. (1962) describe the physics of water movement in soils as related to the liquid-solid contact angle, which is an index to the relative wettability of the soil. A large contact angle decreases the rate of water entering the surface of the soil, while a smaller contact angle increases the rate of water entry. Wetting agents are used to decrease large liquid-solid contact angles, thus increasing infiltration rates into these non-wettable soils.

Osborn et al. (1964) demonstrated that erosion on burned watersheds exhibiting non-wettable properties

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