Phytochemistry, 1975, Vol. 14, pp. 1063–1066. Pergamon Press. Printed in England.

TRITERPENOIDS FROM TEN *LITHOCARPUS* SPECIES OF HONG KONG

WAI HAAN HUI, PHYLLIS D. S. KO, YUK-CHUN LEE, MAN-MOON LI and (in part) (the late) HENRY R. ARTHUR

Department of Chemistry, University of Hong Kong, Hong Kong

(*Received* 21 *August* 1974)

Key Word Index—*Lithocarpus* species; Fagaceae; triterpenes of the oleanane and rearranged oleanane, lupane and rearranged lupane, and hopane groups; phytosterols.

Abstract—From the petrol extracts of the leaves and stems of ten *Lithocarpus* species (*L. attenuata*, *L. cornea*, *L. elizabethae*, *L. glabra*, *L. haipinii*, *L. hancei*, *L. harlandi*, *L. irwinii*, *L. litchioides*, and *L. polystachya*) of the Fagaceae family, were isolated 23 different triterpenoids, and sitosterol and stigmasterol. Of the triterpenoids, 11 belonged to the oleanane and rearranged oleanane group [β-amyrin, friedelin, friedelan-3β-ol, glutinol, taraxerone, taraxerol and its acetate, canophyllol (28-hydroxyfriedelan-3-one), friedelan-2,3-dione (3-hydroxyfriedel-3-en-2-one), pachysandiol-A (2α,3β-dihydroxyfriedelane) and a new compound lithocarpic lactone $C_{30}H_{50}O_2$]. Four compounds were from the lupane and rearranged lupane group (lupenone, lupeol, betulin and taraxasterol), 2 from the hopane group (22-hydroxyhopan-3-one and 3β,22-dihydroxyhopane), and 6 were probably new compounds.

INTRODUCTION

Work on some plants of two genera (*Quercus* [1–3] and *Castanopsis* [4, 5]) of the Fagaceae family of Hong Kong has been reported. The third genus, *Lithocarpus*, has never been previously examined either in Hong Kong or elsewhere, and it does not seem to have been used medicinally, though *ca* 100 species are known, mostly in south-east Asia. Of the 16 identified local species of this genus [6], six are rare. We report here the triterpenoids and sterols isolated from the petrol extracts of both the leaves and stems of the 10 more common species, namely *L. attenuata* (Skan) Schky, *L. cornea* (Lour.) Rehd., L. elizabethae (Tutch.) Rehd., *L. glabra* (Thunb.) Nakai, *L. haipinni* Chun., *L. hancei* (Benth) Rehd., *L. harlandi* (Hance) Rehd., *L. irwinii* (Hance) Rehd., *L. litchioides* Chun, and *L. polystachya* (Wall.) Rehd.

RESULTS AND DISCUSSION

The concentrated petrol extracts of the leaves and stems of each of the 10 *Lithocarpus* species were examined separately by column chromatography on alumina. The distribution of compounds isolated is listed in Table 1. This genus, as well as the other two local Fagaceae genera, appears to be characteristic in yielding the friedelane type of rearranged oleanane derivatives. Friedelin and friedelan-3β-ol have been found in all species examined [1–5] and the occurrence of these compounds in *Quercus* is well known. Other friedelane derivatives isolated in this survey were friedelan-2,3-dione (3-hydroxyfriedel-3-en-2-one), canophyllol (28-hydroxyfriedelan-3-one) which has also been obtained from *Castanopsis concinna* [5], and pachysandiol-A (2α,3β-dihydroxyfriedelane), the natural occurrence of which has only been reported once from *Pachysandra terminalis* [7]. The first two compounds were found in only one species; the last in four species. A new lactone, for which we propose the name lithocarpic lactone, $C_{30}H_{50}O_2$, (M^+, *m/e* 442), mp 319–320°, $[\alpha]_D$ + 54·0°, ν_{max}: 1745, 1194 cm^{-1}, was isolated from the leaves of *L. litchioides* and *L. irwinii*. β-Amyrin, glutinol, taraxerone, taraxerol and its ace-

Table 1. Triterpenoids and steroids from *Lithocarpus* species

Compounds isolated	Species	
	Stems	Leaves
β-Amyrin		*L. cornea*, *L. glabra*, *L. hancei*, *L. harlandi*, *L. litchioides*, *L. polystachya*
Friedelin	all *L.* species	all *L.* species
Friedelan-3β-ol	all *L.* species except *L. litchioides*	all *L.* species
Lithocarpic lactone		*L. irwinii*, *L. litchioides*
Canophyllol (28-Hydroxyfriedelan-3-one)		*L. haipinii*
Pachysandiol-A (2α.3β-Dihydroxyfriedelane)	*L. hancei*	*L. attenuata*, *L. harlandi*, *L. irwinii*, *L. litchioides*
Friedelan-2,3-dione (3-Hydroxyfriedel-3-en-2-one)		*L. irwinii*
Glutinol		*L. cornea*, *L. glabra*, *L. hancei*, *L. polystachya*
Taraxeryl acetate		*L. cornea*
Taraxerone	*L. cornea*	
Taraxerol	*L. cornea*, *L. elizabethae*, *L. glabra*	*L. cornea*, *L. elizabethae*, *L. glabra*, *L. hancei*, *L. harlandi*, *L. litchioides*, *L. polystachya*
Lupenone	*L. harlandi*	
Lupeol	*L. elizabathae*, *L. haipinii*, *L. hancei*, *L. irwinii*, *L. litchioides*	*L. attenuata*, *L. haipinii*, *L. irwinii*
Betulin	*L. elizabethae*, *L. haipinii*	
Taraxasterol	*L. irwinii*	*L. attenuata*, *L. irwinii*
22-Hydroxyhopan-3-one (Hydroxyhopanone)		*L. attenuata*
3β.22-Dihydroxyhopane		*L. attenuata*
A_1, A_2, A_3	*L. cornea*	
B_1, B_2, B_3		*L. polystachya*
Sitosterol	all *L.* species	all *L.* species
Stigmasterol	*L. irwinii*	

tate were other oleanane and rearranged oleanane derivatives obtained.

Hopane, and lupane and rearranged derivatives, which occur in *Castanopsis* species, were also found in some of the species examined. The compounds identified were 22-hydroxyhopan-3-one, 3β,22-dihydroxyhapane of the former group, and lupenone, lupeol, betulin and taraxasterol of the latter. The only previous report on the natural occurrence of 3β,22-dihydroxyhopane was from *C. eyrei* [4].

Three apparently new pentacyclic triterpenoids were obtained from the stems of *L. cornea* in small quantities. The first (A_1), $C_{30}H_{50}O_2$ (M^+, *m/e* 442),

mp 254–256°, was a saturated ketol, ν_{max}: 3525 (OH), 1700 cm^{-1} (C=O); the second (A_2), $C_{30}H_{48}O_2$, (M^+, *m/e* 440), mp 238–242°, a ketol with a trisubstituted double bond, ν_{max}: 3550 (OH), 1715 (C=O), 3050, 1650, 820 cm^{-1} (>C=CH–) and the third (A_3), $C_{30}H_{50}O_2$, (M^+, *m/e* 442), mp 295–297°, a diol with a trisubstituted double bond, ν_{max}: 3380 (OH), 3055, 1650, 820 cm^{-1} (>C=CH–).

Another three unidentified compounds were isolated from the leaves of *L. polystachya*, the first (B_1) m.p. 190–192°, was a saturated ketol, ν_{max}: 3450 (OH), 1710 cm^{-1} (C=O), the second (B_2) mp 179–180°, a saturated hydroxy compound, ν_{max}: 3350 cm^{-1} (OH), and the third (B_3) mp 165–168°, a hydroxy compound with a vinylidene group, ν_{max}: 3350 (OH), 1650, 890 cm^{-1} (>C=CH_2).

Of the phytosterols, sitosterol was found in all species but stigmasterol was in only one.

EXPERIMENTAL

IR spectra were recorded for KBr discs or nujol mulls, NMR spectra in $CDCl_3$, UV spectrum in 95% EtOH, and optical rotations in $CHCl_3$. Known compounds were identified by m.m.p. and IR spectral comparisons with authentic samples.

Extraction. For each of the ten species, air-dried plant material was milled, then extracted twice at room temp. with petrol b.p. 60–80°. The combined extracts were evaporated to a small vol. or to dryness.

L. attenuata. *Leaves* (26 kg): the extract (210 g) was chromatographed on alumina (4·5 kg) eluted with petrol and first gave friedelin (7·0 g), m.p. 260–261°, $[\alpha]_D$ − 28·3°, IR ν_{max}: 1720 cm^{-1}, next friedelan-3β-ol (5·0 g), m.p. 286–289°, $[\alpha]_D$ + 23·9°, IR ν_{max}: 3630 cm^{-1}, then lupeol (1·0 g) 192–198°, $[\alpha]_D$ + 28·1°, IR ν_{max}: 3350, 3070, 1650, 880 cm^{-1} (acetate, m.p. 219–220°), and finally taraxasterol (0·6 g), m.p. 224–226°, $[\alpha]_D$ + 106·7°, IR υ_{max}: 3400, 3080, 1650, 880 cm^{-1} (acetate, m.p. 244–246°). Further elution with petrol–C_6H_6 (1:1) gave first sitosterol (1·5 g), m.p. 139–141°, $[\alpha]_D$ − 35·8°; then 22-hydroxyhopan-3-one (1·1 g), m.p. 254–256° (from $CHCl_3$), $[\alpha]_D$ + 67·0°, MS: *m/e* 442 (M^+) $C_{30}H_{50}O_2$, IR ν_{max}: 3480, 1720 cm^{-1} (sodium borohydride reduction yielded 3β,22-dihydroxyhopane, m.p. 279–282°, IR ν_{max}: 3300 cm^{-1}). C_6H_6 elution gave 3β,22-dihydroxyhopane (0·65 g), m.p. 280–282°, $[\alpha]_D$ + 51·0°, IR ν_{max}: 3300 cm^{-1} (oxidation with Jones' reagent gave 22 hydroxyhopan-3-one, m.p. 253–256°). Finally C_6H_6–$CHCl_3$ (1:1) yielded pachysandiol-A (0·01 g), m.p. 280–283° (from C_6H_6), IR ν_{max}: 3500 cm^{-1}. *Stems* (26 kg): the extract (75 g) was chromatographed on alumina (3 kg) as for the leaves. Elution with petrol afforded friedelin (3·7 g), then friedelan-3β-ol (0·5 g); petrol–C_6H_6 (1:1) gave sitosterol (1·2 g).

L. cornea. *Leaves* (4 kg): the extract (110 g) was chromatographed on alumina (2·5 kg). Elution with petrol–C_6H_6(4:1) gave taraxeryl acetate (0·02 g) m.p. 309–313°, IR ν_{max}: 1740, 1250 cm^{-1}; petrol–C_6H_6(7:3), friedelin (4·1 g); petrol–C_6H_6 (3:7), friedelan-3β-ol (0·4 g); petrol–C_6H_6 (2:4), glutinol (0·5 g), m.p. 210–212 (from petrol), IR ν_{max}: 3480 cm^{-1}; C_6H_6–$CHCl_3$ (9:1), a solid (3·6 g), which on extraction with cold Me_2CO, yielded β-amyrin (0·11 g), m.p. 198–201° (from Me_2CO), IR ν_{max}: 3300 cm^{-1} (acetate, m.p. 238–240°, IR ν_{max}: 1740, 1250 cm^{-1}) in the soluble fraction, and taraxerol (3·4 g), m.p. 282–285°, $[\alpha]_D$ ± 0°, IR ν_{max}: 3500, 3060, 1640, 820 cm^{-1} in the insoluble fraction; C_6H_6–$CHCl_3$ (3:7), sitosterol (0·08 g). *Stems* (8·5 kg): the extract (25 g) was chromatographed on alumina (500 g), elution with petrol first afforded taraxerone (0·06 g), m.p. 249–251°, $[\alpha]_D$ + 10·0°, IR ν_{max}: 3050, 1720, 1640, 820 cm^{-1}, then friedelin (0·08 g), and last friedelan-3β-ol (0·04 g); petrol–C_6H_6 (1:1), taraxerol (0·2 g), then sitosterol (0·25 g); C_6H_6, fine needles of A_1 (0·005 g), m.p. 254–255° (from C_6H_6), MS: *m/e* 442 (M^+), $C_{30}H_{50}O_2$ requires M^+ 442, IR ν_{max}: 3525 (OH), 1700 cm^{-1} (C=O), then needles of A_2 (0·02 g), m.p. 238–242° (from $CHCl_3$), MS: *m/e* 440 (M^+), $C_{30}H_{48}O_2$ requires M^+ 440, IR ν_{max}: 3550 (OH), 1715 (C=O), 3050, 1650, 820 cm^{-1} (>C=CH–); C_6H_6–$CHCl_3$ (1:1), needles of A_3 (0·015 g), m.p. 295–297°, MS: *m/e* 442 (M^+), $C_{30}H_{50}O_2$ requires M^+ 442, IR ν_{max}: 3380 (OH), 3055, 1650, 820 cm^{-1} (>C=CH–).

L. elizabethae. *Leaves* (5 kg): chromatography of the extract (125 g) and elution with petrol gave friedelin (1·0 g), then friedelan-3β-ol (0·01 g); petrol–C_6H_6 (1:1), taraxerol (1·5 g), sitosterol (0·2 g). *Stems* (4 kg): chromatography of the extract (38·4 g) eluted with petrol gave friedelin (0·5 g), then friedelan-3β-ol (0·09 g); petrol–C_6H_6 (1:1), first a mixture which on recryst from petrol yielded taraxerol (0·1 g), the filtrate of which on concn. gave lupeol (0·05 g), then sitosterol (0·3 g); C_6H_6, betulin (0·5 g), m.p. 250–252°, $[\alpha]_D$ + 18·0°, IR ν_{max}: 3385, 3090, 1650, 882 cm^{-1}.

L. glabra. *Leaves* (6·1 kg): chromatography of the extract (226 g) on elution with petrol gave friedelin (0·02 g), then friedelan-3β-ol (0·02 g); petrol–C_6H_6 (1:1), glutinol (1·0 g); petrol–C_6H_6 (2:3), a mixture which on boiling with petrol, yielded taraxerol (7·0 g) in the insol fraction, and β-amyrin (0·4 g) in the most sol fraction; C_6H_6–$CHCl_3$ (9:1), sitosterol (0·2 g). *Stems* (5 kg): chromatography of the extract (90 g) on elution with petrol, afforded friedelin (0·1 g), then friedelan-3β-ol (0·01 g); petrol–C_6H_6 (1:1), taraxerol (1 g); C_6H_6, sitosterol (0·05 g).

L. haipinii. *Leaves* (19·5 kg): the extract (410 g) on chromatography gave on elution with petrol, friedelin (13·5 g), friedelan-3β-ol (9·5 g); petrol–C_6H_6 (1:1), lupeol (1·0 g) and sitosterol (1:1 g); C_6H_6, canophyllol (0·06 g), m.p. 278–281° (from C_6H_6–petrol), IR ν_{max} 3550, 1720 cm^{-1}. *Stems* (14 kg): the extract (24 g) on chromatography gave, in order of elution, friedelin (0·8 g), friedelan-3β-ol (0·3 g), lupeol (0·8 g), sitosterol (0·17 g) and betulin (0·03 g).

L. hancei. *Leaves* (7 kg): compounds isolated from the extract (140 g) were friedelin (5 g), friedelan-3β-ol (1·1 g), glutinol (0·1 g), β-amyrin (0·08 g), taraxerol (0·03 g) and sitosterol (0·5 g). *Stems* (9 kg): compounds obtained from the extract (9 g) were friedelin (0·15 g), friedelan-3β-ol (0·14 g), lupeol (1·0 g), sitosterol (0·2 g) and pachysandiol-A (0·005 g).

L. harlandi. *Leaves* (12 kg): from the extract (300 g) were obtained friedelin (10·7 g), friedelan-3β-ol (8·3 g), β-amyrin (0·2 g), taraxerol (0·5 g), sitosterol (1·0 g), and pachysandiol-A (0·4 g), m.p. 282–285°, (from Me_2CO), IR ν_{max}: 3500 cm^{-1} [diacetate, m.p. 235–236° (from Me_2CO), IR ν_{max}: 1770, 1760, 1233 cm^{-1} (OAc)], which on hydrolysis gave the original diol. *Stems* (10 kg): from the extract (21 g) were isolated friedelin (0·5 g), lupenone (0·7 g), friedelan-3β-ol (0·6 g) and sitosterol (0·1 g).

L. irwinii. *Leaves* (7 kg): chromatography of the extract (45 g) with petrol gave friedelin (7·5 g), then friedelan-3β-ol (1·0 g) and lupeol (0·8 g); petrol–C_6H_6 (3:2), taraxasterol (0·5 g), followed by a solid, which on repeated recryst from $CHCl_3$ gave needles (0·06 g), m.p. 319–320°, $[\alpha]_D$ + 54·0°, IR ν_{max}: 1745, 1194 cm^{-1} (δ- or ϵ-lactone), identical with lithocarpic lactone isolated from the leaves of *L. litchioides*; petrol–C_6H_6 (1:1), sitosterol (0·02 g);

C_6H_6, pachysandiol-A (0·02 g); $CHCl_3$, friedelan-2,3-dione (3-hydroxyfriedel-3-en-2-one) (0·025 g) m.p. 271–273°, $[\alpha]_D$ + 23·7°, MS: *m/e* 440 (M^+) $C_{30}H_{48}O_2$, IR ν_{max} 3340 (OH), 1675, 1640 (conjugate C=O); UV λ_{max}: 276 nm (ϵ 9700), NMR: δ 1·81 (3H, *s*, C-4 CH_3) [7]. [Acetate, m.p. 285–286°, $[\alpha]_D$ + 23·0°, MS: *m/e* 482 (M^+), $C_{32}H_{50}O_3$, IR ν_{max}: 1735, 1214 cm^{-1} (OAc), 1690, 1645 (conjugated C=O)]. *Stems* (21·5 kg): from the extract (75 g) were isolated friedelin (1·5 g), friedelan-3β-ol (0·2 g), lupeol (8·5 g), taraxasterol (1·0 g), and a sterol mixture (0·3 g), m.p. 154–162°, which (50 mg) was separated by preparative TLC on silver nitrate impregnated Si gel G developed 2× with $CHCl_3$–C_6H_6 (1:1) into sitosterol (30 mg) m.p. 138–140°, $[\alpha]_D$ − 35·8°, IR ν_{max}: 3360, 840 cm^{-1}, and stigmasterol (15 mg), m.p. 168–171°, $[\alpha]_D$ − 50·7°, IR ν_{max}: 3360, 840, 970 cm^{-1}.

L. litchioides. *Leaves* (17 kg): chromatography of the extract (51 g) on elution with petrol–C_6H_6 (7:3), gave friedelin (6·9 g), friedelan-3β-ol (1·7 g), β-amyrin (0·09 g), taraxerol (0·2 g), lithocarpic lactone as needles, m.p. 319–320° (from petrol), IR ν_{max}: 1745, 1194 cm^{-1}, MS: *m/e* 442 (M^+), $C_{30}H_{50}O_2$ requires M^+ 442, and sitosterol: petrol–C_6H_6 (1:9), pachysandiol-A (0·15 g). *Stems* (11 kg): from the extract (81 g) were isolated friedelin (0·17 g), lupeol (0·52 g) and sitosterol (1·38 g).

L. polystachya. *Leaves* (6 kg): chromatography of the extract (196 g) on elution with petrol–C_6H_6 (9:1 gradually increased to 1:4) gave friedelin (0·3 g), friedelan-3β-ol (0·06 g), glutinol (1·0 g), β-amyrin (0·2 g), taraxerol (5·3 g), and sitosterol (0·2 g); C_6H_6–$CHCl_3$ (9:1), needles of B_1 (0·27 g) m.p. 190–192° (from Me_2CO), IR ν_{max}: 3450 (OH), 1710 cm^{-1} (C=O); C_6H_6–$CHCl_3$ (7:3), needles of B_3 (0·1 g) m.p. 165–168°, (from Me_2CO–MeOH) IR ν_{max}: 3350 (OH), 1650, 890 cm^{-1} (>CH=CH_2), and C_6H_6–$CHCl_3$ (1:9), needles of B_2 (0·06 g) m.p. 179–180°, (from Me_2CO), IR ν_{max}: 3350 cm^{-1} (OH). *Stems* (7·2 kg): compounds obtained from the extract (22 g) were friedelin (0·1 g), friedelan-3β-ol (0·05 g) and sitosterol (0·3 g).

Acknowledgements—The authors wish to thank Professors K. Kikuchi (Kyoto University) and R. Aoyagi (University of Tokyo) for authentic samples of pachysandiol-A and friedelan-2,3-dione respectively; Mr S. P. Lau, Miss T. P. Siu and (the late Mr H. C. Tang, Government Herbarium, Hong Kong, for identification of plant materials; and the Committee on Higher Degrees and Research Grants, University of Hong Kong, for financial assistance.

REFERENCES

1. Arthur, H. R., Hui, W. H., Lam, C. N. and Szeto, S. K. (1964) *Australian J. Chem.* **17,** 697.
2. Hui, W. H., Ho, C. T. and Yee, C. W. (1965) *Australian J. Chem.* **18,** 2043.
3. Arthur, H. R., Cheng, K. F., Lau, M. P. and Lie, K. J. (1965) *Phytochemistry* **4,** 969.
4. Arthur, H. R. and Ko, P. D. S. (1968) *Australian J. Chem.* **21,** 2583.
5. Arthur, H. R. and Ko, P. D. S. (1969) *Australian J. Chem.* **22,** 597.
6. Tang, H. C. and Leung, W. T. K. (1967) *Check List of Hong Kong Plants* p. 18, Urban Council and Urban Services Department, Hong Kong.
7. Kikuchi, T. and Toyoda, T. (1967) *Tetrahedron Letters* 3181.