

Wool Wax Acids: A Review

K. MOTIUK, Amerchol Corporation, a Unit of CPC International Inc., Amerchol Park, Edison, New Jersey, 08817

ABSTRACT

Wool wax acids consist predominantly of alkanolic, α -hydroxy and ω -hydroxy acids. Each group contains normal, iso, and anteiso series of various chain length. Practically all the acids are saturated. The average weight-percent of the various series is based on recently published results.

INTRODUCTION

The objective of this review is to summarize our present knowledge of the composition of wool wax acids, a material which derives from the saponification of wool wax.

The review covers the period between about 1870 and 1974. What emerges from this review is an up-to-date record of the fractionation techniques which were used in the study of the composition of wool wax acids; and the qualitative and quantitative results as obtained by various investigators.

EARLY INVESTIGATIONS

The history of the qualitative and quantitative investigation of wool wax acids can be described as follows: because of the complexity of the wool wax acids, the data resulting from the use of classical analytical methods were incomplete and often contradictory. Actually, the composition of wool wax acids was established during the last 33 years due to the use of modern analytical techniques.

As early as 1874, Schulze (1) investigated the wool wax acids and reported the presence of a $C_{25}H_{50}O_2$ acid.

De Sanctis (2) fractionated the lead salts of wool wax acids. This method enabled De Sanctis to separate the following components: butyric, isovaleric, caproic, palmitic, oleic, stearic, and cerotic acids.

Darmstadter and Lifschutz (3) isolated lanopalmitic ($C_{16}H_{32}O_3$) and lanoceric ($C_{30}H_{60}O_3$) acids, which were later identified by other investigators as hydroxy acids.

Rohman (4) was the first investigator to report during 1916 an optically active oxystearic acid, but could not find lanoceric acid.

Drummond and Baker (5) carried out an extensive investigation of wool wax, which they extracted from Merino wool with petroleum ether and saponified with boiling alcoholic potassium hydroxide. The recovered fatty acids had a mean molecular weight of 291 and an iodine number of 10-15. The acids were crystallized from ethyl alcohol; the insoluble acids (58%) were considered to consist largely of cerotic acid ($C_{26}H_{52}O_2$). The soluble acids were converted to methyl esters and fractionally distilled at 1 mm pressure. In summarizing his work, Drummond states that:

"1. The fatty acids consisted almost entirely of the saturated acids: cerotic, palmitic and stearic. Smaller amounts of lower acids, e.g., myristic, were detected. 2. No evidence was obtained of the existence of the acids of high oxygen content... or of the optically active acid described by Rohman."

Abraham and Hilditch (6), using fresh wool grease which was saponified with alcoholic KOH, separated the fatty acids as calcium soaps and fractionally distilled the methyl esters of these acids. They reported that: "...Stearic, palmitic and myristic acids were not present in detectable amounts, that there were acids present which resembled myristic, and perhaps stearic, in molecular weight and refractive index but were not identical with these, and that

each ester-fraction was derived from a complex mixture of unusual acids."

Abraham also noted the formation of "lactone" when high molecular weight acid-fractions were heated with inorganic acids.

Kuwata and Ishii (7) separated four wool wax acids: lanomyristic, lanopalmitic, lanostearic, and lanoarachidic. Since the mixture of lanomyristic and myristic acids showed a melting point depression, Kuwata concluded that this acid does not belong to the normal series.

Heiduschka and Nier (8) confirmed the presence of cerotic and lanoceric acids, but could not detect the lactone of lanoceric acid.

It was Kuwata (9) who reported in 1938 that lanopalmitic acid is a stereoisomer of α -hydroxy-palmitic acid; this was done by oxidizing the methyl ester to α -ketopalmitate followed by conversion to pentadecanoic acid. Kuwata's yield in α -hydroxy-palmitic acid was 7%.

Nozoe (10), working with alcoholized wool wax, identified the following hydroxy acids:

dl - and l - α -hydroxy -lauric acid
-myristic
-palmitic
-lanostearic
-lanoarachidic

The investigation of wool wax acids as described so far, while remaining incomplete and contradictory, revealed some of the important characteristics of these acids: (a) besides some well known fatty acids belonging to the normal series, wool wax has among its constituents similar fatty acids belonging to series other than the normal ones; (b) wool wax acids contain optically active α -hydroxy-acids.

The great breakthrough in the qualitative and quantitative study of wool wax acids occurred in 1945 with Weitkamp's (11) publication, "The Acidic Constituents of Degras: A New Method of Structure Elucidation." Weitkamp prepared the wool wax acids from Arlington Mills acid-free degreas by saponifying this material with KOH and separating the soaps from the unsaponifiable with petroleum ether and 60% aqueous ethanol. The acids were converted to methyl esters which were fractionally distilled at 1.95 mm in vacuo.

Initially the distillation of the methyl esters produced a series of fractions differing from each other by one CH_2 unit. This technique provided fractions with odd carbon content (anteiso acids) and even carbon content (normal, iso and hydroxy acids). In order to separate the normal acids from the iso acids, Weitkamp removed the hydroxy acids by precipitation from a petroleum ether solution and converted the remaining acids into methyl esters: these were extended with a hydrocarbon and fractionally distilled. The recovered acids were purified by crystallization to constant melting points.

The 32 wool wax acids which were identified by Weitkamp are summarized in Table I.

The typical acids in each series of wool wax acids were illustrated by Truter (12) as in Table II. It will appear from this table that the iso acids contain a terminal isopropyl group, while the anteiso acids contain a terminal isobutyl group.

It should be noted that Weitkamp's conversion of the fatty acids into methyl esters produced a yield of 88%: the loss of 12% was attributed mainly to adsorption on

TABLE I
Summary of Weitkamp's Data on Wool Wax Acids

Type of acids	Formula	Number of acids	Methyl esters %
Normal acids	$C_{10}H_{20}O_2-C_{26}H_{52}O_2$	9	9.5
Optically active Hydroxy acids	$C_{14}H_{28}O_3-C_{16}H_{32}O_3$	2	4.2
Iso acids	$C_{10}H_{20}O_2-C_{28}H_{56}O_2$	10	29.3
Anteiso acids, Dextrorotatory	$C_9H_{18}O_2-C_{31}H_{62}O_2$	11	37.3
Residue			13.0
Not recovered Total			6.0 99.3%

TABLE II
Typical Acids in Each Series of Wool Wax Acids (12)

$CH_3CH_2CH_2(CH_2)_{11}CH_2COOH$ n-hexadecanoic acid (palmitic acid)
$CH_3CH(CH_3)(CH_2)_{11}CH_2COOH$ iso-hexadecanoic acid (iso-palmitic acid) or 14-methylpentadecanoic acid
$CH_3CH_2CH(CH_3)(CH_2)_{11}CH_2COOH$ 14-methylhexadecanoic acid (anteiso-palmitic acid) or 14-ethylpentadecanoic acid
$CH_3CH_2CH_2(CH_2)_{11}CH(OH)COOH$ α -hydroxy-palmitic acid or 2-hydroxyhexadecanoic acid

Attapulugus clay during the filtration of the methyl esters in a petroleum ether solution. The 6% loss during the distillation of the methyl esters was attributed to thermal instability of oxygenated acids.

In order to establish the structural characteristics of the branched chain acids, Weitkamp used a method which was based on the solidification points of binary mixtures of acids: this method established the position at which the chain does branch.

Because the crystal habits of the acids in a given series were found to be very similar, Weitkamp established the homology of the series through extensive use of crystallography.

Two years after Weitkamp's publication, Velick (13) undertook an X-ray diffraction study of Weitkamp's samples of branched chain fatty acids "with the object of

establishing homology by independent means." This study proved that "both the (crystal) spacings and diffraction patterns provided clear evidence of homology."

The fact that Weitkamp was able to isolate and identify only two hydroxy acids which represent less than 4% of the total wool wax acids, induced Bertram (14) to investigate by different means the percentage of the total hydroxy acids.

Bertram used an American and Australian crude wool wax which he analyzed as shown in Table III.

Since the analysis revealed only a small amount of free sterols, Bertram concluded that "the hydroxyl value of the whole wax must be due to the acids themselves." An assumption was made that only monohydroxy acids are components of wool wax. This assumption and various calculations led Bertram to the conclusion that "... all component acids of the American wax are monohydroxy acids, (while) the acids of the Australian wax contain about 60% monohydroxy acids."

It should be noted that Bertram's conclusions are based on "calculation of composition, observations of viscosity and emulsifying properties and determination of mean molecular weight by the Prahl method." Bertram also advanced the idea that wool wax contains diastolidic esters.

Weitkamp's and Bertram's publications led to extensive investigations of the composition of wool wax acids by modern techniques. Most of these investigations were carried out since 1950 at the South African Council for Scientific and Industrial Research, the Textile Chemistry Laboratory at the University of Leeds, England, and the CSIRO Laboratories in Australia. In the United States, wool wax acids were investigated at the USDA Eastern Regional Research Laboratory, the Department of Biochemistry of Pennsylvania State University and American Cholesterol Products Inc.

COMPOSITION AND PERCENT OF HYDROXY ACIDS IN WOOL WAX ACIDS

Horn, Hougén and Von Rudloff (15) separated in 1953 about 30% of hydroxy acids from wool wax acids derived from a wool wax extracted from Merino fleece; the separation and fractionation was carried out by using the Craig solvent distribution procedure. The authors also converted the total acids into esters which they reduced with lithium aluminum hydride to alcohols, separated the diols from the monoalcohols by column chromatography, converted the diols into acetates and fractionated them by distillation. The composition and percent hydroxy acids can be found in Table IV.

Horn, Hougén, Von Rudloff and Sutton (16) gave the following composition of wool wax acids: unhydroxylated

TABLE III
Analytical Data on American and Australian Crude Wool Wax (14)

	American wax	Australian wax
Acid value, mg KOH/g	11.9	5.9
Saponification value, mg KOH/g	114.6	102.4
Hydroxyl value, mg KOH/g	52.5	36.0
Iodine value (Hanus)	54.75	34.35
Viscosity in cps at 50 C	345.0	216.4
Viscosity in degrees Engler at 50 C	49.5	31.9
Unsaponifiable %	39.5	51.45
Total acids %	60.5	52.7
Hydroxyl value of the acids, mg KOH/g	167.6	102.6
Hydroxyl value of the unsaponifiable, mg KOH/g	145.3	154.0
Free sterols %	0.82	0.02
Mean molecular weight of the acids by titration	329.0	327.0

acids, 62%; α -hydroxy acids, 27%; resinous, polar group of acids, 11%.

These results were obtained by using the Craig solvent distribution method, which makes it possible to carry out the fractionation at room temperature, thereby preventing excessive decomposition of the hydroxy acids.

Conrad (17) calculated the percent hydroxy acids from the analysis of lanolin fatty acids which were recovered from their soaps by a mild treatment. Assuming that the ester number of the acids is due to polymerized hydroxy acids, Conrad corrected the acid and hydroxyl numbers by adding to each the ester number. Using the corrected numbers, Conrad established that 49% of the acids in lanolin fatty acids are hydroxy acids.

Radell, Eisner and Donahue (18) isolated from wool wax acids a nonacidic fraction (12%) which appeared to be a lactone $C_{20}H_{38}O_2$. Based on their investigation, they inferred that this material is a δ -lactone; this would indicate that besides α -hydroxy acids, wool wax contains δ -hydroxy acids. Barnes (19), using conditions similar to the ones used by Radell to prepare wool wax fatty acids, could not find the δ -hydroxy acids.

Horn and Pretorius (20) reinvestigated the hydroxy acids on which Horn et al. reported earlier (15,16) and found that the mixture of monohydroxy acids has an empirical formula $C_{31}H_{62}O_3$. This mixture was converted to lactones which "proved to be more stable and lower boiling than other derivatives. Also, unlike the corresponding hydroxy acids, the lactones showed sharp, well defined melting points."

The lactones were separated by distillation into two fractions: Lactone A ($C_{30}H_{58}O_2$, 50% of the total) and Lactone B ($C_{32}H_{63}O_2$, 30% of the total). The investigation of Lactone A did show that the main hydroxy acid of the mixture is ω -hydroxy-*n*-tricontanoic acid and . . . "it is concluded that the other major component is ω -hydroxy-dotricontanoic acid."

Horn also investigated the high molecular weight hydroxy acids from commercial wool wax and found besides the C_{30} and C_{32} lactones a large amount of lower boiling lactones. This finding lead Horn to make the following observation. "As wool wax obtained from different breeds of sheep may contain different proportions of higher molecular weight hydroxy acids, the greater complexity of the material from commercially recovered wax may be due to it being a mixture of waxes of different provenance. On

TABLE IV

Composition of the Hydroxy Acids of Wool Wax (15)

α -Hydroxy acid	Percentage of mixed acids
n-2-hydroxydodecanoic acid (n- α -hydroxylauric)	0.6
n-2-hydroxytetradecanoic acid (n- α -hydroxymyristic)	3.8
n-2-hydroxyhexadecanoic acid (n- α -hydroxypalmitic)	18.8
2-hydroxyoctadecanoic acid isomers (α -hydroxystearic isomers)	4.6
Total	27.8

the other hand, it has been found that the wool wax on the outer portion of the wool undergoes extensive autoxidation when the sheep are exposed to strong sunlight, and thus it is possible that the commercial wool wax investigated contained a higher proportion of hydroxy acids, which are autoxidation products of wool wax components, than the wax obtained from selected Merino wool. Experiments are now in progress to find out the nature and origin of the minor hydroxy acid components, and it has already been shown by the isolation of higher molecular weight hydroxy acids from freshly secreted wool wax from the inner portions of wool staples that some of these acids are true wax components and not artefacts."

Noble, Eisner and Scanlan (21) attempted to isolate an hydroxy acid concentrate from wool wax acids derived from the saponification of USP lanolin. Since the total acids had an appreciable ester number, they were resaponified and the acids liberated by adding the soap solution to a stirred ice-water solution of HCL. The acids (ester no. 3.2; hydroxyl no. 81.8) were converted into methyl esters and these were fractionated in a Craig countercurrent distribution apparatus between heptane and 45% ethanol, 45% methanol, 10% water. This method made it possible to separate the ester into 38 fractions and a residue. The hydroxyl nos. of two sets of recombined fractions (23.8% and 67.8% of the esters) were found to be 181 and 29.6. The authors state that "the same procedure when applied to the free wool wax acids did not yield a satisfactory hydroxy acid concentrate."

Milburn and Truter (22) investigated the separation of α -hydroxy acids via formation of a copper chelate. The complex was formed by adding an ethanolic solution of

TABLE V

Summary of the Constituents of Wool Wax (12)

Acidic fraction	Approximate content, %
n-acids: 9 members, decanoic to hexacosanoic	7
Iso-acids: 10 members, 8-methylnonanoic to 26-methylheptacosanoic	22
Anteiso-acids: 12 members, (+) 6-methyloctanoic acid to (+) 28-methyltriacontanoic	29
α -Hydroxy- <i>n</i> -acids: 4 members, 2-hydroxydodecanoic to 2-hydroxyoctadecanoic	25
α -Hydroxy-iso-acids: 1 member, 2-hydroxy-16-methylheptadecanoic	3
Total	86
Unidentified residue (mostly unsaturated acids?)	14

copper nitrate to a chloroform solution of wool wax acids and the hydroxy acids recovered by acidifying the complex. The percent recovered hydroxy acids varied from 5.3 to 13.0.

When acids derived from saponification of centrifuged wool grease were converted to esters which in turn were reduced to alcohols by lithium aluminum hydride, the percent α -hydroxy (based on % diols) was found to be about 13%.

ATTEMPTS TO IDENTIFY ALL THE WOOL WAX ACIDS

The extensive work which was carried out on wool wax acids during 1945-1960 paved the way for attempts to establish the full composition of wool wax acids.

Truter (12) summarized in 1956 the composition of wool wax acids as shown in Table V.

Truter suspected that the 14% unidentified residue may consist mostly of unsaturated acids. The fact that Weitkamp did not find unsaturated acids was attributed by Truter to the possibility for removing the unsaturated esters (12%) by Attapulugus clay.

Horn and Ilse (23) summarized in 1956 the composition of wool wax acids as follows: fatty acids, 60.0% (I.V.: 3); resinous acids, 0.7%; hydroxy acids, 32.5%; total recovered, 93.2%. The iodine value is cited as proof of insignificant amounts of unsaturated acids in wool wax acids.

Downing, Kranz and Murray (24) published in 1960 an extensive study of both the fatty acids and alcohols derived from fresh wool wax. The fractionation procedure which was used by Downing et al. can be found in Fig. 1.

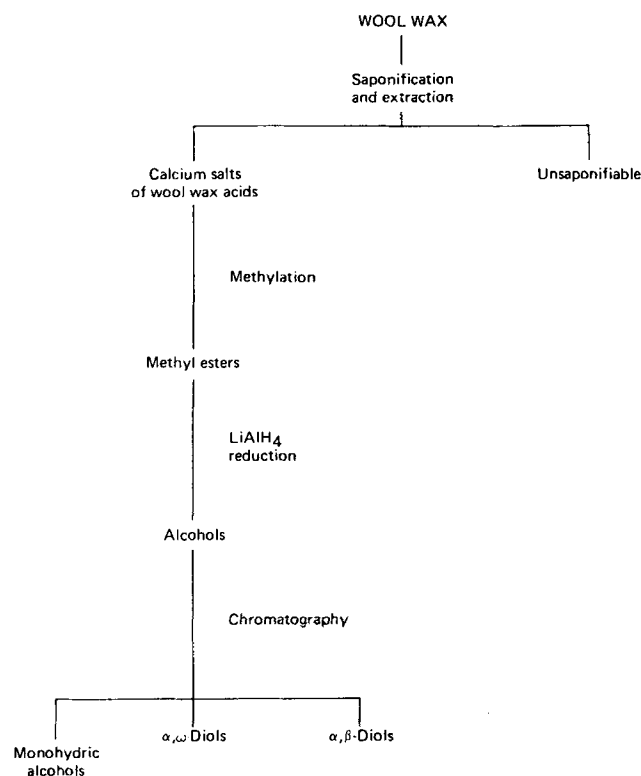


FIG. 1. Fractionation of wool wax into classes of constituents (24).

TABLE VI

Composition of Wool Wax Acids (calculated from Downing's Data, 24)

Acids	Number of acids	Chainlength	Chainlength of major fractions	% of wool wax acids
Normal acids	13	C ₁₂ -C ₃₀	C ₁₄ ,C ₁₆ ,C ₁₈ ,C ₂₄ ,C ₂₆	10
Iso acids	10	C ₁₂ -C ₃₀	C ₁₄ ,C ₁₆ ,C ₁₈ ,C ₂₀ ,C ₂₄ ,C ₂₆	26
Anteiso acids	10	C ₁₃ -C ₃₁	C ₁₄ ,C ₁₉ ,C ₂₁ ,C ₂₅ ,C ₂₇	29
α -Hydroxy acids, normal	12	C ₁₃ -C ₂₄	C ₁₄ ,C ₁₆ ,C ₁₈	14
α -Hydroxy acids, iso	6	C ₁₄ -C ₂₄	C ₁₈ ,C ₂₄	12
α -Hydroxy acids, anteiso	7	C ₁₅ -C ₂₅	C ₁₉ ,C ₂₃	4
ω -Hydroxy acids, normal	5	C ₂₆ -C ₃₄	C ₃₀ ,C ₃₂	3
ω -Hydroxy acids, iso	2	C ₃₀ -C ₃₂	C ₃₀ ,C ₃₂	0.5
ω -Hydroxy acids, anteiso	4	C ₂₇ -C ₃₃	C ₃₁	1
Total	69			94.5

TABLE VII

The Constitution of Wool Wax (25)

Acidic fraction	Percentage
n-Acids:	
15 members, C ₁₀ -C ₃₂ even numbered carbon chains	7
C ₁₃ -C ₁₇ odd numbered carbon chains	
IsoAcids:	
12 members, C ₁₀ -C ₃₂ even numbered carbon chains	23
Anteiso acids:	
12 members, C ₉ -C ₃₁ odd numbered carbon chains	30
α -Hydroxy-n-acids:	
13 members, C ₁₂ -C ₂₄ even numbered carbon chains	
C ₁₃ -C ₂₃ odd numbered carbon chains	15
α -Hydroxy-iso-acids:	
6 members, C ₁₄ -C ₂₄ even numbered carbon chains	11
α -Hydroxy-anteiso-acids:	
7 members, C ₁₃ -C ₂₅ odd numbered carbon chain	4
ω -Hydroxy-n-acids:	
5 members, C ₂₆ -C ₃₄ even numbered carbon chains	3
ω -Hydroxy-iso-acids:	
2 members, C ₃₀ and C ₃₂ carbon chains	0.5
ω -Hydroxy-anteiso-acids:	
4 members, C ₂₇ -C ₃₃ odd numbered carbon chains	1
Total identified	94.5

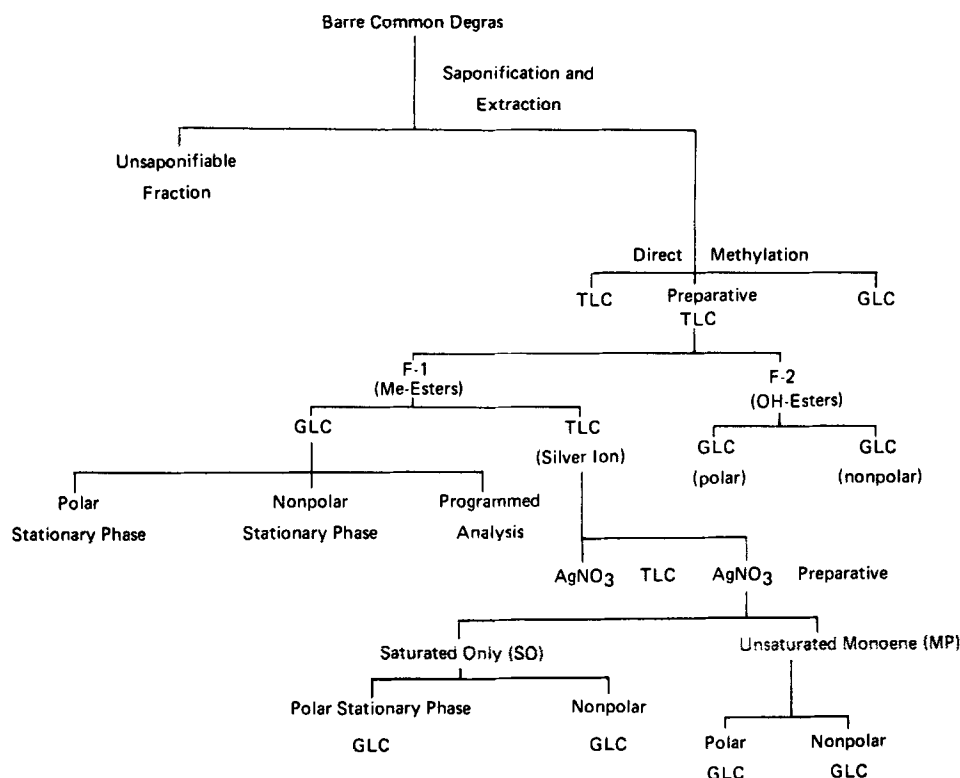


FIG. 2. Process for preparing methyl esters of degrass. Fractionation and characterization scheme (26).

TABLE VIII

Fractions Separated from Lanolin by Column Chromatography (27,28)

Fraction	Weight %	Main constituents
A	0.5	Free acids
B	0.6	Hydrocarbons
C	35.4	Monoesters of sterols and of triterpene alcohols
D	23.7	Mono and polyesters of aliphatic alcohols
E	11.4	Monohydroxyesters of sterols and of triterpene alcohols
F	3.3	Monohydroxyesters of sterols and of triterpene alcohols
G	5.3	Monohydroxyesters of aliphatic alcohols and free triterpene alcohols
H	5.6	Free aliphatic alcohols
I	0.9	Free aliphatic alcohols and sterols
J	4.1	Free sterols
K	4.9	Dihydroxyesters and free diols
L	2.9	Dihydroxyesters and free diols

The composition of the acid fraction was calculated by Downing from the composition of the chromatographed alcohols: alkanolic acids, 60%; ω -hydroxy acids, 5%; α -hydroxy acids, 30%; undetermined, 5%. These results match very closely the results cited previously by Horn and Ilse.

In order to determine the composition of each group of acids, the monohydric alcohols and the two groups of diols which derived from the hydroxy acids were each converted to iodides and next reduced to hydrocarbons with lithium aluminum hydride. The hydrocarbons were purified by column chromatography on alumina and gas chromatographed.

The composition of the wool wax acids was calculated (by K.M.) from Downing's detailed data for the hydrocarbons derived from the iodide fractions (Table VI).

Truter (25) summarized in 1962 the composition of wool wax acids as shown in Table VII. Truter lists a total of 76 acids; there are no unsaturated acids among them.

Pelick and Shigley (26) published in 1967 an analysis of "The Fatty Acids of Degras." The starting material is

described as "Barre Common Degras," but the exact source of the material is unknown. It does appear that this material is a wool grease known as "acid cracked degrass."

Pelick's fractionation and characterization procedure is outlined in Fig. 2. The structure of the various components was established by the use of infrared spectrophotometry and mass spectrometry analysis. It does appear from Pelick's voluminous data that: (a) about ninety fatty acids which were identified range in chain length from 8 to 31 carbons; (b) a small amount of unsaturated acids were found to contain 1 or 2 double bonds; (c) the methyl esters, when fractionated by TLC, consist of 45% alkanolic esters and 55% hydroxy esters. (d) the normal acids range from C_8 to C_{31} ; hexadecanoic acid is the major component.

The iso acids range from C_{10} to C_{30} ; the major components are C_{16} , C_{20} , and C_{26} . The anteiso acids range from C_9 to C_{31} ; the major components are C_{15} , C_{25} and C_{27} .

Among the hydroxy acids, the major component is hydroxy-hexadecanoic acid.

Pelick states that his "... report could differ from other

TABLE IX
Summary of the Composition of Wool Wax Acids (Calculated from Fawaz's data (27,28))

Acids	Number ^a of acids	Chain length	Chain length of major fractions	Wool wax acids %
Normal acids	27	C ₈ -C ₃₈	C ₁₃ ,C ₁₆ ,C ₂₄ ,C ₂₆	22.1 ^b
Iso acids	17	C ₈ -C ₄₀	C ₁₄ ,C ₁₆ ,C ₁₈ ,C ₂₀ ,C ₂₆	22.1
Anteiso acids	18	C ₇ -C ₄₁	C ₁₄ ,C ₁₉ ,C ₂₁ ,C ₂₅ ,C ₂₇	26.3
α-Hydroxy acids normal	23	C ₁₀ -C ₃₂	C ₁₆	21.8
α-Hydroxy acids iso	12	C ₁₂ -C ₃₄	C ₁₈ ,C ₂₄	4.5
α-Hydroxy acids anteiso	12	C ₁₁ -C ₃₃	C ₂₃ ,C ₂₅	0.8
ω-Hydroxy acids normal	14	C ₂₂ -C ₃₆	C ₃₀ ,C ₃₂	3.0
ω-Hydroxy acids iso	8	C ₂₂ -C ₃₆	C ₃₀ ,C ₃₂	0.8
ω-Hydroxy acids anteiso	7	C ₂₃ -C ₃₅	C ₂₅ ,C ₃₁	1.3
Polyhydroxy acids			No details	4.7
Total	138			
Unsaturated acids	42		C ₁₆ ,C ₁₈	2.1
Total				109.5

^aIncludes acids in trace amounts.

^bCorrect figure is most likely 12.1%.

TABLE X

Number of Various Acids in Wool Wax Acids

Author	Number of various acids
Weitkamp (11)	32
Downing (24)	69
Truter (25)	76
Pelick (26)	about 90
Fawaz (27,28)	138 (plus 42 unsaturated acids)

investigations since the exact nature of the wool fat is unknown, and the refining process could cause some alteration to the composition."

The most recent complete study of the composition of wool wax acids was published during 1973-1974 by Fawaz et al. (27,28). Using "pharmaceutical lanolin" as a starting material, Fawaz fractionated the lanolin by column chromatography prior to saponification; this step produced 12 fractions which are listed in Table VIII. Each of the seven ester fractions as well as the original total lanolin were saponified and the methyl esters of the acids fractionated by column chromatography into the esters of nonhydroxy, α-hydroxy, ω-hydroxy, and polyhydroxy acids. The esters of the nonhydroxy acids were column chromatographed on silica gel plus AgNO₃ and collected as saturated and unsaturated fractions. The identification of the individual acids was done by GLC and mass spectrometry. This review includes only the results reported by Fawaz for the acids in total lanolin; these results can be found in Table IX.

SUMMARY

The problems encountered in summarizing the composition of wool wax acids are similar to the problems involved in summarizing the composition of wool wax alcohols: the starting wool waxes which were investigated by various teams during the past twenty years, as well as the methods of saponification, fractionation and identification, were different in each case. Therefore, the difference between the reported results is due to more than one factor.

What should be borne in mind is the fact that: 1) the starting material consisted either of fresh wool wax or pharmaceutical lanolin; 2) the percent composition of wool wax acids, as found by various authors, belongs to carefully prepared acids on a laboratory scale. So, when one averages the percent composition of various wool wax acids as reported by Downing (1960), Truter (1962) and Fawaz (1973-74), the averages — with a few exceptions — are reasonably close to the extremes.

The next two tables summarize the increase in the number of identified wool wax acids since 1945 (Table X) and the average composition of wool wax acids based on the data reported by Downing (24), Truter (25) and Fawaz (27,28). (Table XI).

Pelick's (26) figures, while resulting from a very detailed study, were not included in the averaging, since according to Pelick "the exact nature of the wool fat is unknown." The percentages of polyhydroxy acids and unsaturated acids are tentative because of insufficient data.

TABLE XI

Summary of the Average Composition of Wool Wax Acids (1960-1974)

Acids	Chain length ^a	% of Wool wax acids
Normal acids	C ₈ -C ₃₈	10
Iso acids	C ₈ -C ₄₀	22
Anteiso acids	C ₇ -C ₄₁	28
Normal α-hydroxy acids	C ₁₀ -C ₃₂	17
Iso α-hydroxy acids	C ₁₂ -C ₃₄	9
Anteiso α-hydroxy acids	C ₁₁ -C ₃₃	3
Normal ω-hydroxy acids	C ₂₂ -C ₃₆	3
Iso ω-hydroxy acids	C ₂₂ -C ₃₆	0.5
Anteiso ω-hydroxy acids	C ₂₃ -C ₃₅	1
Polyhydroxy acids		4.5 ^b
Unsaturated acids		2 ^b
Total		100%

^aFawaz (27,28).

^bTentative data.

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