Some Physical Properties of *Simmondsia* Oil

JAIME WISNIAK and **DORON LIBERMAN**, Department of Chemical Engineering,
Ben Gurion University of the Negev, Beer-Sheva, Israel

ABSTRACT

Refractive index, density, viscosity, dielectric constant, specific conductivity, and surface tension of *Simmondsia* oil have been measured at different temperatures.

INTRODUCTION

There is a growing interest in the U.S. and Israel to develop the shrub jojoba (*Simmondsia californica*) as an industrial crop, interest that stems from the unusual properties of the oil that can be extracted from its seeds. Jojoba is unique among plants in that its seeds contain ca. 50% by wt of a practically colorless, odorless wax composed of the straight chain esters of the C_{20} and C_{22} alcohols and acids with one double bond. *Simmondsia* oil resembles sperm oil in chemical composition and behavior, and, if a sufficient supply were available at a competitive price, it would undoubtedly find use as a substitute for sperm oil and high priced waxes like carnauba and bees wax. *Simmondsia* and its derivatives have been found to have a wide range of uses that go from stabilization of penicillin products and hair tonic, to plasticizer for vinyl polymers. The sulfurized oil is suitable as an ink vehicle, factice, and high pressure lubricant (1). It is, thus, of interest to determine the temperature dependence of the physical properties of the oil that will be useful in basic and design work.

Many vegetable and animal oils have been investigated systematically with respect to a variety of physical properties, and most of the data available have been compiled by Markley (2). Refractive indices of normal saturated acids were determined by Dorinson, et al., (3) and found to vary linearly with the temperature in the range 20-80 C, Privett and others (4) extended these measurements to several unsaturated acids and their methyl and glyceryl esters. Viscosities and densities of fatty materials have been measured extensively for a large number of fats and oils and related to the length and degree of unsaturation of the chain (5,6). In 1952, Gros and Feuge (7) reported their results on the measurement of the surface and interfacial tensions of saturated acids from acetic to stearic and their methyl and ethyl esters and found that this property decreased in the order pure acid, methyl ester, ethyl ester. Data on the specific and dielectric constant of fatty materials appear in Markley's book (2).

MATERIALS

The jojoba seeds obtained in this work were obtained from shrubs grown at the Negev Institute for Arid Zone Research, now a part of the Ben-Gurion University of the Negev. Cold-pressing produced a medium color oil that had the following characteristics: refractive index (20 C), 1.4652; iodine value (Wijs), 83.2; mp, 13 C; acid number, 6.7; and saponification number, 107. The gas chromatographic analysis performed according to the method suggested by Miwa (8) gave the following results: C_{34}, 0.1%; C_{36}, 1.6%; C_{40}, 32%; C_{42}, 49%; C_{44}, 9%; C_{46}, 0.9%; and C_{48}, 0.1%. The oil was used as such without further purification.

PHYSICAL CHARACTERIZATION

In every case where possible, instrument temperature was controlled to ±0.1 C using a Haake model NK-22 constant-temperature bath and a mercury thermometer calibrated with a Hewlett-Packard quartz thermometer, model 2801 A.

Refractive Index

Measurements were performed with a Bausch & Lamb Abbe-3L precision refractometer that gave direct readings to four significiant figures and estimated values reproducible to the near 0.00025. The instrument was calibrated carefully with the test piece supplied by the manufacturer and checked with 1-bromonaphthalene.

The refractive indices were measured in the range 25-75 C, in steps of ca. 5 C. Experimental results appear in Table I without correction for the effect of temperature upon the refractometer prism. These results show a straight line relationship that can be expressed as follows:

$$n = 1.47341 - 0.000360\ t,$$

with t in C and an accuracy of ±0.00001.

The only data available for comparison are those of Craig (9) for erucic acid, one of the components of *Simmondsia* oil:

$$n = 1.46892 - 0.000346\ t$$

for the range 20-85 C. The refractive index of *Simmondsia* oil shows to be somewhat larger, in agreement with the data of Craig that point to an increase in the index with increased chain length. The specific refraction r calculated according to:

$$r = \frac{n^2 - 1}{n^2 + 2}\ \frac{1}{d}$$

and the data of Table II gave the value 0.3196 ± 0.0008 in the temperature range examined.

Density

Densities were determined in a 8.5 ml modified picnometer (Fig. 1) provided with an expansion chamber A and a calibrating mark B. Operation of the pycnometer was as follows. First, it was filled to end C by applying suction to the other end, and then it was submerged in the constant

TABLE I

Refractive Indices, n

Temperature, C	n	Temperature, C	n
25.2	1.4645	55.2	1.4535
30.0	1.4625	60.1	1.4520
35.0	1.4610	65.3	1.4500
40.0	1.4590	70.4	1.4480
45.1	1.4570	75.6	1.4465
50.0	1.4550		

TABLE II

Densities

Temperature, C	g/ml	Temperature, C	g/ml
25.6	0.8656	106.2	0.8123
38.0	0.8572	113.5	0.8076
46.6	0.8514	123.6	0.8008
55.6	0.8459	129.4	0.7971
64.6	0.8393	145.0	0.7872
74.9	0.8330	148.6	0.7848
84.4	0.8266	164.8	0.7743
97.7	0.8181		

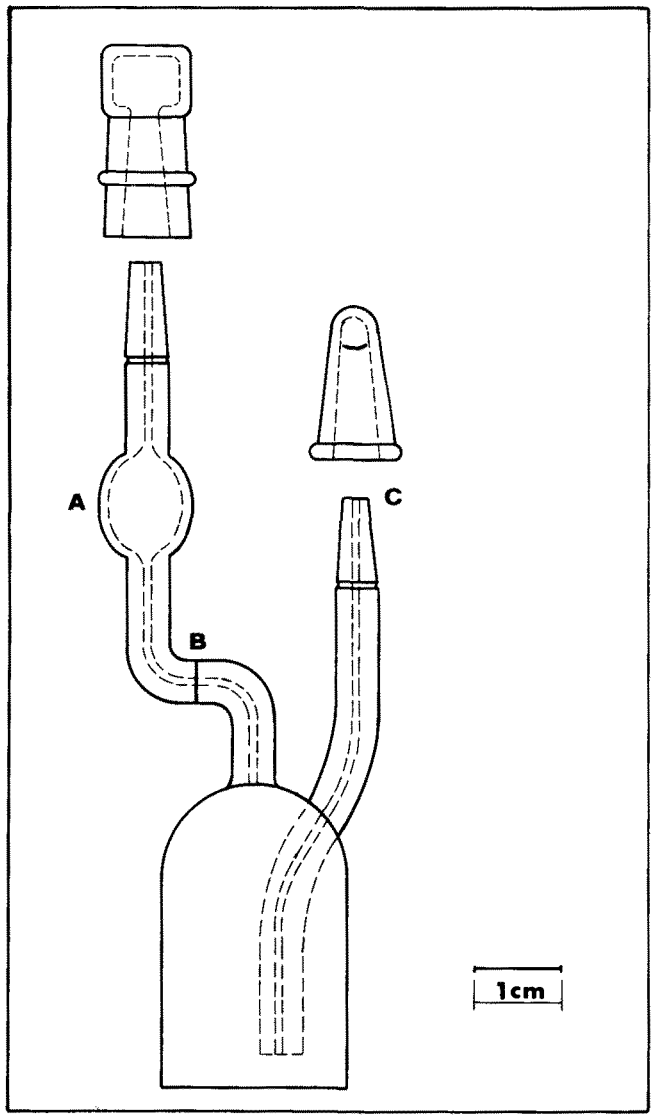

FIG. 1. Modified pycnometer. A. expansion chamber; B.,C. filling marks.

TABLE III

Viscosities

Temperature, C	Centipoise	Temperature, C	Centipoise
25.6	35.2	60.8	11.9
30.5	29.6	65.6	10.6
35.7	24.9	75.4	8.5
40.7	21.0	85.6	6.9
45.8	18.0	101.5	5.2
51.0	15.6	110.1	4.5
55.6	13.7		

TABLE IV

Specific Conductivities, C, and Dielectric Constants, ϵ

Temperature, C	C [mho/cm]	ϵ
27.0	8.86×10^{-13}	2.680
32.5	6.02×10^{-12}	2.886
46.0	8.80×10^{-12}	2.848
60.2	1.24×10^{-11}	2.840
74.6	1.66×10^{-11}	2.789
84.6	2.36×10^{-11}	2.783
98.6	4.60×10^{-11}	2.760
107.0	5.29×10^{-11}	2.726
122.8	9.96×10^{-11}	2.703
140.0	11.52×10^{-11}	2.646

temperature bath. After temperature equilibration, the excess oil was removed by the capillary action of a filter paper in contact with C. When the oil retreated to mark A, the pycnometer was removed from the bath, cooled to room temperature, dried, and weighed. The expansion chamber A prevented significant oil spilling during the heating period. Volume calibration was performed by using double distilled water as a filling fluid. At least four measurements were made at each temperature level. Experimental results appear in Table II and show a linear variation that can be expressed as follows:

$$d = 0.8821 - 0.000656\,t,$$

with t in C and an accuracy of ±0.0004. The range of densities is typical of vegetable oils (2).

Viscosity

The absolute viscosity of the oil was determined in the temperature range 25-110 C and the experimental results appear in Table III. The measurements were performed with a Haake falling ball viscometer, model B, and the density data shown in Table II. Successive determinations were made until the last five showed a variation of less than 0.2%.

The experimental results can be correlated with the following Arrhenius-type equation:

$$\eta = 0.004995 \exp\left(\frac{2646}{T}\right),$$

with T in C.

The kinematic viscosity values at 100 F (26.83 centistoke) and 210 F (6.48 centistoke) indicate that the viscosity index of *Simmondsia* oil is 225.

Dielectric Constant

The dielectric constant may be determined by several methods, namely, from measurements of electrical capacities of mechanical forces between charged conductors, or of the wave length of electrical waves. In the present work, it was decided to measure the dielectric constant according to the German Norm DIM 53483 (10), so that the results could be compared with those available for transformer oils. The measurements were made at the fixed frequency of 1000 hertz using an impedance bridge made by General Radio Co., Cambridge, Mass. (model 650-A). Table IV gives the values of the parameter at different temperatures, and this can be seen to be in the range of the typical fatty materials (2).

Specific Conductivity

Measurements were performed according to the German Norm DIN 53482 (11) at 500 volt dc, using a Megohm bridge manufactured by General Radio Co. (model 544-B).

The experimental results appear in Table IV for the temperature range of 32-140 C and show that the specific conductivity of *Simmondsia* oil is similar to that of oleic acid (2).

Surface Tension

This property was determined at 23.5 C by measuring with a 500 mg precision balance, model L (Federal Pacific Electronic Co., Newark, N.J.) the force required to pull a platinum wire. Successive measurements gave the value 34.0 dyne/cm. The experimental set up did not allow the study of the effect of temperature upon this variable.

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