Suo 39(5): 113–123, 1988

KEIJO LEHTONEN, MARTTI KETOLA, KIRSTI HAIHU and KALEVI PIHLAJA

EFFECT OF HUMIFICATION ON THE COMPOSITION OF THE SOLVENT-EXTRACTABLE MATTER IN *SPHAGNUM* AND *CAREX* PEATS

Maatumisen vaikutus rahka- ja saraturpeista orgaanisilla liuottimilla uuttautuvan aineksen koostumukseen

Lehtonen, K., Ketola, M., Haihu, K. & Pihlaja, K. 1988: Effect of humification on the composition of the solvent-extractable matter in *Sphagnum* and *Carex* peats. (Tiivistelmä: Maatumisen vaikutus rahka- ja saraturpeista orgaanisilla liuottimilla uuttautuvan aineksen koostumukseen.) — Suo 39:113–123. Helsinki. ISSN 0039-5471

Solvent-extractable matter of *Sphagnum* (S) and *Carex* (C) peats of different degrees of humification (S, H2–H8; C, H3–H8) were isolated, saponified and analyzed. The C peat material was found to contain more extract than the S peat (C, 9.3%; S, 5.9%, on average). In both peat series the extract content increased with increasing degree of humification. In both peats the unsaponifiable, non-volatile polymeric matter comprised the biggest part, nearly one half on average, of the saponified extracts, which also were analyzed for their lipid components and other volatile materials. These fractions accounted for over one third and nearly one fifth, respectively. The total amounts of all these three categories generally increased, as did those of the individual lipid groups, with increasing humification. However, the relative minimum of the polymers and the relative maximum of the analyzed lipid compounds were found in the samples of H4 in both peat series. Fatty and ω-hydroxy acids were the most abundant lipid groups, together accounting for 70–90% of the analyzed lipids. Sterols and 1-alkanols were clearly more abundant in the S peat. The relative amounts of the lipid groups did not show a distinct dependence on the degree of humification in either peat series. The individual lipid group compositions of both peat types were very similar although some exceptions were found.

Keywords: *Carex* , humification, peat lipids, *Sphagnum*

K. Lehtonen, M. Ketola, K. Haihu & K. Pihlaja, Department of Chemistry, University of Turku, SF-20500 Turku, Finland

INTRODUCTION

Peat is a potential raw material for the production of fine chemicals. The extractable matter (peat bitumen) obtained from peat by neutral organic solvents contains numerous lipidic compounds. The wax fraction of peat extract has been of particular interest in Finland with regard to substitution of imported earth and other natural waxes. Recently, the composition of peat extracts have been subjected to increasing interest (e.g. Ekman 1981, Ekman and Ketola 1981a, b, Fagernäs 1986, and Ketola 1987). The available know-

ledge of extract contents and lipid compositions of numerous separate samples of different heterogenous peat types of various degrees of humification are plentiful, but unfortunately without covering the whole humification range in any case. Thus, the more detailed knowledge of humification effects on peat lipids of the principal peat types, those composed of only one or two, equally proportioned, peat-forming plant species, has been lacking until recently. We have studied these effects with *Sphagnum* (S), *Bryales* (B) and *Carex–Bryales* (CB) peats from Finland (Ketola et al. 1986b, Lehtonen et al. 1988). The main results of these studies were as follows: (i) the extract and lipid contents and compositions are dependent on the peat type, (ii) the degree of humification of peat affects these contents and compositions, and (iii) this effect is dependent on the peat type.

The aim of this research was to repeat the study of the effects of humification on the extractable lipids of *Sphagnum* and *Carex* (C) peats from Sweden. The extract contents, the composition of the saponified extracts (analyzed lipid compounds, other volatile materials and non-volatile matter), and the composition of analyzed lipids (fatty, ω-hydroxy and α,ω-alkanedioic acids, 1-alkanols, sterols and *n*-alkanes) are determined and the results are compared with those obtained from the peats mentioned above. The data concerning the C peat are the first, and they are used to show whether or not the humification effects on the lipids of CB peat are the same as the average of those of the pure B and C peats, i.e. whether or not the humification effects additively.

MATERIALS AND METHODS

Peat samples

The peat material was taken from Norrbomuren fen (60°30'N, 17°3'E) in eastern Sweden in summer 1985 with a volume accurate (1 016 cm^3) peat drill. The fen has a surface area of over 1 000 hectares and it is growing mainly various *Sphagnum* species on its middle part while *Carex* sp. are dominating on the edges. The series of S peat consisted of four samples with the degrees of humification of H2 (depth 50–70 cm), H4 (160–180 cm), H6 (65–85 cm) and H8 (115–135 cm) (von Post 1922). Microscopic analysis of peat constituents showed that the S peat constituted mainly (88–99%) of *Sphagnum* species except the most humified (H8) sample which contained *Eriophorum vaginatum* (Er) as dominating species and was classified as ErS peat (Table 1). The C peat series also included four samples with different degrees of humification: H3 (30–50 cm), H4 (75–95 cm), H6 (100–120 cm) and H8 (130–150 cm). In all samples of the C peat *Carex* species were predominating (70–86%, Table 1). The minor constituents in both peat series were *Eriophorum* and *Equisetum* species and lignous (N) material. The technical characteristics for the studied peat samples are shown in Table 2.

Extraction and isolation procedures

The peat materials were air dried at 20–25°C and ground to pass through a 1 mm sieve. The moisture contents of the peat (Table 2) were obtained by drying at 105°C for 24 h; the determination was carried out in triplicate. The solvent extractable matter was isolated from the peat samples (5.0–13.1 g) by the Soxhlet method with dichloromethane-acetone (9:1 v/v) for 20 solvent cycles (2 h). Before extraction the internal standards *n*-heptadecanoic acid (Sigma Chemical Company, 99%), 2-hexadecanol (EGA Chemie, 97%), 5α-cholestane (Fluka AG, 97%) and cholesterol (Fluka AG, puriss.) were added to the samples for quantification by gas chromatography. To get the total monomeric lipids the samples of crude peat extracts (40–60 mg) were saponified with

Table 1. Botanical characterization of the *Sphagnum* and *Carex* peat samples based on microscopic plant analysis.

Taulukko 1. Rahka- ja saraturvenäytteiden mikroskooppiseen kasvianalyysiin perustuvat kasvijäännöskoostumukset.

Peat sample *Turvenäyte*	Plant constituents* *Kasvijäännöskoostumus**
S H2	S/99%, (Er+N)/1%
S H4	S/93%, Er/3%, N/4%
S H6	S/88%, Er/7%, N/5%
ErS H8	S/39%, Er/48%, N/10%, Eq/3%
C H3	C/70%, Er/13%, N/9%, S/4%, Eq/4%
C H4	C/83%, Er/5%, N/8%, S/2%, Eq/4%
C H6	C/86%, N/11%, Eq/2%, B/1%
C H8	C/78%, N/21%, Eq/1%

*S, *Sphagnum*; Er, *Eriophorum*; N, Nanolignid; Eq, *Equisetum*; C, *Carex*; B, *Bryales*

20 ml of 0.4 M KOH/ethanol (containing 10% water) for 6 h under reflux. After acidification with 0.2 M sulphuric acid, the solution was extracted with diethyl ether (3 x 20 ml). The combined ether extracts were washed with distilled water and dried over anhydrous sodium sulphate for 20 h. After evaporating the solvent under vacuum at 25°C, the saponified extracts (30.4–49.8 mg) were fractionated using a chromatographic column (12 x 1 cm i.d.) filled with magnesium silicate (Florisil, 60–100 mesh, Fluka AG), which contained 7% water. The neutral extractives were eluted with hexane/diethyl ether (7:3 v/v, 100 ml). The acidic matter was obtained with the same solvent mixture but to which 4% acetic acid had also

Table 2. Technical characteristics of the *Sphagnum* (S) and *Carex* (C) peat samples.

Taulukko 2. Rahka- (S) ja saraturvenäytteiden (C) tekniset ominaisuudet.

Peat sample *Turvenäyte*	Sampling depth *Näytesyvyys* cm	pH[a]	Bulk density[b] *Turpeen tiheys* kg m^{-3}	Ash *Tuhka* %	Moisture[c] *Kosteus* A/%	B/%	Effective heat value *Tehollinen lämpöarvo* MJ kg^{-1}	Extract[d] *Uute* %
S H2	50–70	3.8	54.9	1.3	93.6	29.2	18.0	2.4
S H4	160–180	3.4	74.9	0.9	92.5	34.5	18.7	5.0
S H6	65–85	3.2	136.7	0.7	86.6	34.5	21.3	8.1
ErS H8	115–135	3.6	115.5	0.9	88.5	21.0	21.0	8.1
C H3	30–50	4.3	93.6	2.8	89.5	16.1	22.7	9.8
C H4	75–95	4.5	92.0	3.0	90.9	23.0	22.4	6.5
C H6	100–120	4.5	94.1	2.9	90.7	16.3	23.6	9.8
C H8	130–150	4.8	119.2	3.5	88.3	33.9	23.4	11.2

[a] pH of pressed water.
[b] As dry mass/natural volume.
[c] A, moisture of fresh sample; B, moisture of air-dried sample.
[d] Dichloromethane-acetone (9:1 v/v) extract (wt% of dry peat).

been added. The neutral extracts were further fractionated on silica gel plates (Kieselgel 60 F_{254}, 20 x 20 cm, 0.25 mm layer thickness, Merck) by developing with petroleum ether (40–60°C)-diethyl ether (7:3 v/v). The subfractions containing hydrocarbons (R_f 0.88–0.94), alcohols (R_f 0.22–0.38) and sterols (R_f 0.08–0.22) as well as the acids were analyzed for their individual constituents.

Gas chromatography and mass spectrometry

Gas chromatography (GC) and mass spectrometry (GC-MS) were applied to the various fractions of the extracts. The acids, i.e. fatty, ω-hydroxy and α,ω-alkanedioic acids, were directly analyzed from the acid fractions. The neutral compounds, 1-alkanols, sterols and *n*-alkanes were analyzed separately from their subfractions. Before analysis the acids were converted to methyl esters by diazomethane, and hydroxy compounds to their trimethylsilyl ether derivatives by the BSTFA reagent (Lehtonen et al. 1988). Diazomethane was generated from Diazald (N-methyl-N-nitroso-p-toluenesulphonamide, EGA-Chemie). The silylation reagent BSTFA (N,O-bis(trimethylsilyl)trifluoroacetamide with 1% of TMCS (trimethylchlorosilane)) was purchased from Fluka AG. The compounds were analyzed by a Hewlett-Packard 5710A gas chromatograph equipped with a flame ionization detector (FID) and a fused silica capillary column coated with the SE-54 phase as described earlier (Ketola et al. 1986a). Compound concentrations were obtained on the basis of electronically integrated (using a Hewlett-Packard 3390A integrator) GC peak areas relative to those of internal standards (*n*-heptadecanoic acid, 2-hexadecanol, 5α-cholestane, cholesterol), and the calibrated relative mass responses for the individual compounds. The amount of non-volatile matter was determined as a difference between total and volatile materials.

For GC-MS analysis the apparatus and analyzing conditions were those described earlier (Ketola et al. 1986a). Compound identification was based on the GC retention times and on comparison of their EI mass spectral fragmentation patterns (70 eV) with those of standards or published data. Analytical grade organic solvents and inorganic reagents were used as received. Standards included *n*-fatty (*n*-alkanoic) acids and 1-alkanols (both C_{12}–C_{30}), ω-hydroxy (ω-hydroxyalkanoic) and α,ω-alkanedioic acids (both C_{10}–C_{16}) and *n*-alkanes (C_{16}–C_{40}) as well as phytol, β-sitosterol and stigmasterol (obtained from Sigma Chemical Company, EGA Chemie and Fluka AG). In addition, two α,ω-alkanedioic acids (C_{18}, C_{26}), and one ω-hydroxy acid (C_{26}) were synthesized in our laboratory (Ketola et al. 1986a).

RESULTS AND DISCUSSION

Extract content

On a dry weight basis the extract content varied between 2.4 and 8.1% (average 5.9%) and between 6.5 and 11.2% (average 9.3%) for *Sphagnum* (S) and *Carex* (C) peats, respectively (Table 2). In both peat types the amount of extract increased with increasing degree of humification. These observations are in good agreement with earlier results obtained for S (Ketola et al. 1986b), B and CB (Lehtonen et al. 1988) and ErS, S and CS peats (Luukkanen 1986). In contrast, Ekman (1981) found no correlation between peat bitumen yields and the degree of humification or the composition of dominant peat-forming plants (*Sphagnum*, *Carex*, *Eriophorum*).

In the S peat samples, the amount of extract increased almost linearly in the range from H2 to H6. The ErS H8 sample was an exception, containing 8.1% extract (dry weight), which is of the same magni-

tude as that of the S H6 sample (Table 2). The value for the ErS H8 peat is, however, in agreement with values for ErS H8 peat presented by Luukkanen (1986) — 6 to 11%. In the C peats, the extract content increased from H4 to H8. The most weakly decomposed sample, C H3, was an exception, having extractives in high concentration (9.8%, Table 2).

Thus, in general, the amount of extract increased with increasing degree of humification for both S and C peats although at different concentration levels.

Fraction composition of the extracts

Non-volatile polymeric matter was the most abundant fraction (nearly 50% on average) of the saponified extracts in both peat types (Figs. 1 and 2). Average proportions of analyzed lipids and other volatile materials accounted for over one third and nearly one fifth, respectively. The absolute amounts of these three fractions in the S peat increased with increasing degree of humification from S H2 to S H6 (Fig. 1). From S H6 to ErS H8 only the amount of polymers increased. In C peat the amounts of the three fractions also tended to increase from C H4 to C H8 (Fig. 1). The decrease in the total amount of extract from C H3 to C H4 was caused by a decrease in the amounts of all the above fractions. The relative extract compositions of both peat types as a function of the degree of humification are similar (Fig. 2). Both peats showed a maximum for total lipids and a minimum for non-volatiles in the H4 samples.

The above results are quite different from those previously obtained for the B or CB peats, in which the analyzed lipids formed the most abundant fraction of peat extracts, except in the most humified (H6 and H8) B peat samples (Lehtonen et al. 1988). This indicates the relationship between the extract composition and humification is different in the different peat types.

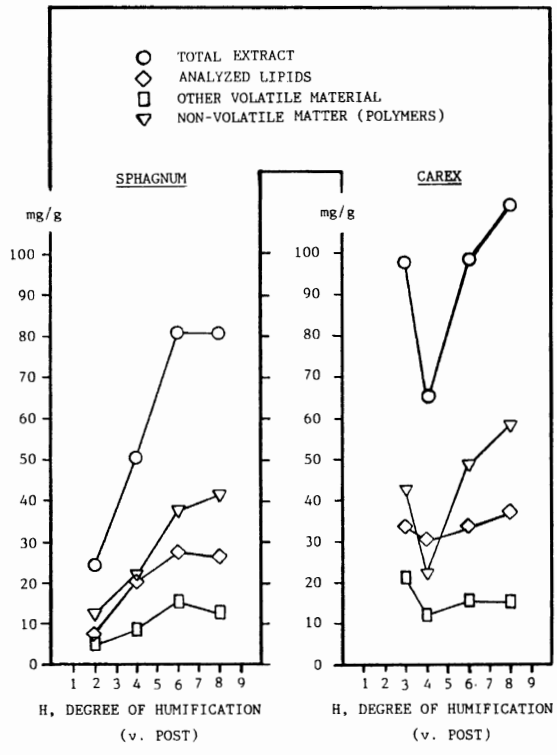

Fig. 1. Extract composition of the *Sphagnum* and *Carex* peats (mg/g dry peat) vs the degree of humification.

Kuva 1. Rahka- ja saraturpeiden uutekoostumus (mg/g kuivaa turvetta) vs maatumisaste

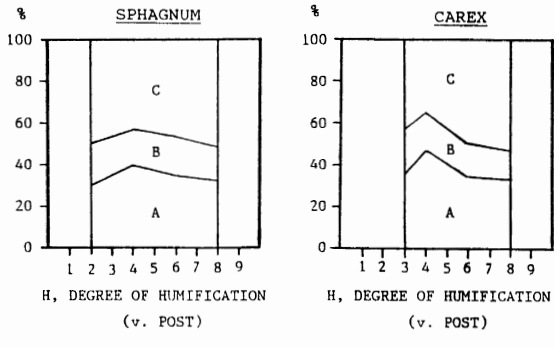

Fig. 2. Relative composition of the *Sphagnum* and *Carex* peat extracts vs the degree of humification. A, analyzed lipids; B, other-volatile material; C, non-volatile matter (polymers).

Kuva 2. Rahka- ja saraturveuutteiden suhteellinen koostumus vs maatumisaste. A, analysoidut lipidit; B, muu haihtuva aines; C, haihtumaton aines (polymeerit).

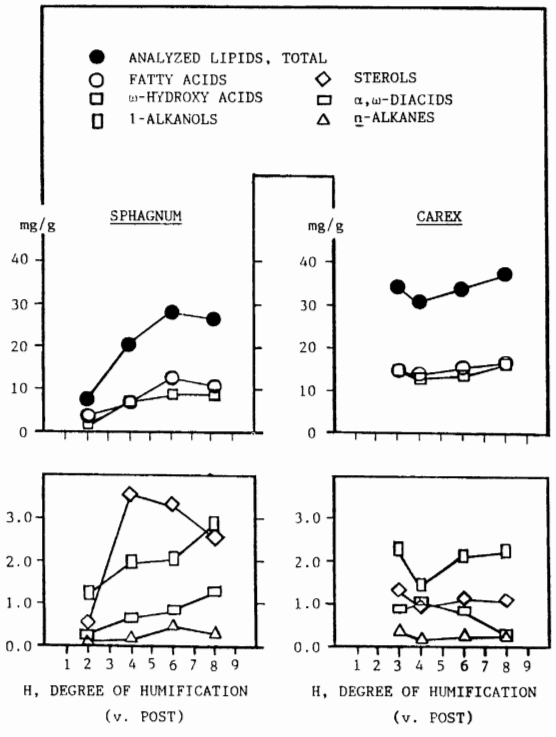

Fig. 3. Composition of the analyzed lipids of the *Sphagnum* and *Carex* peats (mg/g dry peat) vs the degree of humification.

Kuva 3. Rahka- ja saraturpeiden analysoitujen lipidien koostumus (mg/g kuivaa turvetta) vs maatumisaste

Analyzed lipids

The content of the analyzed lipids was higher in the C peat samples, and accounted for by fatty and ω-hydroxy acids, the most abundant fatty groups of both peat types (Fig. 3). Together they accounted for nearly 90% and over 70% of the total analyzed lipids in the C and S peats, respectively (Fig. 4). The S peat contained relatively more sterols (average: S, 12% (2.5 mg/g); C, 3% (1.1 mg/g)) and 1-alkanols (average: S, 11% (2.0 mg/g); C, 6% (2.0 mg/g)) compared to the C peat. α,ω-Alkanedioic acids and *n*-alkanes accounted for only 3.8% (0.75 mg/g) and 1.3% (0.25 mg/g) respectively of the analyzed lipids in the S peat on average. The corresponding values in the C peat series were 2.3% (0.75 mg/g) for the diacids and 0.8% (0.25 mg/g) for the *n*-alkanes.

In the S peat samples the amounts of all the above groups except sterols increased from S H2 to S H6 (Fig. 3). The decrease in the amount of total analyzed lipids in the range S H6 to ErS H8 resulted mainly from a decrease in fatty acids and sterols. In the C peat samples the amounts of all

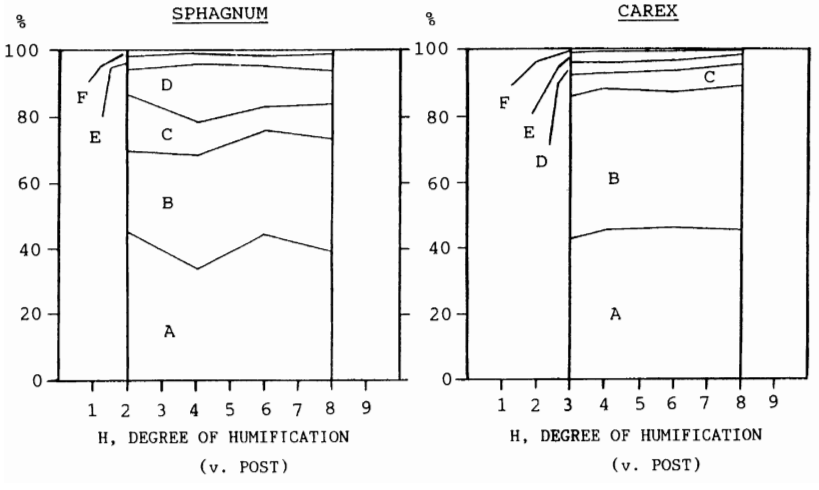

Fig. 4. Relative composition of the analyzed lipids of the *Sphagnum* and *Carex* peats vs the degree of humification. A, fatty acids; B, ω-hydroxy acids; C, 1-alkanols; D, sterols; E, α,ω-alkanedioic acids; F, *n*-alkanes.

Kuva 4. Rahka- ja saraturpeiden analysoitujen lipidien suhteellinen koostumus vs maatumisaste. A, rasvahapot; B, ω-hydroksihapot; C, 1-alkanolit; D, sterolit; E, α,ω-alkaanidihapot; F, n-alkaanit.

the other lipid groups except alkanedioic acids generally increased in the range from C H4 to C H8 (Fig. 3). The decrease in total lipids in the step from C H3 to C H4 resulted from a decrease in the amounts of all groups except diacids. The change in the proportions of the lipids analyzed for in both peats was irregular with increasing humification (Fig. 4). In the case of the S peat series the relative amounts of fatty acids and *n*-alkanes decreased, (D) from S H2 to S H4, increased, (I) from S H4 to S H6 and decreased, (D) from S H6 to ErS H8. The other groups of compounds behaved as follows: 1-alkanols and α,ω-alkanedioic acids D-D-I, ω-hydroxy acids I-D-I and sterols I-D-D. Correspondingly in the C peat series (C H3 → C H4 → C H6 → C H8), the courses of the lipid groups were D-I-D for 1-alkanols, sterols and *n*-alkanes, I-I-D for fatty acids, D-D-I for ω-hydroxy acids, and I-D-D for alkanedioic acids. No explanation to account for the changes in the lipid compositions during the humification process in either case can be given.

The lipids analyzed for consisted of straight-chain aliphatic fatty compounds and sterols. The fatty groups were C_{13}–C_{32} fatty acids, C_{12}–C_{28} ω-hydroxy acids with no odd carbon homologues, C_9–C_{28} α,ω-alkanedioic acids with azelaic acid (C_9) as the only odd carbon homologue, C_{12}–C_{34} 1-alkanols, C_{16}–C_{33} *n*-alkanes, C_{16} and C_{18} monoenoic fatty acids (obviously palmitoleic and oleic acids, the most abundant natural isomers), and C_{18} monoenoic ω-hydroxy acid (obviously *trans*-18-hydroxy-9-octadecenoic acid, Ekman and Ketola 1981b). Phytol, pristane and phytane were also included in the above groups. Even carbon numbered homologues, mainly C_{26}, C_{24}, C_{22} and C_{28}, were predominate in the other fatty groups except the *n*-alkanes, in which odd carbon homologues, especially C_{31}, C_{29}, C_{25} and C_{27}, were clearly the most abundant. In the sterol fractions β-Sitosterol occurred in high amounts accounting for 73 and 65%, on average, of the S and C peat sterols, respectively. Other sterol constituents were stigmasterol, stigmastanol, kampesterol, kampestanol, brassicasterol, brassicastanol and β-sitostanol. The carbon number distributions of the analyzed lipid groups will be published later.

The most characteristic differences between the two peat types at the individual compound level were found in the occurrence of some fatty and ω-hydroxy acids and phytol and in the distribution of β-sitosterol and β-sitostanol. These differences are summarized in Table 3.

The composition of S peat lipids and the effect of humification upon them were similar with those previously reported by Ketola et al. (1986b). However, the data concerning S peat sterols, α,ω-alkanedioic acids and *n*-alkanes are the first. Comparison of the present results of the total and relative content and composition of the analyzed lipids and the effect of humification upon them for C peat with the previous data of B and CB peats (Lehtonen et al. 1988) suggested that C and B are additive in the mixed CB peats. Both peat types have characteristic fractions and individual compounds. For example, S peat is rich in sterols, while low 1-alkanol and sterol contents are characteristic for C peat. The individual compound characteristics for S and C peats are described in Table 3.

Other-volatile fraction

The most common compounds in the other-volatile fraction were triterpenoids. In acidic fractions, triterpenoid acids such as betulinic and ursolic acids occurred in the moderate amounts. Some other cyclic acids were also found. Triterpenols (lupeol, betulinol, etc.) were dominant in the alcohol fractions. In the hydrocarbon fractions, the triterpenes: taraxer-14-ene (M^+ m/e 410 (18%), m/e 395 (14), m/e 286 (59), m/e 271 (45), m/e 218 (35), m/e

Table 3. Characteristic differences between *Sphagnum* and *Carex* peat lipids at the individual compound level.

Taulukko 3. Rahka- ja saraturpeiden uuteainekoostumuksen eroavuuksia yhdistetasolla.

Fatty acids, average % of	*Sphagnum*	*Carex*
C_{18}	10.4	1.9
C_{20}	3.5	8.6
C_{22}	11.1	6.5
C_{24}	25.5	15.2
C_{28}	5.3	14.7
others	44.2	53.1
Total	100.0	100.0
ω-Hydroxy acids, average % of		
C_{20}	2.5	9.6
C_{22}	13.0	8.0
C_{24}	24.4	9.5
C_{28}	16.6	31.5
others	43.5	41.4
Total	100.0	100.0
1-Alkanols, average % of phytol*	1.6	0.8
β-Sitosterol*/β-sitostanol*, average ratio	95:5	75:25

*Phytol = 3,7,11,15-tetramethyl-2-hexadecen-1-ol.
β-Sitosterol = (3β)-Stigmast-5-en-3-ol.
β-Sitostanol = (3β,5α)-Stigmastan-3-ol.

204 (100)) from higher plants (Ageta & Arai 1983) and diploptene (hop-22(29)-ene) (M^+ m/e 410, m/e 191 (100)) (Pihlaja et al. 1986) were the most abundant compounds. The former accounted for 31 and 30% (based on relative GC peak areas) and the latter for 18 and 16% of the hydrocarbon fractions in S and C peats, respectively. Long-chain acyclic methyl ketones were also included to this group and they will be discussed in detail elsewhere (Lehtonen and Ketola in preparation).

Non-volatile fraction

The composition of the non-volatile matter of the extracts are not described here in detail. However, this fraction consists of a mixture of unsaponifiable polymers, the structure of which is somewhere between peat estolides (mainly ω-hydroxy acid polymers) (Sundgren & Rauhala 1949, Ekman & Ketola 1981b, Ketola et al. 1986a) and humic or fulvic acids. To explain the low proportion of the non-volatile fraction in the total extract in the samples of H4 of both peats and to identify its composition in more detail is the aim of future studies.

SUMMARY AND CONCLUSIONS

The effect of humification on the extract composition of *Sphagnum* (S) and *Carex* (C) peats can be summarized as follows:

(i) The extract content of C peat (average value 9.3%) was clearly higher than

that of S peat (5.9%). The extract content of both peat types generally increased with increasing humification.

(ii) The unsaponifiable, non-volatile polymeric matter was the most abundant fraction, comprising nearly one half of the saponified extracts, in both peats. The analyzed lipids and the other-volatile materials accounted for over one third and nearly one fifth of the saponified total extracts, respectively. The total amounts of the three fractions generally increased with increasing degree of humification. Interestingly, the relative minimum of the polymers and the relative maximum of the analyzed lipids appeared in the samples of H4 in both peat types.

(iii) Fatty and ω-hydroxy acids were the most abundant lipid groups accounting together for 72 and 88% of the total analyzed lipids on average in the S and C peats, respectively. Sterol and 1-alkanol contents were appreciably higher in the S than in the C peat. α,ω-Alkanedioic acids and *n*-alkanes occurred as minor groups in both peats. The total amounts of the separate lipid groups generally increased with increasing humification. Their relative amounts seemed to vary at random.

(iv) At the individual compound level the analyzed lipid fractions in both peat series showed very similar compositions although some exceptions were also found. The effect of humification on individual compounds showed no characteristic features.

In general: (1) The extract content is dependent on the peat type and increases during the humification process, (2) the extract composition depends on the peat type and the degree of humification of the peat, (3) the lipid contents and compositions and the humification effects upon them are dependent on the peat type, and (4) peat types are characterized by certain lipid groups and individual compounds.

ACKNOWLEDGEMENTS

The authors thank Mrs. M-L. Nissi for her skillful assistance and Ms. K. Wiinamäki and Mr. P. Oksman for recording the mass spectra. We are also grateful to Mr. T. Varila for the peat samples and to the Academy of Finland for financial support.

REFERENCES

Ageta, H. & Arai, Y. 1983: Fern constituents: pentacyclic triterpenoids isolated from Polypodium niponicum and P. formosanum. — Phytochemistry 22:1801–1808.

Ekman, E. 1981: Fractionation and characterization of extracts of peat and peat-forming plants. — Technical Research Centre of Finland. Publications 2/1981, 28 p.

Ekman, R. & Ketola, M. 1981a: Analysis of lipid components in peat from a Finnish Sphagnum bog. — Kem.-Kemi 8:488–493.

Ekman, R. & Ketola, M. 1981b: Long-chain ω-hydroxy acids in Finnish Sphagnum peat. — Finn. Chem. Lett.: 44–48.

Fagernäs, L. 1986: Lipid content of peat extracts. — Tech. lic. thesis. University of Åbo Akademi, 1986, Åbo, Finland.

Ketola, M., Lehtonen, K. & Helenius, R. 1986a: Constituents of the acidic lipid polymers from a Finnish peat. — Finn. Chem. Lett. 13:155–164.

Ketola, M., Lehtonen, K. & Tolonen, K. 1986b: Maatumisasteen vaikutus Sphagnum-turpeen uuteainekseen ja sen komponentteihin. (Summary: Effect of the degree of humification on the lipid material of Sphagnum peat and on its components.) — In: Hallikas, J. (ed.), VTT Symposium 65. Turve- ja humussymposiumi (Peat and humus symposium), Turku 2–3.9.1985, Finland: 13–19. Technical Research Centre of Finland, 1986, Espoo, Finland.

Ketola, M. 1987: Suoturpeen uuteainesta koskeva kemiallinen tutkimus Turun yliopistossa 1981–1986. Suomen Akatemian tutkimuspro-

jektin 09/255 loppuraportti. Turun yliopisto, 37 s. (The chemical study on the extractable material in peat considering its utilization for the medicinal and other technological purposes 1981–1986. Final Report of the Research Project 09/255 of the Academy of Finland, University of Turku, pp. 37, in Finnish), 1987, Turku, Finland.

Lehtonen, K., Ketola, M. & Tolonen, K. 1988: Maatumisen vaikutus Bryales- ja Carex–Bryales-turpeiden uuteainekseen. (Summary: Effect of humification on the lipid material of Bryales and Carex–Bryales peats.) — In: Lehtovaara, J., Kanervirta, M-L. & Hallikas, J. (eds.), VTT Symposium 85. Suo ja turve (Bog and peat), Jyväskylä 27–28.5.1987, Finland: 65–76. Technical Research Centre of Finland, 1988, Espoo, Finland.

Luukkanen, A. 1986: Eräiden kemiallisten ja fysikaalisten ominaisuuksien vaikutus turpeen bitumisaantoon. — In: Hallikas, J. (ed.), VTT Symposium 65. Turve- ja humussymposiumi, Turku 2–3.9.1985, Finland: 28–35. Technical Research Centre of Finland, 1986, Espoo, Finland.

Pihlaja, K., Mattinen, J., Dombi, G. & Malinski, E. 1986: ^{13}C Chemical shifts of 22(29)-hopene (diploptene) and some related hopane derivatives. — Finn. Chem. Lett. 13:151–154.

Post, L. von 1922: Sveriges geologiska undersöknings torvinventering och några av dess hittills vunna resultat. — Svensk Mosskulturföreningens Tidskrift 1:1–27.

Sundgren, A. & Rauhala, V.T. 1949: Preliminary note on fatty acids of peat. — Suomen Kemistilehti B22: 24–32.

TIIVISTELMÄ:

MAATUMISEN VAIKUTUS RAHKA- JA SARATURPEISTA ORGAANISILLA LIUOTTIMILLA UUTTAUTUVAN AINEKSEN KOOSTUMUKSEEN

Työssä tutkittiin turpeen maatumisen aiheuttamia muutoksia ruotsalaisten rahka- (*Sphagnum*, S) ja saraturpeiden (*Carex*, C) orgaanisiin liuottimiin uuttautuvan aineksen koostumuksessa. Molemmat turvenäytesarjat koostuivat neljästä maatumisasteeltaan erilaisesta näytteestä (S, H2–H8; C, H3–H8), jotka oli kairattu Norrbomuren-suon (60°30'N, 17°3'E) rahka- ja sarakerrostumista vertikaalisesti. Ilmakuivatut turvenäytteet uutettiin Soxhlet-laitteessa dikloorimetaani-asetonilla (9:1 v/v) ja saadut uutteet saippuoitiin. Saippuoitu uute fraktioitiin Florisil-pylväs- ja tasokromatografisesti happo-, hiilivety-, alkoholi- ja sterolijakeisiin. Happamet yhdisteet esteröitiin diatsometaanilla ja hydroksiyhdisteet trimetyylisilyloitiin BSTFA-reagenssilla, minkä jälkeen kunkin näytteen rasvahappo-, ω-hydroksihappo-, α,ω-alkaanidihappo-, *n*-alkaani-, 1-alkanoli- ja sterolikoostumus määritettiin kaasukromatografian (HRGC) ja massaspektrometrian (HRGC-MS) avulla.

Saraturve sisälsi selvästi runsaammin uutetta kuin rahkaturve (uutetta keskimäärin: C, 9.3%; S, 5.9%). Molemmilla turvelajeilla uutteen määrä kasvoi turpeen maatumisen myötä.

Uuteaines koostui pääosin saippuoinnissa hajoamattomasta, haihtumattomasta polymeerisesta aineksesta, jota S-turpeen uute sisälsi keskimäärin 48% ja C-turpeen uute 45%. Analysoitujen lipidiyhdisteiden yhteismäärä oli keskimäärin 34% S-turpeella ja 37% C-turpeella. Loppuosa uutteista koostui analysoimattomista haihtuvista yhdisteistä, jotka olivat pääosin triterpenoideja. Kunkin kolmen ryhmän kokonaismäärä kasvoi eri tavoin turpeen maatuessa, kuitenkin siten, että analysoitujen lipidiyhdisteiden yhteismäärällä oli suhteellinen maksimi ja polymeeriaineksella vastaavasti suhteellinen minimi maatumisastetasolla H4 molemmilla turvelajeilla.

Tutkituista yhdisteistä runsaimmin esiintyi rasvahappoja (C_{13}–C_{32}) ja ω-

hydroksihappoja (C_{14}–C_{28}), joiden yhteismäärä oli keskimäärin lähes 90% ja yli 70% C- ja S-turpeiden analysoiduista lipideistä. Sterolit (β-sitosteroli dominoi) ja 1-alkanolit (C_{12}–C_{34}) esiintyivät selvästi runsaampina S-turpeessa. α,ω-Alkaanidihapot (C_9, C_{14}–C_{28}) ja *n*-alkaanit (C_{16}–C_{33}) olivat kummankin turvelajin pienkomponentteja. Yhdistesarjoissa, kuten tavallista, parillishiililukuiset homologit dominoivat paitsi *n*-alkaanien tapauksessa, missä paritonhiililukuiset jäsenet esiintyivät selvästi runsaampina. Turpeen maatuessa myös yksittäisten lipidiryhmien määrät kasvoivat (poikkeukset: S, sterolit; C, α,ω-alkaanidihapot). Maatumisvaikutus ryhmien suhteellisiin osuuksiin oli epäsäännöllinen ilman merkittäviä korrelaatioita ja terävämpi S-turpeella.

Yhdistetasolla molempien turvelajien uutteet muistuttivat suuressa määrin toisiaan, joskin selviä yksittäisiä erojakin esiintyi. Maatumisvaikutus yhdistetasolla oli samansuuntainen ryhmätasoon verrattuna, mutta epäsäännöllisempi.

Received 3.V.1988
Approved 15.XII.1988