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ABSTRACT

The lipids and fatty acids from the fruit-coats, pollens, and seeds of a number of palm species belonging to seven subfamilies were characterized and used to evaluate the taxonomic position of the Palmae. Fruit-coat and pollen lipids gave no definite patterns and therefore did not offer data for taxonomic considerations. The seed lipids, on the other hand, showed remarkable persistence for fatty acids in a number of the subfamilies. Contrary to established belief, lauric and myristic acids were not the principal fatty acids in all groups. The amount of these acids depended on the gross anatomy of the seed.

INTRODUCTION

The family Palmae, estimated to consist of about 217 genera and about 2500 species (Burret, 1956), ranks among the Graminae and Leguminosae in economic importance to man. Apart from their many other uses (clothing, timber, fuel, building material, fibre, paper, dyes, sugar, wine, etc.) the entire world still depends upon the palm family for some important vegetable oils and waxes. Palm classification which has been based on recognized morphological and anatomical features is a relatively young field compared with the well-studied groups such as the Leguminosae and the grasses. The family is a unique and isolated group of monocotyledons with no known ancestral links (Corner, 1966). As a result there are many uncertainties in the accepted classification of palms which arise from lack of theory or understanding as well as from lack of information.

This communication which sums up the results of the investigation of the lipids (mainly fatty acids) of the mesocarps, kernels, and pollens is presented in an attempt to evaluate the taxonomic standing of 35 species belonging to seven subfamilies in the Palmae.

MATERIALS AND METHODS

The palm fruits, seeds, and pollens, except for those of *Raphia* spp., were collected from the Palmetum of the Nigerian Institute for Oil Palm Research, near Benin City. *Raphia* fruits and pollens were collected from experimental groves in a nearby stream and from other parts of the country. The pollens were hand-collected, sealed under vacuum and kept in the deep-freeze until ready for use.

Extraction of lipids

The mesocarps were scraped off the nuts and homogenized with a small volume of iso-propanol in a mortar or Waring blender. The mixture was filtered and the residue further extracted with chloroform–methanol (2:1, by vol.) at room temperature. The combined extracts were concentrated *in vacuo*, the water-soluble impurities in the concentrate removed according to the methods of Folch, Lees, and Stanley (1957), and the chloroform layer concentrated and stored under nitrogen in the deep-freeze. The seed or kernel lipids were similarly extracted after pulverization in a ball mill. Pollen lipids were extracted as earlier described (Opute, 1975).

Chromatography of lipids

Lipid classes and the fatty acids were investigated through a combination of thin layer and gas-liquid chromatography. Qualitative t.l.c. was carried out on 250 nm Prekotes (Applied Science) and developed in petroleum ether–ether–formic acid (70:30:1, by vol.). Polar lipids were characterized by using chloroform–methanol–acetic acid–water (85:15:10:4, by vol.) as the solvent system. The lipid classes were identified by using authentic samples as standards and by reference to relative R_F values (Kates, 1972).

The fatty acid methyl esters were prepared by transmethylation of the lipids according to the methods of Feldman, Johnson, Culp, and Gowan (1962). The concentrated hexane extracts of the fatty acid methyl esters were chromatographed isothermally on a 2·1 m × 6 mm (i.d.) glass column packed with HI-EFF 1,4-butanediol succinate polyester (Applied Science) on AW-DMCS Chromosorb W (80–100 mesh), using a Pye Series 104 gas chromatograph equipped with a flame ionization detector. Oxygen-free nitrogen was used as the carrier gas at a flow rate of 50 ml min^{-1}. The fatty acids were identified through the use of authentic samples and the plot of the log of retention times against carbon number. Concentrations of each component were calculated from peak areas by triangulation and expressed as percentages of the total.

RESULTS AND DISCUSSION

Tables 1, 2, and 3 outline the fatty acid patterns of the mesocarp, pollen, and seed lipids of the palms studied, and are presented according to subfamilies (Beccari and Pichi-Sermolli, 1956). The qualitative patterns of the mesocarp or fruit-coat lipids and the quantitative analysis of the corresponding fatty acids (Table 1) resembled one another in all palms. Triglycerides were the major lipid class while palmitic, oleic, and linoleic acids were the major fatty acids. In this regard they were

TABLE 1. *Fatty acid distribution in palm fruit-coat lipids*

Subfamily	Palm sp.	Fatty acids (%)							
		10:0	12:0	14:0	16:0	18:0	18:1	18:2	18:3
Arecoideae	*Areca sp.*	—	—	—	27·2	13·4	34·9	13·8	10·8
	Bentinckia nicobarica	—	1·0	1·5	21·3	7·4	20·3	30·9	12·4
	Veitchia merrillii	—	—	—	40·1	3·3	21·1	32·4	3·0
	Verschaffeltia splendida	1·5	—	5·6	26·1	5·1	7·7	32·7	18·1
Bactroideae	*Aiphanes acanthophylla*	3·6	—	17·1	23·5	3·8	4·1	33·3	14·5
Borassoideae	*Borassus flabellifer*	—	—	2·8	16·8	5·9	53·5	14·9	5·4
Caryotoideae	*Caryota mitis*	3·1	—	7·1	27·2	3·8	4·2	28·0	20·9
Cocoideae	*Arecastrum romanizoffianium*	1·7	0·7	5·9	33·2	2·7	6·8	26·6	21·7
	Butia capitata	t	t	t	34·1	2·2	20·3	28·0	11·0
	Elaeis guineensis	—	—	1·0	42·1	3·8	44·3	8·6	—
	E. oleifera	—	—	0·2	20·8	1·0	55·1	20·3	—
Lepidocaryoideae	*Raphia sudanica*	—	—	—	29·7	1·6	39·7	26·6	1·8
	R. hookeria	—	—	0·5	32·3	5·2	13·2	47·3	1·1
	R. vinifera	—	t[a]	t	35·2	2·6	32·8	29·8	t
	R. regalis	—	t	t	17·0	33·2	48·8	t	t
Sabaloideae	*Seronoa repens*	—	0·6	0·6	25·9	3·9	27·2	16·0	23·2

[a] t = trace.

generally similar to fruit-coat lipids and fatty acids of other plants (Hilditch and Williams, 1964). The pollen lipids, on the other hand, contained both neutral (triglycerides) and polar lipids (phospholipids and glycolipids) with a fatty acid composition (Table 2) of a higher level of unsaturation due to the presence of linolenic acid, an acid usually associated with green tissues of plants. The amount of polar lipids and linolenic acid in fruit-coat lipids was closely correlated with the degree of greenness of the fruit mesocarp. Thus the oil palm (*Elaeis guineensis*) fruits which appeared red in colour due to the preponderance of carotenoids did not contain appreciable amounts of polar lipids and linolenic acid.

TABLE 2. *Fatty acid distribution in palm pollen lipids*

Subfamily	Palm sp.	Fatty acids (%)								
		10:0	12:0	14:0	16:0	18:0	18:1	18:2	18:3	20:0
Arecoideae	*Bentinckia nicobarica*	1·6	0·7	0·5	28·9	4·6	16·9	29·6	16·3	
	Archontophoenix alexandrae	0·4	—	0·8	36·3	2·7	10·9	39·5	17·9	1·3
	Ptychosperma sanderianus	—	—	—	30·1	3·9	12·7	42·7	10·6	t
	Roystonia regia	0·6	t	1·2	22·9	6·0	4·9	34·0	27·2	2·5
Borassoideae	*Latania borbonica*	1·6	—	4·1	29·5	4·0	6·9	33·3	20·5	t
Caryotaoideae	*Caryota mitis*	1·1	1·2	3·6	26·7	3·9	7·0	37·5	16·4	1·2
Cocoideae	*Cocos nucifera*	—	—	—	28·7	4·4	9·5	34·8	20·2	1·2
	Elaeis guineensis	—	0·2	0·5	27·1	6·0	7·9	37·4	20·9	1·2
	E. oleifera	—	0·4	0·5	38·8	6·1	1·1	27·7	23·0	1·8
Lepidocaryodeae	*Raphia hookeri*	8·6	t	13·1	22·1	4·0	2·9	42·0	6·6	—
	R. regalis	0·4	0·4	0·6	26·1	8·3	10·1	32·2	17·1	—
	R. sudanica	7·4	t	4·5	18·6	11·5	13·7	41·3	2·0	—
	R. vinifera	4·5	t	3·5	28·2	5·1	17·3	35·5	3·3	—

The pollen lipids, especially fatty acids, like those of the fruit-coat lipids, neither deviated significantly in the subfamilies investigated nor from those of other plants (Ching and Ching, 1962; Standifer, 1966; Opute, 1975). The seed lipids, on the other hand, varied from a little over 1% in the *Raphia* species to well over 60% in *Elaeis guineensis*. In the majority of species, typified by *E. guineensis*, triglycerides were the principal storage lipids accompanied by trace amounts of sterols and phospholipids, while in certain others, represented by the *Raphia* species, the lipids contained varied polar types mainly phospholipids and glycolipids with small amounts of triglycerides, waxes, and sterols. In mature plant seeds the major class of lipids is triglycerides, which may constitute between 10 and 70% of the dry weight, while phospholipids and glycolipids normally represent less than 2% of the total seed lipids (Wolff, 1966). Known exceptions to this rule, as of date, occur in the seeds of a member of the Graminae, *Briza spicata*, which contained some 20% of lipid of which about 78% was galactosyl diglycerides (Smith and Wolff, 1966) and in the plant species *Simmondsia californica* (Green, Hilditch, and Stainsby, 1936) and *Murraya koenigii* (Kartha and Singh, 1969) in which the major lipid component was wax ester and hydrocarbon.

Based on these results, therefore, fruit-coat and pollen lipids of palms did not offer data for critical taxonomic considerations. On the other hand, seed or kernel lipids of palms contained an unusual and extremely varied mixture of saturated and unsaturated fatty acids (Table 3). Of the seven subfamilies investigated, the majority of species in each subfamily manifested relatively close patterns of fatty

TABLE 3. *Fatty acid distribution in palm seed lipids*

Subfamily	Palm sp.	Fatty acids (%)								
		8:0	10:0	12:0	14:0	16:0	18:0	18:1	18:2	18:3
Arecoideae	*Areca sp.*	t	t	18·5	19·8	12·0	2·2	22·3	25·3	—
	Bentinckia nicobarica	t	t	32·9	24·4	13·3	4·2	11·8	13·9	—
	Onchosperma horrida	t	t	54·2	23·0	7·2	t	15·6	t	—
	Roystonia regia	t	t	44·5	14·0	7·5	3·3	18·5	9·9	—
	Veitchia merrillii[a]	t	0·4	t	1·2	22·9	5·2	27·6	40·7	—
	Verschaffeltia splendida	t	t	14·9	23·6	18·1	3·2	20·0	20·2	—
Bactroideae	*Aiphanes acanthophylla*	t	t	41·5	20·5	10·2	3·4	15·8	7·4	—
	Bactris major	1·8	1·6	50·8	24·6	7·0	2·7	7·6	3·8	—
Borassoideae	*Borassflabellifer*[a]	t	t	t	t	29·5	4·4	31·9	34·2	—
	Hyphaene schatan	t	t	34·6	16·5	9·0	3·7	30·0	4·8	—
	Latania loddigesii	2·7	1·0	37·9	13·1	7·1	4·4	28·4	5·3	—
Caryotoideae	*Caryota mitis*	t	t	10·4	13·5	27·5	2·0	20·5	15·3	3·1
	C. urens	1·8	1·8	24·0	15·3	27·3	t	17·5	12·4	—
Coccoideae	*Arecastrum romanizoffianum*	t	1·8	58·1	21·4	6·1	2·4	10·3	t	—
	Buttia capitata	12·0	15·8	43·2	6·4	4·2	3·0	11·9	3·5	—
	Cocos nucifera	9·5	4·6	51·0	17·5	7·6	3·0	5·1	1·2	—
	Elaeis guineensis	2·7	7·0	46·9	14·1	7·8	1·3	18·5	1·7	—
	Orbingya cohune	7·0	5·9	50·8	18·4	9·0	3·2	5·6	—	—
	Elaeis oleifera	1·4	1·3	31·7	20·8	11·3	2·8	26·0	4·8	—
Lepidocaryoideae	*Raphia hookeri*	t	t	0·8	1·7	23·0	1·8	31·1	32·5	4·2
	R. sudanica	t	t	1·0	1·2	27·0	3·9	35·8	28·8	1·6
	R. vinifera	t	t	0·7	1·1	28·3	3·7	22·9	38·6	2·8
	R. farinifera	3·1	t	t	1·9	38·7	4·5	35·6	14·7	t
	R. regalis	7·3	t	4·0	6·3	25·6	5·3	19·3	30·5	t
Sabaloideae	*Coccothrinax argentea*	0·6	0·8	43·8	14·4	7·7	4·4	17·6	10·7	—
	C. miraguama	t	t	44·9	15·1	8·0	4·5	14·6	13·0	—
	Livistonia rotundifolia[a]	t	t	t	0·5	22·4	8·5	38·3	29·8	tt
	Sabal blackburniana	0·5	0·5	24·4	11·9	8·1	2·0	37·1	15·6	—
	S. mexicana	0·7	0·5	21·6	9·2	6·5	2·2	41·6	17·7	—
	S. palmetto	t	t	15·9	10·4	7·1	5·0	46·4	15·2	—
	S. texana	t	t	21·7	8·6	5·9	2·3	44·4	16·8	—

[a] 'Raphia' type palms.

acid distribution with remarkably little quantitative variation. Of significance was the high concentration of lauric and myristic acids, the former acid being more dominant and exceeding 40% by weight of the total fatty acids in a number of species. Myristic acid concentration on average varied between 15 and 20%. The regular persistence of these two acids in almost all species of palms hitherto studied had led to the inclusion of the family Palmae among the few families of plants said to be rich in lauric and myristic acids (Hilditch and Williams, 1964).

The results obtained in this study which confirms a previous one (Opute, 1978*a*) clearly show that in the subfamily Lepidocaryoideae, and in a few isolated palms in other groups, lauric and myristic acids occurred in minor quantities or as trace amounts. Palms in this category generally had fats with a higher degree of unsaturation due to the presence of large amounts of oleic and linoleic acids. This high degree of unsaturation was directly correlated with the paucity of the fats and the presence of vegetable ivory in the endosperms (Opute, 1978*b*). Two variations of seed endosperms were also confirmed: the 'oil palm kernel' type with seeds consisting of relatively hard oily endosperms, greyish or brownish in colour, and the '*Raphia*' type, made up of very hard, stony and waxy endosperms containing vegetable ivory. The former which is typical of most plant endosperms yielded lipids, the bulk of which were triglycerides containing the saturated acids (lauric and myristic) as major fatty acids, while the latter gave lipids which contained

varied polar types and yielding unsaturated acids (oleic and linoleic) as principal fatty acids.

In palms, therefore, the dominance or presence of lauric and myristic acids or the unsaturated fatty acids (oleic and linoleic) seems to depend on the anatomy of the endosperm. This statement is further strengthened by reference to the fatty acid composition of three palms (asterisked in Table 3) not belonging to but resembling palms in the subfamily Lepidocaryoideae, in their seed anatomy. *Veitchia merrillii* (subfamily Arecoideae), *Borass flabellifer* (subfamily Borassoideae), and *Livistonia rotundifolia* (subfamily Sabaloideae) resembled the seeds of *Raphia* (subfamily Lepidocaryoideae) in not only possessing substantial amounts of vegetable ivory but also in containing high levels of unsaturated fatty acids. Similarly the seeds of the date palm, *Phoenix dactylifera* (subfamily Phoenicoideae), which resembled *Raphia* seeds in their anatomy was reported by Hilditch and Williams (1964) as possessing little endosperm fats and having high saponification and iodine values which are indicative of unsaturated fatty acids.

Using anatomical and morphological evidence, Beccari and Pichi-Sermolli (1956) suggested 12 subfamilies in their classification of palms. The lipid compositions of representatives from seven of these sub-families were investigated in this study. On the basis of lipid classes and fatty acid compositions, the three palms, *Borassus flabellifer*, *Livistonia rotundifolia*, and *Veitchia merrillii*, which are at present included in three different subfamilies, deserve a much closer look. On the basis of their lipid and fatty acid composition these palms have very strong affinity with the subfamily Lepidocaryoideae. On the other hand, the results reported here imply that the subfamilies Arecoideae and Sabaloideae contained scattered species of variable and heterogenous characteristics perhaps suggesting evolutionary differences. However, it is considered premature at this stage, on the strength of available data, to suggest further subdivision of these families. As new information based on more analyses and studies become available, clear-cut relations between the lipid and fatty acid patterns of the palm seeds and the suggested subfamilies would emerge. Nevertheless while more data on the seed lipids of members of the Palmae is desirable, it is pertinent to suggest here that biochemical data obtained from the study of palms could be relevant to their phylogenetic and taxonomic relationships.

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