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ANALYSIS OF CHAULMOOGRA OILS

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[In 1938 and 1939 these authors published, in a specialty periodical, a series of articles which record the results of chemical studies on the chaulmoogra oils, studies which are exceptional in their field from both the qualitative and quantitative viewpoints. It is believed that the three which deal with the constitution of the oils ordinarily used in the practice of leprosy workers should be made available to them generally, hence they are reproduced here, with permission, in part with some condensation. The first two articles of the series* are not reprinted, but in Tables IV and V of the last article here reprinted the authors have included the characteristics and analyses of the two oils concerned. Anyone particularly interested in the technical descriptions of apparatus and procedures used are referred to the original articles.

The condensations that have been made consist mainly of elimination of descriptions of procedures and of the constituent substances where those descriptions are repeated. For consideration of space certain of the tables have been combined, but the original numbers have been retained. A tabulation of calculations of specific optical rotation in the first article is not reproduced.—Editor]

ALEPRIC, ALEPRYLIC, ALEPRESTIC AND ALEPROLIC ACIDS, NEW HOMOLOGS OF CHAULMOOGRIC ACID.†

In analyzing *Hydnocarpus wightiana* oil by the method described by us (1), the high optical rotation and iodine numbers of the lower boiling fractions of ethyl esters indicated that there must be present at least one more optically active fatty acid

*Cole, H. I. and Cardoso, H. T. Analysis of chaulmoogra oils. I. *Carpotroche brasiliensis* (sapucainha oil); and II. *Oncoba echinata* (gorli) oil. Jour. American Chem. Soc. **60** (1938) 614 and 617.

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besides those already known (chaulmoogric, hydnocarpic and gorlic (2) acids). By repeated fractional vacuum distillation of 200 liters of *H. wightiana* ethyl esters and fractional crystallization of the free acids we have succeeded finally in isolating two new homologs of chaulmoogric acid. The presence of two other homologs has been proved and they have been obtained 70.5 and 42% pure, respectively. Lack of sample prevented further purification. Because of their relationship to the treatment of leprosy we have named these four new homologs, alepric, aleprylic, aleprestic and aleprolic acids.

Alepric acid is the next lower homolog to hydnocarpic acid, differing from it by C_2H_4 and having the formula $C_{14}H_{24}O_2$. Our final sample still contained a small amount of another unsaturated acid as indicated by the iodine number and optical rotation. The acid is colorless when liquid, white when solid, almost odorless and melts at 48°. The melted acid upon solidifying forms characteristic beautiful branching crystals rising above the surface of the acid. They are very similar to those already reported by us as characteristic of hydnocarpic and chaulmoogric acids (3). Our purest sample of alepric acid gave a specific optical rotation of +77.12°. The theoretical value from the molecular weight-optical rotation curve is +80°.

Aleprylic acid is the next lower homolog to alepric acid, containing two carbon atoms and four hydrogen atoms less than the latter; it has the formula $C_{12}H_{20}O_2$. It was obtained absolutely pure. It crystallizes in the same characteristic manner as the other homologs, melts sharply at 32° and has a specific optical rotation of +90.78°. It is colorless when liquid, white when solid and has a slight aromatic odor when warmed.

Aleprestic acid is the next lower homolog to aleprylic acid, differing from it by C_2H_4 and having the formula $C_{10}H_{16}O_2$. It was obtained only 70.5% pure (Table I, 51W, 2) based upon its specific optical rotation, which would be +100.5° as determined from the curve for the other homologs of these acids.

Although the next homolog to aleprestic acid may be present, our experimental data neither prove nor disprove its presence (Table I, 49W, 3, 4 and 5). On the other hand the second homolog below aleprestic acid is definitely proven to be present by the boiling point of the ethyl ester and the optical rotation and iodine number (Table I, 49W, 1). Computed from its rotation value we have obtained it 42% pure. We have named this

lowest homolog aleprolic acid. It differs from aleprestic acid by C_4H_8 and has the formula $C_6H_8O_2$. From the curve of the other homologs its specific optical rotation would be +120.5° when pure.

In these low boiling fractions of *H. wightiana* ethyl esters there is also present an optically inactive unsaturated acid containing one double bond and probably a saturated acid. The sample at our disposal was not large enough to isolate and identify these acids (Table I, 49W, 2 and 50W, 2).

EXPERIMENTAL

The *H. wightiana* oil used was obtained from Ernakulam, India. The ethyl esters were made in the usual manner by esterifying with ethyl alcohol and sulfuric acid and washing to remove glycerol and acid. Two hundred liters of the ethyl esters was fractionally distilled in a 2-liter still at 10 mm. The first 10 percent (20 liters) fractions were redistilled in the same manner. The 2 liters of low boiling esters thus obtained was refractionated carefully several times in a Podbielniak Model B high temperature fractionating apparatus at 10 mm. The apparatus and technique used were described in a previous paper (1). Plateaus in the distillation curves were finally obtained at 122, 148 and 174° (Table I). These fractions upon being changed to acids and recrystallized several times from acetone proved to be three new homologs of chaulmoogric acid (Table I, 51W, 2; 31W, 2; 53W, 2). The fourth and lowest homolog is clearly shown to be present in fraction 49W, 1, by the very sharp drop in rotation in the next higher fraction, 49W, 2.

TABLE I. *Fractional distribution of low boiling point ethyl esters of* H. wightiana *oil.*

Fraction	Run	B.P.°C. (10 mm.)	Cc.	Rotation	Sp. rot. $[\alpha]^{25}D$	Iodine no.
1[a]	49W	58–66	1.5	42.4	42.68	100.2
2	49W	66–88	8.2	5.6	....	....
3	49W	88–100	2.1	8.6	....	....
4	49W	100–118	11.0	20.7	....	....
5	49W	118–120	10.0	44.0	....	....
6[b]	49W	120–122	5.0	51.0	....	....
7	49W	122–127	10.0	40.7	....	....
8	49W	127–129	5.2	24.7	....	....
9	49W	129–140	8.0	25.5	....	....
10	49W	140–146	7.0	33.1	....	....
11[c]	49W	146–148	44.0	52.6	....	....
Fractions 49W, 2-5, redistilled						
1	50W	58–82	1.1	15.2	....	....
2[d]	50W	82–86	4.0	2.8	....	....
3	50W	86–100	5.0	6.4	....	....
4	50W	100–114	4.0	8.8	....	....
5	50W	114–120	7.0	25.3	.....	.....
6	50W	120–120	7.0	49.6	.....	.....
Fractions 49W, 6 and 50W, 6, redistilled						
1	51W	114–122	5.0	44.8	.....	.....
2[e]	51W	122–122	7.0	54.6	60.94	96.64
Ethyl aleprate (final distillation)						
1	53W	160–174	2.0	....	66.25	.....
2[f]	53W	174–174	7.0	....	66.54	100.70
3	53W	174–174	2.5	....	65.41	.....
Ethyl aleprylate (final distilation)						
1[g]	31W	148	20.0	71.7	79.14	113.4
2	31W	148	20.0	71.7	79.14	113.4

[a] Ethyl aleprolate 42% pure. [b] Impure ethyl aleprestate. [c] Impure ethyl aleprylate. [d] Unidentified acids. [e] Ethyl aleprestate 70.5% pure. [f] Ethyl aleprate 94.2% pure. [g] Pure ethyl aleprylate.

Alepric Acid.—Alepric acid was much more difficult to isolate than aleprylic acid, as it was impossible to free it entirely from the other unsaturated acid and from palmitic acid without very great loss. We finally obtained it 96.4% pure as calculated from actual and theoretical rotations (77.1 and 80.0). The constants for alepric acid and for ethyl aleprate are given in Tables II and III.

Analysis: Calculated for $C_{14}H_{24}O_2$: C, 74.93; H, 10.78; iodine number, 113.4; molecular weight, 224.2. Found: C, 74.86; H, 10.86; iodine number (Hanus), 116.7; molecular weight, 224.5.

Aleprylic acid.—Of this acid, next lower in the series to alepric acid, about ten times as much could be isolated as of alepric or aleprestic acid. *H. wightiana* oil contains about 3 percent of it.

Aleprestic acid.—This acid, the next lower homolog to aleprylic acid, occurs in very small amounts in *H. wightiana* oil (less than 0.5%). It was obtained 70.5% pure.

Aleprolic acid.—Of this acid, the lowest homolog of chaulmoogric acid yet discovered and the second lower one after aleprestic acid, we obtained only a very small amount even from the large sample mentioned above. The boiling point of its ethyl ester (65° at 10 mm.) and its specific rotation indicated its presence, and from the latter we were able to determine its purity (42%).

From our distillation curves we were unable to say whether or not the homolog between aleprestic and aleprolic acids was present. We were unable to isolate the optically inactive unsaturated acid with one double bond indicated as present by the iodine number.

TABLES II AND III. *Constants of* (a) *optically active fatty acids found in chaulmoogra oils, and* (b) *their ethyl esters.*

Substance	Mol. wt.	M.P. °C.	B.P. °C. (10 mm.)	Sp. rot. $[\alpha]^{25}D$	Iodine no.	Ref. index $n^{25}D$	Sp. gr. 25°/25°
A. Fatty acids							
Chaulmoogric acid	280.2	68.5	—	60.3	90.5	—	—
Hydnocarpic acid	252.2	60.5	—	69.3	100.7	—	—
Alepric acid	224.2	48.0	—	77.1	113.4	—	—
Aleprylic acid	196.2	32.0	—	90.8	129.7	—	—
Aleprestic acid	168.1	....	—	100.5[a]	151.2	—	—
Homolog not found	140.1	....	—	110.5[a]	181.5	—	—
Aleprolic acid	112.1	....	—	120.5[a]	226.7	—	—
Gorlic acid	278.2	6.0	—	60.7	182.5	—	—
B. Ethyl esters							
Ethyl chaulmoograte	308.3	—	222	55.4	82.5	1.4592	0.901
Ethyl hydnocarpate	280.2	—	200	61.9	90.5	1.4578	.907
Ethyl aleprate	252.2	—	174	66.5	100.7	1.4562	.915
Ethyl aleprylate	224.2	—	148	79.1	113.4	1.4550	.925
Ethyl aleprestate	196.2	—	122[a]	86.5[a]	129.7	1.4538[a]	....
Homolog not found	168.1	—	96[a]	94.1[a]	151.2	1.4526[a]	....
Ethyl aleprolate	140.1	—	70[a]	101.8[a]	181.5	1.4514[a]	....
Ethyl gorlate	306.3	—	232	55.6	167.0	1.4667	.912

[a] Calculated.

SUMMARY

Four optically active fatty acids hitherto unknown have been discovered in *Hydnocarpus wightiana* oil. They have been named alepric, aleprylic, aleprestic and aleprolic acids.

The characteristics of these new acids and their ethyl esters are given and their relationship to their previously known homologs, hydnocarpic and chaulmoogric acids, is shown.

REFERENCES

(1) Cole and Cardoso. Jour. American Chem. Soc. **60** (1938) 614.
(2) Cole and Cardoso. Jour. American Chem. Soc. **60** (1938) 612.
(3) Cole and Cardoso. Jour. American Chem. Soc. **59** (1937) 963.

ANALYSIS OF CHAULMOOGRA OILS

III. *HYDNOCARPUS WIGHTIANA* OIL*

Of the various chaulmoogra oils used in the treatment of leprosy, that expressed from the seeds of *Hydnocarpus wightiana* is by far the most generally employed. This is largely due to the fact that an oil of excellent quality is easily obtainable in large quantities at a reasonable price. *H. wightiana* occurs abundantly in southwestern India. The tree grows to a height of 7 to 10 meters. The fruit measures 6 to 12 cm. in diameter. The seed is about 2 cm. long with longitudinal grooves and a knot on the end. The species is one of the most abundant and easily accessible of the *Hydnocarpaceae*. Although *H. wightiana* oil has been so widely used for the past fifteen years in the treatment of leprosy, no accurate qualitative or quantitative analysis has ever been made due to the difficulty in separating the constituents. In 1905 Power and Barrowcliff (1) reported that the total fatty acids of this oil consisted chiefly of hydnocarpic and chaulmoogric acids and that they found evidences of a still lower homolog of the same series having the formula $C_{14}H_{24}O_2$ in the mother liquor but were unable to isolate it. Since the iodine number of the final mother liquor was so large (140.7) they concluded that it indicated the presence of an acid or acids belonging to the linolic or linolenic series. Our analysis shows that acids of neither of these series are present but that the high iodine number (and high rotation, 50.4) that they obtained are due to gorlic acid (2). No evidence of the presence

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of palmitic acid was found by them and they make no mention of oleic acid. Since their analysis was made, practically nothing has been added to our knowledge of the composition of this important medicinal oil. A single reference has been made to the possible presence of gorlic acid (3). We have succeeded in analyzing *H. wightiana* oil by the method for chaulmoogra oils given in the first article of this series (4). Our analysis is shown in Table I. It shows six fatty acids not previously reported in this oil, four of which are new homologs of chaulmoogric acid.

EXPERIMENTAL

The sample of oil was taken from a 300-liter drum of *H. wightiana* oil, cold-pressed from fresh, selected seeds imported for the routine production of leprosy drugs from Brazil from the Ernakulam Trading Co., Ernakulam, South India. The characteristics of the oil were as follows: specific gravity 25/25, 0.9549; free fatty acids (as % oleic), 2.7; saponification number, 201; iodine number (Hanus), 98.4; specific rotation +55.0°; refractive index (at 25°), 1.4799; unsaponifiable matter, 0.25%.

Method of analysis.—Since the medicinal properties of chaulmoogra oils depend on the percentage of optically active acids, the analysis is reported in percentage of the various fatty acids present. The sample of oil was saponified and the fatty acids liberated and washed in the usual manner. The solid acids were separated from the liquid acids by crystallization from 80 percent ethyl alcohol. The two fractions were changed to ethyl esters and then fractionally distilled in a Podbielniak Model B high temperature fractionating apparatus. The details of the separation and distillation were given in the first article of this series, the only change being that the two final crystallizations for the separation of the liquid acids were made with 80 percent acetone to prevent the formation of ethyl esters.

TABLE I. *Percentage composition of the fatty acids of* H. wightiana *oil (from Tables II and III).*

Acids	Percent
Hydnocarpic	48.7
Chaulmoogric	27.0
Gorlic	12.2
Oleic	6.5
Palmitic	1.8
Lower homologs of chaulmoogric acid (alepric, aleprylic, aleprestic, aleprolic and unidentified acids)	3.4
Loss	0.4

QUALITATIVE ANALYSIS

The fatty acids of *H. wightiana* were identified as follows:

Hydnocarpic acid.—This acid was isolated easily from fraction 2, Table III, by repeated crystallization from 80 percent ethyl alcohol. It gave the correct optical rotation, iodine number, neutralization equivalent and melt-

ing point for pure hydnocarpic acid, as well as the characteristic crystalline growth previously described (5).

Chaulmoogric acid.—Pure chaulmoogric acid was obtained readily from fraction 4, Table III, by crystallization to constant melting point from 80 percent ethyl alcohol. It gave the correct optical rotation, iodine number, neutralization equivalent and melting point for pure chaulmoogric acid (5).

Gorlic acid.—Ethyl gorlate was isolated by several fractional distillations of fraction 4, Table II. It gave the correct optical rotation, iodine number and boiling point for ethyl gorlate. Changed to acid it also gave the correct constants for gorlic acid (2).

TABLES II AND III. *Fractional distillation of ethyl esters from* (a) *liquid acids and* (b) *solid acids of* H. wightiana *oil.*

Fraction	B.P.,°C (10 mm.)	Cc.	Sp. rotn. $[\alpha]^{25}D$	Iodine no.	Hydnocarpate	Chaulmoograte	Gorlate	Oleate	Palmitate	Lower homologs
A. Ethyl esters from liquid acids (15.7% of total fatty acids) [a]										
1	120–187	3.3	50.64	86.7	....	....	....	....	0.9	2.4[c]
2	187–203	24.0	46.79	95.4	15.2	....	3.3	4.5	1.0	....
3	203–207	14.0	46.25	121.7	5.0	....	6.1	2.9	....	....
4	207–212	55.7	49.01	142.0	....	13.3	39.3	3.1	....	....
Residue		3.0								
Percent in liquid fraction					20.2	13.3	48.7	10.5	1.9	2.4
Percent in total fatty acids					3.2	2.1	7.7	1.6	0.3	0.4
B. Ethyl esters from solid acids (84.3% of total fatty acids) [b]										
1	117–189	5	53.13	83.3	....	....	....	....	1.4	3.6[c]
2	191–202	55	57.57	91.3	49.7	....	1.6	3.3	0.4	....
3	202–210	5	54.75	93.6	4.2	....	0.3	0.5	....	....
4	210–214	35	52.38	90.3	....	29.6	3.4	2.0	....	....
Percent in solid fraction					53.9	29.6	5.3	5.8	1.8	3.6
Percent in total fatty acids					45.5	24.9	4.5	4.9	1.5	3.0

[a] Constituents in percentages of the liquid fraction.
[b] Constituents in percentages of the solid fraction.
[c] Alepric, aleprylic, aleprestic, aleprolic and unidentified acids.

Oleic acid.—Oleic acid was not obtained pure but its presence was indicated in the liquid fraction by the distillation curve of the ethyl esters and by the correct iodine numbers for mixtures containing ethyl oleate in fractions 2, 3 and 4, Table II. The elaidic acid test could not be used as gorlic acid gives a similar reaction. Hydrogenation tests were equally unsatisfactory in the presence of hydnocarpic and chaulmoogric acids.

Palmitic acid.—It is practically impossible to separate ethyl palmitate from hydnocarpate by distillation, but the separation can be accomplished easily by cooling a fraction of esters high in palmitate in the icebox. By separating the solid ethyl palmitate and crystallizing it twice from alcohol it was obtained pure (melting point 24°). Upon changing it to palmitic acid and crystallizing two or three times the correct melting point and neutralization equivalent for palmitic acid was obtained.

Alepric acid.—This acid, the next lower homolog to hydnocarpic acid, occurs in very small amount (less than 0.5%) in *H. wightiana* oil. No attempt was made to isolate it in the sample here analyzed but it was isolated from a much larger sample (200 liters) and its properties were

determined. The method of separation of this homolog and the determination of its properties as well as those of the following ones form the subject of another paper.†

Aleprylic acid.—Of this acid, next lower in the series to alepric acid, about ten times as much could be isolated as of alepric or aleprestic acid. *H. wightiana* oil contains about 3 percent of it.

Aleprestic acid.—This acid, the next lower homolog to aleprylic acid, occurs in very small amounts in *H. wightiana* oil (less than 0.5%). It was obtained 70.5 percent pure.

Aleprolic acid.—Of this acid, the lowest homolog of chaulmoogric acid yet discovered and the second lower one after aleprestic acid, we obtained only a very small amount even from the large sample mentioned above. The boiling point of its ethyl ester (65° at 10 mm.) and its specific rotation indicated its presence, and from the latter we were able to determine its purity (42%).

From our distillation curves we were unable to say whether or not the homolog between aleprestic and aleprolic acids was present. We were unable to isolate the optically inactive unsaturated acid with one double bond indicated as present by the iodine number.

QUANTITATIVE ANALYSIS

The total fatty acids of *H. wightiana* oil when separated into liquid and solid acids by the method described by us consisted of 84.3 percent solid acids and 15.7 percent liquid acids. Although the separation is by no means complete, the breaks in the distillation curves of the ethyl esters made from these two fractions are much more distinct than when the whole esters are used. Complete separation is not necessary, as the amounts of the various constituents can be computed by taking advantage of the boiling points, optical activity and iodine numbers, or the absence of one or both of the two latter constants, as described in part one of this series. The results of these computations are given in Tables II and III and these are summarized in Table I. Fractions 1 of Table II and Table III were too small to be further divided, but we know from distillation of much larger samples that there is about ten times as much aleprylic acid in this first fraction as there is of the homolog above and below it or of the optically inactive, unsaturated acid. We have therefore figured these two fractions on the basis of the specific optical rotation of ethyl aleprylate (79.14), which gives us 0.9 percent for the amount of saturated ester present in fraction 1, Table II, and 1.4 percent in fraction 1, Table III. This is admittedly only an approximation.

SUMMARY

The qualitative and quantitative analyses of the total fatty acids of *H. wightiana* oil have been made by the method described in the first article of this series.

This is the first quantitative analysis that has been made of this oil. Six constituents not previously reported have been found, four of which are new homologs of chaulmoogric acid.

† The preceding paper here reprinted.

This analysis shows *H. wightiana* oil to be quite similar in composition to *Carpotroche braziliensis* oil.

REFERENCES

(1) Power and Barrowcliff. Jour. Chem. Soc. **87** (1905) 884.
(2) Cole and Cardoso. Jour. American Chem. Soc. **60** (1938) 612.
(3) Anon. Bull. Imp. Inst. **34** (1936) 145.
(4) Cole and Cardoso. Jour. American Chem. Soc. **60** (1938) 614.
(5) Cole and Cardoso. Jour. American Chem. Soc. **59** (1937) 963.
(6) Cole and Cardoso. Jour. American Chem. Soc. **61** (1939) 2349.

ANALYSIS OF CHAULMOOGRA OILS

IV. *HYDNOCARPUS ANTHELMINTICA* OIL

V. *TARAKTOGENOS KURZII* (CHAULMOOGRA) OIL*

IV. *HYDNOCARPUS ANTHELMINTICA* OIL

The oil expressed from the seeds of *Hydnocarpus anthelmintica* is extensively used in the treatment of leprosy, ranking next to *H. wightiana* oil in therapeutic importance. *H. anthelmintica* occurs abundantly in Siam, Cambodia, Cochin China, and Laos. It also has been reported from Burma. The tree grows to a height of 20 to 25 meters and is generally found in valleys from sea level to 1300 meters altitude. It has been successfully cultivated in Hawaii and the Belgian Congo. The ripe fruits are more or less globular in shape and vary in size from 8 to 15 centimeters in diameter. The seeds are of approximately the same shape and size as those of *H. wightiana* (1 to 2 centimeters long) but are readily distinguished from the latter because of their smoother and thicker shell. The oil is used by the natives of Siam for cutaneous affections. The seeds form an article of export to China where they are known as Ta-fung-chi or Ta-feng-tzu.

As early as 1905 Power and Barrowcliff (1) attempted to analyze *H. anthelmintica* oil. They reported that the total fatty acids of this oil contained chaulmoogric, hydnocarpic, oleic and palmitic acids. Although several qualitative analyses have been made since, no one has succeeded in making a quantitative analysis due to the difficulty in separating the constituents. We have succeeded in analyzing *H. anthelmintica* oil by the method for chaulmoogra oils given in the first article of this series (2). The constituents and percentage composition are given in Table I.

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Besides the acids previously reported as present, our analysis shows that gorlic acid and a small percentage of a lower homolog of hydnocarpic acid are also present.

TABLE I. *Percentage composition of the fatty acids of* H. anthelmintica *and* T. kurzii *oils (from Tables II and III).*

Acids	*H. anthelmintica*	*T. Kurzii*
Hydnocarpic	67.8%	34.9%
Chaulmoogric	8.7%	22.5%
Gorlic	1.4%	22.6%
Oleic	12.3%	14.6%
Palmitic	7.5%	4.0%
Lower homologs of hydnocarpic acid	0.1%	0.4%
Loss	2.2%	1.0%

EXPERIMENTAL

The sample of *H. anthelmintica* oil was obtained from a 300-liter drum imported several years ago from Siam by the Departamento de Prophylaxia da Leprada São Paulo, who generously donated the sample for our analysis. Although the oil was more than five years old, its characteristics indicate that very little decomposition had taken place. The characteristics determined at the time of the analysis were as follows: specific gravity 25/25, 0.952; free fatty acids (as % oleic) 2.9; saponification number, 203.3; iodine number (Hanus), 89.2; specific optical rotation, $[\alpha]^{25}D+49.70$; refractive index $[n]_{25}D$ 1.4772; unsaponifiable matter, 0.50%.

Method of analysis.—[See preceding article.]

TABLE II. *Fractional distillation of ethyl esters from liquid acids of* H. wightiana *and* T. kurzii *oils.*

Fraction	B.P.,°C (10 mm.)	Cc.	Sp.rotn. $[\alpha]^{25}D$	Iodine no.	Hydnocarpate	Chaulmoograte	Gorlate	Oleate	Palmitate	Lower homologs
H. anthelmintica (*17.9% of total fatty acids*)										
1	153–187	1.0	36.89	....	....	....	....	....	0.69	0.61
2	187–201	36.0	36.56	82.01	27.60	....	....	16.50	2.66	....
3	201–207	25.0	36.49	94.11	16.24	....	3.20	13.00	....	....
4	207–209	8.0	35.49	98.98	4.47	....	1.66	4.26	....	....
5	209–215	4.5	38.34	104.20	....	2.52	1.53	1.81	....	....
Loss		2.5								
Percent in liquid fraction					48.31	2.52	6.39	35.57	3.35	0.61
Percent in total fatty acids					8.64	0.45	1.15	6.37	0.60	0.11
T. kurzii (*41.7% of total fatty acids*)										
1	161–185	2	30.59	....	....	....	....	....	1.55	0.98
2	185–201	28	34.37	94.78	14.17	....	6.09	12.97	2.20	....
3	201–207	8	40.23	112.8	3.67	....	3.24	3.22	....	....
4	207–217	39.7	48.78	138.3	....	11.87	32.20	6.24	....	....
Residue		1.3								
Percent in liquid fraction					17.84	11.87	41.53	22.43	3.75	0.98
Percent in total fatty acids					7.45	4.95	17.3	9.35	1.56	0.41

TABLE III. *Fractional distillation of ethyl esters from solid acids of* H. anthelmintica *and* T. Kurzii *oils.*

Fraction	B.P.,°C (10 mm.)	Cc.	Sp.rotn. $[\alpha]^{25}D$	Iodine no.	Hydnocarpate	Chaulmoograte	Gorlate	Oleate	Palmitate
H. anthelmintica *oil (82.1% of total fatty acids)*									
1	191–201	69	51.10	80.05	57.0	....	....	4.8	7.2
2	201–211	18	51.79	84.08	15.1	....	....	1.7	1.2
3	211–215	11	51.93	84.35	....	10.0	0.31	0.69	....
Loss		2							
Percent in solid fraction				....	72.1	10.0	0.31	7.19	8.4
Percent in total fatty acids				....	59.2	8.21	0.25	5.90	6.9
T. kurzii *oil (58.3% of total fatty acids)*									
1	191–202	41.5	47.67	82.10	32.0	....	....	5.27	4.23
2	202–209	19.3	51.74	94.30	14.94	....	1.35	3.01	....
3	209–217	38.6	54.38	99.05	....	30.11	7.72	0.77	....
Loss		0.6							
Percent in solid fraction				....	46.94	30.11	9.07	9.05	4.23
Percent in total fatty acids				....	27.37	17.55	5.28	5.28	2.47

QUALITATIVE ANALYSIS

[The acids found were identified as described in the preceding article. *Chaulmoogric* was obtained from the acids from fraction 3, Table III; *hydnocarpic* from fraction 2, Table III; *gorlic* from fraction 3, Table II; *oleic* from fractions 2, 3, 4 and 5, Table II; *palmitic* as before.]

Lower homologs.—The presence of at least one homolog of hydnocarpic acid was indicated by the optical rotation and boiling point of fraction 1, Table II. The sample was too small to attempt to identify this compound.

QUANTITATIVE ANALYSIS

The total fatty acids of *H. anthelmintica* oil when separated into liquid and solid acids by the method described by us consisted of 17.9% liquid acids and 82.1% solid acids. Although the separation is by no means complete, the breaks in the distillation curves of the ethyl esters made from these two fractions are much more distinct than when the whole esters are used. Complete separation is not necessary as the amounts of the various constituents can be computed by taking advantage of the boiling points, optical rotations and iodine numbers, or the absence of one or both of the two latter constants, as described in Part I of this series of articles. The results of these computations are given in Tables II and III and these are summarized in Table I. Fraction 1, Table II was computed on the assumption that it was a mixture of alepric acid (5) and a saturated acid.

V. *TARAKTOGENOS KURZII* (CHAULMOOGRA) OIL

Chaulmoogra is the native name for *Taraktogenos kurzii* oil which has been used for centuries in Burma and India in the treatment of leprosy. In recent years, however, the word "chaulmoogra" has been used generically to indicate any oil containing chaulmoogric acid which might be used in the treatment of lep-

rosy, such as *H. wightiana* or *C. brasiliensis* oil. *Taraktogenos kurzii* is a tree widely distributed in Burma. It is also found in Siam, Eastern Bengal and Assam. *T. kurzii*, called *kalaw* by the Burmese, grows to a height of 15 to 20 meters in dense forests. The fruits are globular, varying in size from 8 to 15 cm. in diameter. The seeds are larger than those from *H. wightiana* with a smoother and thicker shell. The fruit ripens in June or July, falls in the rainy season and is usually no longer fresh when gathered. Consequently the true chaulmoogra oil of commerce is always of poor quality, with a very high free fatty acid content. It is often adulterated and other hydnocarpus oils are frequently sold as chaulmoogra oil. Because of these disadvantages its use in leprosy treatment has been largely superseded by authentic *H. wightiana* and *H. anthelmintica* oils, which are cheaper and of better quality. Plantations would eliminate these disadvantages. In fact the oil for this analysis was obtained from a plantation at Vicosa, Minas Geraes, where Dr. Rolfs has succeeded in acclimatizing *T. kurzii* to Brazil. It flourishes there, producing heavy crops of fruits.

The first analysis of chaulmoogra oil was made by Power and Gornall (6) in 1904. They reported that the oil contained both chaulmoogric and hydnocarpic as well as small amounts of palmitic and linolic acids. Other investigators have added very little to our knowledge of chaulmoogra oil. No quantitative analysis has ever been made. We have made an analysis of this oil by the method described in the first article of this series (2). The constituents and percentage composition of chaulmoogra oil are given in Table I. Besides the acids mentioned by Power and Gornall, we have found that the oil also contains gorlic and oleic acids and a small amount of a lower homolog of hydnocarpic acid. No linolic or linolenic acid was found. The high iodine numbers of certain fractions, which led previous investigators to suspect the presence of linolic or linolenic acid, are due to the presence of gorlic-acid, which has two double bonds. If gorlic acid should prove to be of greater value in leprosy treatment than the other optically active fatty acids, then the true chaulmoogra oil would be preferable to the other oils we have analyzed since it contains the highest percentage of this acid (see Table V).

Previous statements that the oil does not keep well are not true. The bad reputation of the oil is due to the fact that the oil is practically never expressed from fresh dried seeds, and oil

from old seeds is always irritating. *T. kurzii* oil which we cold-pressed from fresh, dried seeds has changed very little after standing for three years and is still non-irritating upon injection. We have found this generally true of all the chaulmoogra oils we have analyzed.

EXPERIMENTAL

The sample of oil was obtained by cold pressing of fresh, dried seeds kindly donated by the Escola Superior de Agricultura at Vicosa, Minas Geraes. The sample of oil was three years old before it was analyzed but the characteristics of the oil had changed only very slightly in that time. At the time of analysis they were as follows: specific gravity 25/25, 0.952; free fatty acids (as % oleic), 1.3; saponification number, 200.6; iodine number (Hanus), 101.5; specific optical rotation $[\alpha]^{25}D$ +49.80; refractive index $[n]_{25}D$ 1.4790; unsaponifiable matter 0.29%.

The analysis was made on the total fatty acid content of the oil since the medicinal properties of the oil depend upon the percentage of the optically active acids present, and was made in the same manner as that of *H. anthelmintica* oil.

QUALITATIVE ANALYSIS

The fatty acids of *T. kurzii* oil were found to contain chaulmoogric, hydnocarpic, gorlic, oleic and palmitic acids with a very small percentage of a lower homolog of hydnocarpic acid. The acids were identified in the same manner as those from *H. anthelmintica* oil.

QUANTITATIVE ANALYSIS

The total fatty acids of *T. kurzii* oil when separated into liquid and solid fatty acids by the method described by us consisted of 41.7% liquid acids and 58.3% solid acids. After distillation of the ethyl esters made from these two fractions, the amounts of the various constituents present were computed as previously described. The results of these computations are given in Tables II and III and these are summarized in Table I. Fraction 1, Table II, was computed on the assumption that only alepric and palmitic acids were present, as the sample was too small to be separated further.

TABLE IV. *Characteristics of chaulmoogra oils.*

	Hydnocarpus wightiana	*Hydnocarpus anthelmintica*	*Taraktogenos kurzii*	*Carpotroche brasiliensis*	*Oncoba echinata*
Specific gravity 25/25	0.955	0.952	0.952	0.955	....
Free fatty acid (as % oleic)	2.7	2.9	1.3	3.6	4.3
Saponification number	201.0	203.3	200.6	201.8	193.7
Iodine number (Hanus)	98.4	89.2	101.5	108.0	96.4
Spec. optical rotation $[\alpha]^{25}D$	55.0	49.7	49.8	53.8	51.7
Refractive index $[n]^{25}D$	1.4799	1.4772	1.4790	1.4790	....
Unsaponifiable matter, %	0.25	0.50	0.29	....	....

TABLE V. *Percentage composition of total fatty acids of chaulmoogra oils.*

Acids	*Hydnocarpus wightiana*	*Hydnocarpus anthelmintica*	*Taraktogenos kurzii*	*Carpotroche brasiliensis*	*Oncoba echinata*
Hydnocarpic	48.7	67.8	34.9	45.0	None
Chaulmoogric	27.0	8.7	22.5	24.4	74.9
Gorlic	12.2	1.4	22.6	15.4	14.7
Lower homologs of hydnocarpic	3.4	0.1	0.4	?	?
Oleic	6.5	12.3	14.6	6.3	2.2
Palmitic	1.8	7.5	4.0	6.6	7.8
Loss	0.4	2.2	1.0	2.3	0.4

SUMMARY

The qualitative and quantitative analyses of *Hydnocarpus anthelmintica* and *Taraktogenos kurzii* (chaulmoogra) oils have been made by the methods described in the first article of this series. They are the first quantitative analyses that have been made of these two important medicinal oils.

The percentage compositions of these oils are given in Table I. A summary of the characteristics and percentage compositions of the five oils of the chaulmoogra group so far analyzed in this series of articles is given in Tables IV and V.

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