♣ Diozonide of Jojoba Wax as Intermediate for Synthesis[1]

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Jojoba wax reacts with ozone yielding diozonide, which is a viable synthetic intermediate. The diozonide of jojoba wax is a white solid of low titre which decomposes violently around 110-120 C. We have studied several synthetic methods based on the diozonide, such as the preparation of dialdehyde; the corresponding dicarboxylic acid, and derivatives of the latter, such as metal soaps, esters and polyesters. Many additional paths may start from the diozonide intermediate and its derivatives.

The structural elucidation of the fatty ester mixture that constitutes jojoba wax involved, at a certain stage, ozonolysis of the fatty acids and fatty alcohols derived from the oil. Results indicated that both ends of the wax molecules have a double bond at the ω-9 position, with a very low double bond content at other sites (1,2). The alternative possibility of using oxidative cleavage of jojoba wax with permanganate and a phase-transfer agent has been reported by other workers of our Institutes (3). This method yields the dicarboxylic acids; however, other synthetic paths, such as those based on the reductive cleavage of the ozonide, are unattainable.

Although the nomenclature of individual components of the reaction mixture is straightforward, the generic names of some mixtures derived from jojoba wax after the decomposition of the ozonide are rather cumbersome. To avoid such difficulties, the molecular section enclosed between the double bonds of jojoba wax will be designated "endojojoba," which, on adding the proper prefixes and suffixes, will yield the generic names.

RESULTS AND DISCUSSION

Jojoba wax can be reacted with ozone to yield a stable diozonide, which may be used as the starting material for various synthetic paths, as shown in Figure 1. Reaction of the wax with ozone takes place under a wide range of conditions—solvent, temperature and ozone concentration—in analogy with other fatty materials (4-7). In the present work a double ozonide was obtained without the use of a solvent. The convenience of avoiding solvent recovery, evaporation losses and fire hazards may by far supersede the slight losses caused by side reactions, when the ozonization process is run without solvent on a practical scale. When the product is cooled to room temperature, a white, soft solid with the smell of pelargonaldehyde is obtained. At room temperature the diozonide is relatively stable, due to its large C:O ratio. Thus, samples of the ozonized material have been preserved in the laboratory for many months with only slight deterioration. (A warning is made later in this paper about ozonide's behavior at higher

temperatures). Ozonized jojoba wax has been proposed for application against acne (8).

Reaction paths of synthetic interest for ozonides may be hydrolytic, reductive or oxidative. The latter decomposition path leads to carboxylic acids and the others to aldehydes or their derivatives, depending on the medium composition. Two main fractions are obtained on starting with jojoba wax diozonide: a C_9 compound which may be pelargonaldehyde, perlargonic acid or other derivatives, and correspondingly a mixture of bifunctional endojojoba derivatives, all containing a central ester moiety. The residue after separation of the C_9 fraction is a versatile starting material for synthesis. The dialdehyde shown in Figure 1 (endojojobadialdehyde) may be obtained by catalytic hydrogenation of the diozonide, similarly to other ozonized fatty materials (9,10), or by reductive cleavage in the presence of triphenylphosphine (11,12), zinc dust (13), or sodium iodide (14), followed by separation of pelargonic aldehyde. In order to obtain clean aldehydes, ozonization should be carried out under milder conditions than those of the present work, namely at low temperatures and in the presence of solvents (14). In the present work, ozone had to be introduced at temperatures up to 50 C, causing side reactions which led to the formation of carboxylic acids to some extent (15).

Many other reductive scission reactions of diozonide are possible; one of them is shown in Figure 1. The same reactions also may be carried out starting from the isolated dialdehyde, thus avoiding separation of the corresponding C_9 by-products.

Oxidative decomposition of the diozonide, as shown in Figure 1, was carried out immediately following ozonization of the oil. The temperature in the reactor was raised to 90 C, and oxygen containing some ozone as catalyst was bubbled through until the value of a characteristic property of the system leveled off.

Two such properties are shown in Figure 2 (curves b and c), as a function of total oxygen fed into the reactor; the refractive index of the liquid decreases while the acid number increases as carboxylic acids are formed. After removing the pelargonic acid from the resulting mixture, the remaining material (endojojobadioic acid) may be purified by recrystallization. Another possibility for monitoring the reaction progress is to follow the disappearance of the CH peak in the ozonide moiety, at δ 5.0 ppm.

A warning about handling of diozonide at high temperatures: although the diozonide of jojoba wax was formed safely at 40-50 C and the oxidative decomposition was carried out at 90-95 C, heating to higher temperatures may be dangerous. Thus, heating the diozonide to 110-120 C caused fast decomposition which may be dangerous and hard to control. Because of the seasonal and geographical variability of jojoba wax composition (16,17), it would be advisable to check the thermal stability of the diozonide up to 90-95 C before attempting oxidative cleavage on a large scale.

Reaction of the dicarboxylic acid with alkali solutions was immediate, yielding the corresponding salts after
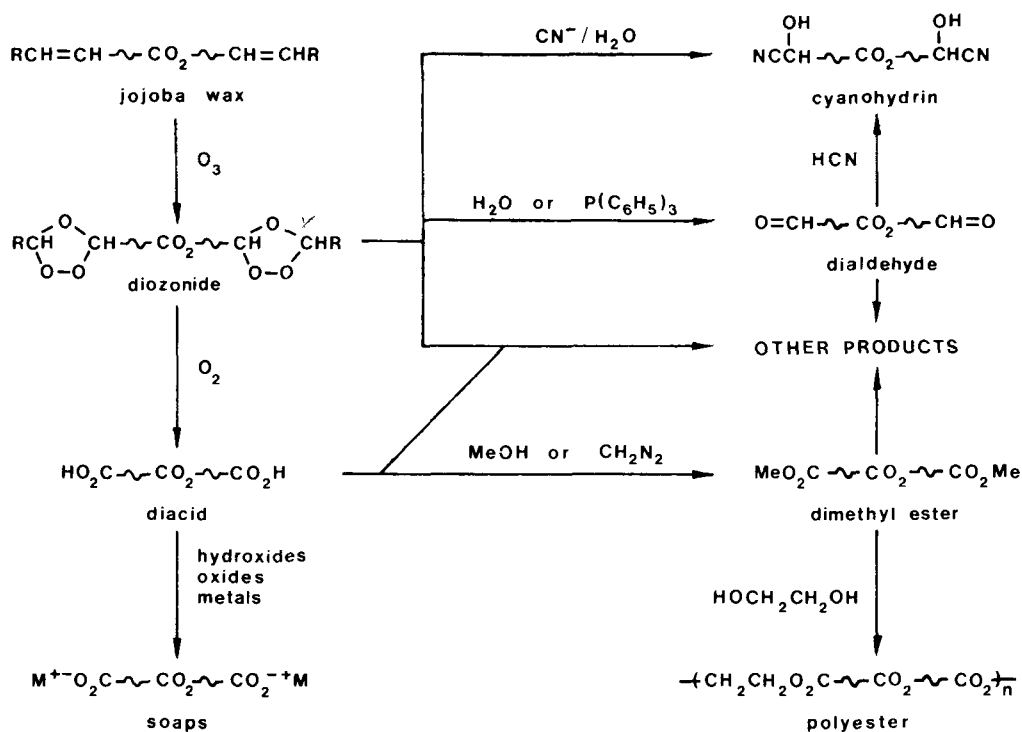
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FIG. 1. Derivatives of jojoba wax via ozonization. (R, n-octyl; wavy lines represent polymethylene chains.)

evaporation. With pulverized metals such as zinc or aluminum, some heating was needed to bring the process to completion. These products may serve as catalysts, lubricant oil additives and metal soaps. The zinc salt may be used as a fungicide in skin conditions. Attempts to isolate a stable ammonium salt were not successful, and only a partial neutralized solid was obtained.

The dimethyl ester of the dicarboxylic acid can be prepared with good yield by a Fischer type esterification combined with azeotropic distillation of water. Diazomethane may be used to finish off the esterification, but it may, of course, be used to esterify the dicarboxylic acid directly. This dimethyl ester is a good intermediate for a varied set of syntheses. For example, polyesters could be prepared with ethylene glycol. At the high temperatures required by the polymerization process, it is probable that the central ester group undergoes transesterification to a certain extent; however, this need not be a terminating reaction as divalent molecules are produced which may participate in the polycondensation. Processes taking place at low temperatures probably discriminate between the central ester group and the less hindered methyl ester groups at both ends of the molecule.

EXPERIMENTAL

Materials. Jojoba wax ("Apache") was decolorized with bleaching powder (2%) at 60 C for one hr and filtered in a centrifugal filter with the aid of Cellite Oxygen was dry industrial grade. Alkaline bases and zinc dust were analytical reagents; triphenyl phosphine, Diazald, ethylene glycol and solvents were synthesis grade reagents.

Elemental analyses. The values given below are compared to those of the corresponding products derived from a hypothetical jojoba wax of formula $C_{42}H_{80}O_2$ (MW 616), with double bonds at positions ω-9 and ω'-9.

Ozonization of jojoba wax. The wax was placed in a 2-1 jacketed reactor provided with a magnetic stirrer. The cover of the reactor held a thermometer with a long stem and a delivery tube with a perforated gas distributor at its lower end, both reaching deep into the jojoba wax. The reactor cover also was connected to an effective condenser where organic vapors were condensed into a liquid which was collected in a round-bottomed flask. The gas emerging from the condenser was passed through a potassium iodide solution in order to detect the emergence of ozone at the end of C=C ozonization or to absorb the ozone catalyst at the ozonide oxidation step. Oxygen was fed into the ozone generator at ca. 6.5 mol/hr where ozone was produced at a rate of about 11g/hr (0.23 mol/hr). The gas was bubbled through the magnetically stirred oil. After about 5 hr the viscosity of the liquid increased and it was necessary to heat it gradually to 40-50 C, by circulating warm water through the jacket of the reactor. The refractive index (n_D^{60}) of the reaction mixture decreased as the ozonization proceeded, as shown in curve a of Figure 2. The NMR triplet at δ 5.3 ppm, characteristic of the olefinic proton, was gradually replaced by a triplet at δ 5.0 ppm belonging to the ozonide. The ozone supply was interrupted when a deep brown color of iodine developed in the iodide solution trap. This coincided with the refractive index leveling off in curve a and the disappearance of the olefin NMR peak.

The material balance of this reaction was not accurate;

based on the reaction stoichiometry, a weight increase of 15.6% could be expected. The increase was always lower, typically about 14-14.5%. This probably was due to ozonide decomposition and the loss of volatile products. Small amounts of pelargonaldehyde always were found in the trap attached to the reactor condenser.

Elemental analysis of a typical diozonide sample: C, 68.89%; H, 11.12%; calculated for $C_{42}H_{80}O_8$, derived from the hypothetical jojoba wax: C, 70.78%; H, 11.24.

Reductive decomposition of the diozonide. Jojoba wax diozonide (15 g) was reduced to a mixture of aldehydes by triphenylphosphine (15 g) in petroleum ether (75 ml), as described in the literature (9,10). After filtering the solid precipitate, evaporating the solution and filtering again, the low molecular weight aldehydes (4.5 g, mainly nonanal) were distilled in vacuum. The residue was recrystallized from light petroleum ether, yielding a solid of low titer (9.1 g); the NMR spectrum corresponded to the dialdehyde, with a characteristic triplet at δ 9.7 ppm. No clean dialdehyde could be attained, as it always showed a residual acid number, probably due to the presence of mixed aldehyde-carboxylic acid molecules. The latter contention was supported by TLC on silica plates, which showed some spots that reacted to both aldehyde and acid detection reagents. Similar results were obtained on subjecting the diozonide to steam distillation in the presence of zinc dust.

Neutral decomposition of the diozonide. The diozonide was subjected to a steam distillation by which it decomposed and the low MW fraction (mainly nonanal) was distilled. The residue was the dialdehyde which could be further recrystallized from petroleum ether. The resulting product showed high acid numbers pointing to a high content of carboxylic acids.

Oxidative decomposition of the diozonide. The diozonide was heated to 90 C in the same reactor where it was prepared, and a stream of oxygen containing some ozone as catalyst was passed until all the diozonide decomposed. The process could be followed by the drop in the refractive index (n_D^{60}), the rise in the acid number, and the disappearance of the ozonide peak at 5.0 ppm. Curves b and c in Figure 2 show the behavior of two properties of the reaction mixture by means of which the progress of decomposition may be monitored. After vacuum distillation of the low molecular weight carboxylic acid (mainly nonanoic acid), a white solid residue of endojojobadioic acid was obtained, which had mp 60 C after recrystallization from light petroleum ether; yield 66.5%. Analysis: C, 65.36%; H, 9.94%; calculated for $C_{24}H_{44}O_6$, derived from the hypothetical jojoba wax: C, 67.28%; H, 10.28%. Equivalent weight: found 247; calculated 214.

Dimethyl ester of endojojobadioic acid. Method a. The product obtained from ozonization and oxidative decomposition of 1 kg of jojoba wax was left in the same reactor, and an azeotropic distillation attachment was connected to the cover of the reactor. The content was diluted with 250 ml of dichloromethane, 50 ml of dry methanol and 7.5 g of p-toluenesulfonic acid. The azeotropic distillation of water was carried out on heating to 75 C for several days, until the acid number of the oil levelled off at about 12. The solvent and methanol were evaporated. The residue was distilled in vacuum yielding a low boiling fraction (50-52 C/4 torr) of methyl nonanoate and a brownish residue of acid value 15 which was the dimethyl ester of endojojobadioic acid. This esterification method is a variation of that in (18), using
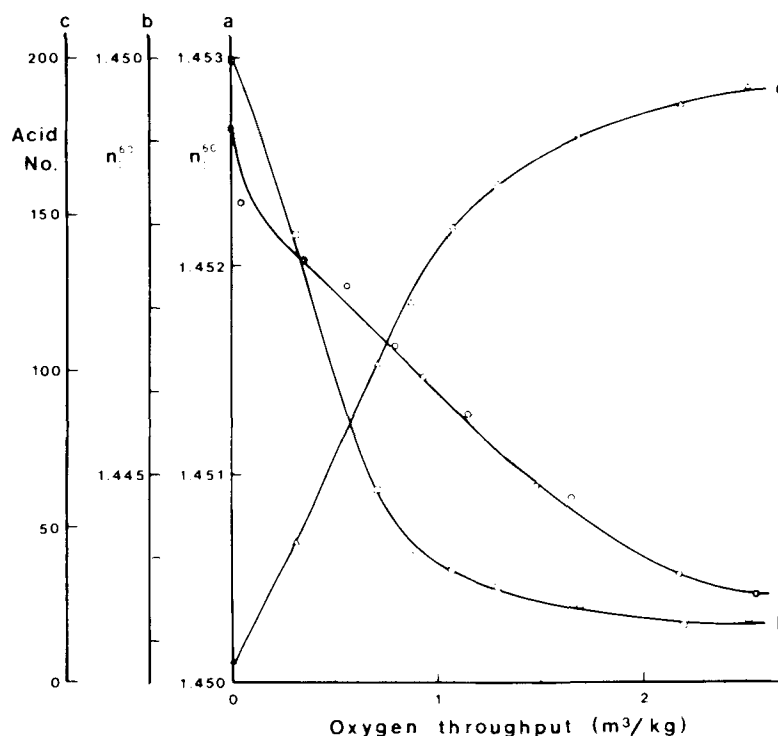

FIG. 2. Monitoring of neat jojoba wax ozonization (curve a) and decomposition of jojoba wax diozonide by oxygen (curves b and c).

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here a milder catalyst and a lower boiling solvent, with the intention of avoiding scission of the central ester moiety of the starting material.

Method b. Recrystallized endojojobadioic acid (100 g) was dissolved in diethyl ether (150 ml). Diazomethane in ether was prepared from Diazald (19) and slowly added to the acid solution, until nitrogen evolution ceased. The solvent was evaporated and a colorless, viscous liquid, the dimethyl ester, was obtained. The same method also was applied to finish off esterification by method a. Analysis: C, 69.40%; H, 10.50%; calculated for $C_{26}H_{48}O_6$, derived from the hypothetical jojoba wax: C, 68.42%; H, 10.52%.

Metal salts of endojojobadioic acid. Method a. Salts of alkaline metals were prepared by dissolving the recrystallized acid in methanol containing some toluene, neutralizing with the corresponding hydroxide in methanol solution and evaporating the solvent.

Method b. Metal soaps of zinc and aluminum were prepared by melting the mixture of acid with pulverized metal, under nitrogen, with constant stirring until all the metal disappeared. By this procedure only about 80% of the proton equivalents could be neutralized without causing discoloration of the product.

Polyester from endojojobadioic acid. Dimethyl ester of endojojobadioic acid (54 g), and ethylene glycol (140 g) were refluxed for 18 hr until constant weight was attained. The cold mixture was poured into 250 ml of water, extracted with ether, dried over anhydrous sodium sulfate and evaporated. The yellowish liquid residue (65 g) is the result of transesterification of the methyl groups by β-hydroxyethyl groups with elimination of methanol. A test tube was attached to a Kjeldahl ball, connected in turn to a rotatory evaporator (Buchi's Rotavapor). The transesterification residue (12 g) was placed in the test tube and the set was rotated and continuously evacuated. The test tube was immersed in a tubular oven at 200 C for about 4 hr and at 235 C for 3 more hr. The weight was reduced to about 8 g, leaving an elastic residue which swelled in benzene but could not be dissolved in ordinary solvents.

REFERENCES

1. *Jojoba: New Crop for Arid Lands, New Raw Material for Industry*, National Academy Press, Washington D.C. 1985.
2. Wisniak, J., in *Progress in the Chemistry of Fats and other Lipids*, edited by R.T. Holman, Pergamon Press, Oxford, 1977, pp. 167-218.
3. Galun, A.B., S. Grinberg, A. Kampf and E. Shaubi, *J. Amer. Oil Chem. Soc. 61*:1088 (1984).
4. Chinn, L.J., *Selection of Oxidants in Synthesis: Oxidation at the Carbon Atom*, Marcel Dekker, New York, 1971, pp. 147-162.
5. Murray, R.W., in *Techniques and Methods of Organic and Organometallic Chemistry*, Vol. 1, edited by D.B. Denney, Marcel Dekker, New York, 1969, pp. 1-31.
6. Belew, J.S., in *Oxidation*, Vol. 1, edited by R.L. Augustine, Marcel Dekker, New York, 1969, pp. 259-335.
7. Milas, N.A., and J.T. Nolan Jr., *Adv. Chem. Ser. 21*:136 (1959).
8. DeVillez, R.L., *U.S. patent* 4,451,480, 1984.
9. Throckmorton, P.E., and E.H. Pryde, *J. Amer. Oil Chem. Soc. 49*:641 (1972).
10. Throckmorton, P.E., *Ibid. 49*:643 (1972).
11. Lorenz, O., and C.R. Parks, *J. Org. Chem. 30*:1976 (1965).
12. Lorenz, O., *Anal. Chem. 37*:101 (1965).
13. Whitmore, F.C., and J.M. Church, *J. Am. Chem. Soc. 54*:3712 (1982).
14. Bailey, P.S., and R.E. Erickson, *Org. Synth., Coll. Vol. 5*:489 (1973).
15. Harries, C., and H.O. Turk, *Chem. Ber. 39*:3732 (1906).
16. Miwa, T.K., *J. Amer. Oil Chem. Soc. 48*:259 (1971).
17. Dunstone, R.L., A. Benzioni, M.L. Tonnet, P. Milthorpe and A.Shani, *Aust. J. Plant Physiol. 12*:355 (1985).
18. Clinton, R.O., and S.C. Laskowski, *J. Am. Chem. Soc. 70*:3135 (1948).
19. Aldrich Chemical Co., *Diazald*, Bull. No. AL-113, Milwaukee, Wisconsin, U.S.A.