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SURFACE HYDROCARBON COMPONENTS OF TWO SPECIES OF *Nasutitermes* FROM TRINIDAD[1]

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Abstract—Colonies of *Nasutitermes costalis* (Holmgren) and *N. ephratae* (Holmgren) were collected from five locations in Trinidad. Cuticular hydrocarbons were characterized by gas chromatography–electron impact mass spectrometry and quantified by capillary gas chromatography. Sixteen major components were identified; all but one component (12, 16-dimethyltriacontane) were common to both species. The methyl-branched hydrocarbons were predominant in *N. costalis*, while the majority of the hydrocarbon components in *N. ephratae* were *n*-alkanes. One hydrocarbon (11,15-dimethylheptacosane) was found in abundance in samples of *N. ephratae* from Trinidad but was not previously reported from collections of this species in Panama. In addition to the morphology of the soldiers and alates and the architecture of the arboreal nests, *N. costalis* and *N. ephratae* from Trinidad can easily be separated by chromatograms of the hydrocarbons. *N. costalis* has an enormous 13,17-dimethylhentriacontane peak (mean = 42.4% of total hydrocarbon). In *N. ephratae* this peak is much smaller and the 12,16-dimethyltriacontane peak is completely missing. *N. costalis* from Trinidad and *N. corniger* from Panama appear to have cuticular hydrocarbon profiles that are more similar to one another than are those of *N. ephratae* from Trinidad and Panama.

[1]Isoptera: Termitidae: Nasutitermitinae.

Key Words—Chemotaxonomy, Isoptera, Termitidae, Nasutitermitinae, cuticular hydrocarbons, Neotropical termites, *Nasutitermes costalis*, *Nasutitermes corniger*, *Nasutitermes ephratae*, Caribbean insects.

INTRODUCTION

The tropicopolitan genus *Nasutitermes* Dudley is the largest genus in the Isoptera, containing approximately 212 species worldwide (based on compiled lists in Snyder, 1949; Roonwal, 1962; Araujo, 1977). Taxonomic discrimination is based on morphological characters that are often subtle and variable or most prominent in imagoes, which are rarely collected. As part of a broad examination of the taxonomy of Neotropical *Nasutitermes* in progress by B.L. Thorne, this study was initiated with two specific goals. First, we planned to compare the hydrocarbon components of *N. ephratae* (Holmgren) collected in Trinidad with those of a Panamanian population near the opposite end of the recognized species distribution (Howard et al., 1988). Second, we wished to examine hydrocarbon patterns for *N. costalis* (Holmgren) collected near its Type locality (Trinidad) and contrast those with hydrocarbon profiles of *N. corniger* (Motschulsky) collected near its Type locality (Panama, as reported in Howard et al., 1988).

Soldiers of *N. corniger* and *N. costalis* are currently impossible to discriminate without locality information. Nest architecture is also indistinguishable. When collections are made outside of the confirmed *N. corniger range* (Central America; see Thorne, 1980) or away from the recognized *N. costalis* distribution (Caribbean islands: Snyder, 1949; Araujo, 1977), species determination is equivocal. There is currently confusion over the extent of the distribution of each of these species in northern South America, with overlapping reports of each, and identifications of each from as far as Bolivia and Brazil (Roonwal and Rathore, 1976; reviewed in Thorne, 1980). In both the present report and in the Howard et al. (1988) study, the termites were collected by B.L. Thorne (supplemented in the latter project by material collected by S.C. Levings). Field collection methods and observations of nest architecture are thus directly comparable between the two locations.

In the past we have been successful using cuticular hydrocarbons to sort the morphologically variable species of dampwood termites, *Zootermopsis* spp., into distinct, consistent hydrocarbon phenotypes (Haverty et al., 1988). These chemical phenotypes were then used to identify morphological characters for unequivocal separation of nonsoldier morphs (castes) (Thorne and Haverty, 1989). Furthermore, we used these hydrocarbon phenotypes to identify two subspecies of,*Z. nevadensis* (Hagen), *Z. n. nevadensis* (Hagen) and *Z. n. nuttingi* (Haverty and Thorne), on the basis of agonistic behavior (Haverty and Thorne, 1989). In broad terms, we sought here to supplement the data base on

surface hydrocarbons in *Nasutitermes* (Howard et al., 1988) and to see if this information (Howard and Blomquist, 1982) would help us resolve diagnostic problems within the genus. We report here the results of the characterization and quantification of the surface hydrocarbons of *N. costalis* and *N. ephratae* from Trinidad.

METHODS AND MATERIALS

Termites were collected from five separate locations in Trinidad. Trinidad is a continental island in the southeast corner of the Caribbean, where the island arcs approach the South American mainland. Fourteen colonies of *N. costalis* were collected from the following sites: six colonies from William Beebe Biological Station at Simla, Arima Valley (10°42′N, 61°17′W), one from Caura Valley (10°44′N, 61°22′W), four from Mt. St. Benedict (10°40′N, 61°24′W), and three from Matura Beach (10°40′N, 61°02′W). Nine colonies of *N. ephratae* were collected from four locations: three from Caura Valley, two from Mt. St. Benedict, three from Matura Beach, and one from Aripo Savannah (10°37′N, 61°12′W). Entire arboreal nests, or large sections of nests, were collected in the field and confined in plastic bags. Within 24 hr, live insects were removed from the carton matrix by briskly tapping a portion of nest material over sorting trays. One hundered large (female) workers were selected with forceps for extraction of hydrocarbons. Additional workers and soldiers from each colony, preserved in alcohol, have been deposited as vouchers in the collection of the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts. Species were determined on the basis of nest architecture and the pattern of setae on the tergal sclerites (Emerson, 1925; Thorne, 1980; Thorne and Levings, 1989).

Cuticular lipids were extracted in the field by immersing 100 large workers in 10 ml hexane for 10 min. Extracted workers also were preserved in alcohol as vouchers. Hexane extracts were returned to Massachusetts, then allowed to evaporate to dryness. Dry extracts were shipped to Berkeley, California, for chromatographic analysis. Extracts were redissolved in 10 ml hexane and the hydrocarbons separated from other components by pipetting the 10-ml extract and an additional 8 ml of hexane through 3 cm of activated BioSil-A in Pasteur pipet mini-columns. Hydrocarbon extracts were evaporated to dryness under a stream of nitrogen and redissolved in 30 μl of hexane for analysis.

Hydrocarbons from each sampled colony were quantified with a Hewlett Packard 5890 gas chromatograph, equipped with a fused silica capillary column (30 m × 0.2 mm ID, HP-1), operated in the split mode (with a split ratio of 8:1) with a flame ionization detector (FID). Components were separated by a temperature program from 150°C to 320°C at 3°/min with a final hold of 10 mins. Peaks were characterized by retention time, and areas under the curves

(=quantity of a particular component) were automatically quantified by a Hewlett Packard 3390A electronic integrator. The proportion of each hydrocarbon component was computed by summing the areas of the peaks of each hydrocarbon component to calculate the area of all hydrocarbon peaks and then dividing the peak area of each hydrocarbon by the total. Proportions were converted to percentages; then summary statistics were computed for each hydrocarbon for each species.

After hydrocarbon components were quantified by FID, all samples for each species were combined to ensure an adequate sample for mass spectral characterization of each hydrocarbon component. These termites contain low absolute quantities of cuticular hydrocarbons (Howard et al., 1988). One hundred workers is the minimum number for quantification of hydrocarbon peaks but is not a sufficient sample for mass spectral identification of minor hydrocarbon components. By combining samples for each species, we were able to obtain sufficient material to identify the hydrocarbon peaks and ignore those that were not hydrocarbons (mass spectra were not characteristics of aliphatic hydrocarbons). Hydrocarbons were identified by gas chromatography–electron impact mass spectrometry, using the same Hewlett Packard 5890 gas chromatograph equipped with a Hewlett Packard 5970B Mass Selective Detector interfaced with Hewlett Packard Chemstation computer. Operating conditions were the same as those used for FID analyses.

Electron impact (EI) mass spectra were obtained at 70 eV. Retention times and mass spectra of extracted *n*-alkanes were compared with an external standard mixture (n-C_{22}, n-C_{24}, n-C_{28}, and n-C_{32}). Methyl-branched alkanes were tentatively identified by calculating their equivalent chain lengths (ECL) (Jackson and Blomquist, 1976). Mass spectra of methylalkanes were interpreted as described by Blomquist et al. (1987).

RESULTS AND DISCUSSION

The extraction technique that has worked so effectively with other species of termites (Howard et al., 1978, 1980a, b, 1982; Haverty et al., 1988, 1990) was not totally satisfactory with these *Nasutitermes*. Usually the hexane extract that has passed through the mini-column contains only hydrocarbons. In our samples numerous other components, presumably terpenoid defense secretions, coeluted with the hydrocarbons and may have masked some minor hydrocarbon components. However, comparison of our results with those of Howard et al. (1988) for *N. ephratae* and *N. corniger* indicates that only very minor hydrocarbon components might have been missed.

GC-MS analyses of the cuticular hydrocarbons of *N. costalis* and *N. ephratae* from Trinidad show that each species has hydrocarbon mixtures that are

qualitatively and quantitatively distinct from one another. Sixteen major hydrocarbon components were characterized (Table 1). Hydrocarbon components consist of a homologous series of *n*-alkanes (from *n*-C_{21} through *n*-C_{30}), two isomeric series of internally branched monomethyl alkanes (11-; 13-; 15-methylnonacosane and 11-; 13-; 15-methylhentriacontane), and a series of internally branched dimethylalkanes (11,15-dimethylnonacosane, 13,17-dimethylnonacosane, 11,15-dimethylhentriacontane, and 12,16-dimethyltriacontane). We identified no unsaturated components. One component was found only in *N. costalis*: 12,16-dimethyltriacontane (12,16-DimeC_{30}) (Table 2).

The majority of the hydrocarbons of *N. ephratae* (mean of 56.7%) are *n*-alkanes, whereas the *n*-alkanes comprise less than 30% of the hydrocarbon mixture of *N. costalis* (Tables 2 and 3). Within the *n*-alkane portion of the hydrocarbon profiles of these species, both appear to partition the various components similarly; C_{25} is the predominant *n*-alkane (Table 3). The apportionment of the branched alkanes is dramatically different between the two species. In *N. ephratae* the predominant branched hydrocarbons have a parent chain with 29 carbons, whereas in *N. costalis* the predominant branched alkane has a par-

TABLE 1. HYDROCARBONS IDENTIFIED FROM LARGE FEMALE WORKERS OF *Nasutitermes costalis* AND *N. ephratae* FROM TRINIDAD

Hydrocarbon	ECL[a]	CN[a]	Diagnostic MS ions
n-Heneicosane	21.00	21	296
n-Docosane	22.00	22	310
n-Tricosane	23.00	23	324
n-Tetracosane	24.00	24	338
n-Pentacosane	25.00	25	352
n-Hexacosane	26.00	26	366
n-Heptacosane	27.00	27	380
11,15-Dimethylheptacosane	27.63	29	168/169, 196/197, 239, 267
n-Octacosane	28.00	28	394
n-Nonacosane	29.00	29	408
11-; 13-; 15-Methylnonacosane[b]	29.32	30	168/169, 280/281; 196/197, 252/253; 224/225
11,15-; 13,17-Dimethylnonacosane[b]	29.61	31	168/169, 224/225, 239, 295; 196/197, 267
n-Triacontane	30.00	30	422
12,16-Dimethyltriacontane	30.60	32	182/183, 224/225, 253, 295
11-; 13-; 15-Methylhentriacontane[b]	31.33	32	168/169, 308/309; 196/197, 280/281; 224/225, 252/253
13,17-Dimethylhentriacontane	31.64	33	196/197, 224/225, 267, 295

[a] ECL = equivalent chain length, CN = carbon number.
[b] An isomeric mixture or two or more components coelute in this peak.

TABLE 2. MEAN PERCENT HYDROCARBON AND STANDARD DEVIATION FROM LARGE FEMALE WORKERS OF *Nasutitermes costalis* AND *N. ephratae* FROM TRINIDAD

	N. costalis (14 colonies)					*N. ephratae* (9 colonies)				
Hydrocarbon[a]	$\bar{X}$	SD	Min. value[b]	Max. value	Proportion ≤0.5% of total[c]	$\bar{X}$	SD	Min. value[b]	Max. value	Proportion ≤0.5% of total[c]
n-C_{21}	2.07	1.74	0.00	5.22	0.29	5.51	3.64	0.00	12.64	0.11
n-C_{22}	2.34	2.18	0.00	5.46	0.36	6.97	4.43	0.00	13.84	0.11
n-C_{23}	1.79	1.66	0.00	4.17	0.36	5.91	4.36	0.00	14.63	0.11
n-C_{24}	2.84	1.79	0.00	5.77	0.07	7.92	4.26	3.71	16.47	0.00
n-C_{25}	6.03	3.02	2.84	14.19	0.00	11.58	7.08	5.33	27.31	0.00
n-C_{26}	2.15	1.66	0.00	5.72	0.07	4.12	4.09	0.00	13.98	0.11
n-C_{27}	2.57	2.13	0.00	6.93	0.29	5.26	4.31	0.00	10.64	0.33
11,15-DimeC_{27}	1.95	1.89	0.00	5.32	0.29	6.45	4.90	0.00	15.57	0.22
n-C_{28}	1.05	1.42	0.00	3.48	0.57	1.41	2.21	0.00	5.04	0.67
n-C_{29}	3.94	2.89	0.00	8.32	0.14	2.30	2.49	0.00	6.28	0.44
11-; 13-; 15MeC_{29}	4.17	1.19	2.11	6.51	0.00	13.82	11.16	0.00	33.52	0.22
11,15-; 13,17-DimeC_{29}	8.39	3.41	0.00	13.59	0.07	16.06	5.17	7.83	24.69	0.00
n-C_{30}	4.67	2.27	0.00	7.96	0.07	5.69	5.77	0.00	14.27	0.44
12,16-DimeC_{30}	9.09	4.98	0.00	17.25	0.07	0.00	0.00	0.00	0.00	1.00
11-; 13-; 15-MeC_{31}	4.56	2.86	0.00	8.54	0.21	2.57	4.54	0.00	13.24	0.67
13,17-DimeC_{31}	42.42	10.98	20.35	59.30	0.00	4.43	7.31	0.00	18.62	0.67

[a] Hydrocarbons are the same as those reported in Table 1. Carbon number (C_n) is the total number of carbons in the parent chain, excluding the methyl groups.
[b] Values not necessarily zero but may have very low quantity (≤0.5% of the total hydrocarbon) or were simply not detectable for a given GLC analysis.
[c] Proportion of the chromatograms where a given hydrocarbon was not detectable.

TABLE 3. MEAN PERCENTAGE AND STANDARD DEVIATION OF EACH HYDROCARBON WITHIN SAME HYDROCARBON CLASS AND MEAN PERCENTAGE AND STANDARD DEVIATION OF *n*-ALKANES AND METHYL-BRANCHED ALKANES FROM LARGE FEMALE WORKERS OF *N. costalis* AND *N. ephratae* FROM TRINIDAD

Hydrocarbon[a]	*N. costalis* (14 colonies)		*N. ephratae* (9 colonies)	
	$\bar{X}$	SD	$\bar{X}$	SD
n-Alkanes				
n-C_{21}	6.03	4.44	8.95	4.36
n-C_{22}	6.36	5.12	11.52	5.82
n-C_{23}	4.80	3.99	9.33	4.98
n-C_{24}	9.02	3.82	14.15	6.32
n-C_{25}	26.23	22.21	19.50	6.56
n-C_{26}	6.54	3.21	7.06	5.17
n-C_{27}	7.09	4.72	10.03	7.82
n-C_{28}	2.43	3.18	2.42	3.70
n-C_{29}	12.50	9.50	4.00	4.12
n-C_{30}	19.00	15.21	13.03	15.59
Branched alkanes				
11,15-DimeC_{27}	2.86	2.86	12.90	8.48
11-; 13-; 15-MeC_{29}	6.08	1.70	27.34	18.65
11,15-; 13,17-DimeC_{29}	11.64	3.93	46.20	31.50
12,16-DimeC_{30}	12.49	6.12	0.00	0.00
11-; 13-; 15-MeC_{31}	6.97	4.09	5.03	8.60
13,17-DimeC_{31}	59.96	5.22	8.53	13.64
Total *n*-alkanes	29.44	16.52	56.67	18.07
Total branched alkanes	70.56	16.52	43.33	18.07

[a] Hydrocarbons are the same as those reported in Table 2.

ent chain of 31 carbons (Table 3). Probably the most obvious difference, for chemotaxonomic discrimination of these two species, is the disparity between the comparatively large amount of 13,17-DimeC_{31} in *N. costalis* and the apparent absence of 12,16-DimeC_{30} in *N. ephratae*. This pattern was consistent in all 23 sampled colonies.

One of the species we examined from Trinidad, *N. ephratae*, was also examined by Howard et al. (1988) from Panama. These two localities are near the eastern and western extremes of its distribution. Striking similarities in morphology of both soldiers and primary reproductives and in arboreal nest architecture make us confident that specimens from Panama and Trinidad belong to the same "morphospecies" (Thorne, 1980). Specimens from these locations have been determined as such by both T.E. Snyder and A.E. Emerson, who examined material from both localities, although they did not collect first-hand.

Based on preliminary data, genera of staphylinid termitophiles (*Perinthus* and *Termatogaster*) found in *N. ephratae* nests from Panama and Trinidad overlap in part, but the beetle species are different (Thorne, in preparation).

Howard et al. (1988) reported numerous terminally branched monomethyl components that occurred in very low abundance ($\leq 1.85\%$ of the methyl-branched components) in Panamanian *N. ephratae*. These components may have been present in our samples but in concentrations below the detectability of our GLC system, or they may have been masked by the terpenoid defense secretions. Nonetheless, the very low abundance of these components renders them inadequate as taxonomic characters (Haverty et al., 1989; Page et al., 1990).

We observed additional significant qualitative differences between the Trinidad and Panama populations of *N. ephratae*. Howard et al. (1988) reported considerable quantities of 12,16-DimeC_{30} in *N. ephratae*; we never identified this component in this species from Trinidad. In addition, we identified a plentiful component (11,15-DimeC_{27}) in both *N. ephratae* and *N. costalis* from Trinidad that was not identified in either *N. ephratae* or *N. corniger* from Panama. The homolog of this component (11,15-DimeC_{29}) was identified in significant amounts from the three *Nasutitermes* from Panama and Trinidad and is the predominant component of the cuticular hydrocarbon profile of *N. ephratae* from Trinidad.

Hydrocarbon profiles of *N. corniger* from Panama and *N. costalis* from Trinidad are more similar than are the hydrocarbon patterns of *N. ephratae* from Panama and Trinidad. Not only do *N. costalis* and *N. corniger* share the same hydrocarbon components, with the exception of the minimally abundant 11,15-DimeC_{27} ($\leq 2.9\%$ of the branched-hydrocarbon component), but they apparently possess the two predominant dimethyl alkanes, 12,16-DimeC_{30} and 13,17-DimeC_{31}, in roughly equivalent proportions: 12.5 vs 14.2 and 60.0 vs 55.9% of the methyl-branched alkanes, respectively (Table 3) (Table 2; Howard et al., 1988). Based on these analyses, it appears that *N. costalis* from Trinidad and *N. corniger* from Panama, two "distinct" species, are more similar in terms of surface hydrocarbons than are populations of *N. ephratae* from these same locations. Morphology and nest architecture of *N. costalis* and *N. corniger* are also quite similar and are currently being examined in detail (Thorne, in preparation).

This present study represents only the third report of the cuticular hydrocarbons of species of *Nasutitermes*, one of the most ubiquitous and abundant pantropical groups of termites. Moore (1969) provided the first preliminary description of the cuticular lipids of the Australian termite, *N. exitiosus* (Hill). He reported that the unsaturated component comprised the majority of the cuticular lipids. Analysis of the saturated fraction revealed normal paraffins from C_{24} to C_{47}. No methyl-branched components were described. His results are drastically different from those reported here or by Howard et al. (1988).

Similarities among the hydrocarbon mixtures of the three species of *Nasutitermes* most recently examined, here and by Howard et al., (1988), *and* the apparent qualitative and quantitative differences in hydrocarbon profiles of *N. ephratae* from the extremes of the species' distribution raise some interesting questions. Are cuticular hydrocarbons valuable chemotaxonomic characters for all *Nasutitermes* species or do hydrocarbon profiles show intraspecific variability, as has been found with defense secretion components (Gush et al., 1985)? In this study, the hydrocarbon component (11,15-DimeC_{27}) is the homolog to a component (11,15-DimeC_{29}) found in all of the investigated *Nasutitermes* species from both localities. Because of this close chemical similarity, the presence or absence of the additional variant (11,15-DimeC_{27}) might be due to a minor polymorphism between the two *N. ephratae* populations.

As has been found with other taxonomic character systems, hydrocarbon profiles may not show exact qualitative and/or quantitative species specificity, especially across a broad geographic range. Further sampling within *Nasutitermes* and in other groups should be encouraged to determine the prevalence of such variability and to ascertain its biological and taxonomic relevance.

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