Factors Affecting the Electrical Resistivity of Soybean Oil Methyl Ester

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ABSTRACT: Factors affecting the electrical resistivity of soybean oil methyl ester (which is important in some industrial applications) were investigated by the addition of polar constituents [free fatty acids (FFA), water, phospholipids, monoglyceride, sterol, tocopherol, peroxides, and β-carotene] to alumina-purified soybean oil methyl ester (APSBOMe). Investigation of measuring conditions showed that reproducible results were obtained when the potential was greater than 25 V, and the charging time was greater than 10 s. The resistivity of APSBOMe increased logarithmically as temperature decreased linearly. FFA had little effect on resistivity. Saturation with water lowered the resistivity of APSBOMe much more than that of alumina-purified soybean oil (APSBO). Phospholipids reduced the resistivity significantly when added to dry ester, but the addition of water affected the resistivity of the samples containing phospholipids only slightly. Monoglyceride, sterol, tocopherol, and hydroperoxide affected the resistivity of dry methyl ester similarly, but only monoglyceride showed a significant synergistic effect with water. Diacylperoxide and β-carotene had little effect on the resistivity of the ester.

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KEY WORDS: β-Carotene, charging time, electrical resistivity, free fatty acids, oxidation products, polar components, soybean oil methyl ester, temperature, voltage.

Industrial uses of vegetable oils as replacements for various petroleum-based products have been considered recently because of environmental concerns and vegetable oil's biodegradability. The use of soybean oil as a carrier for printing ink is an example of this trend. In some digital printing processes, an image is produced by an electrostatic charge, and a carrier with a high electrical resistivity is required. The electrical resistivity of a material is defined as the resistance to the current passing across a 1-cm cube of the material. Investigations of the electrical resistivity of soybean oil (SBO) (1) showed that, like mineral oils, its resistivity is affected by temperature (2) and polar components such as water, phospholipids, and monoglyceride (3).

The relatively high viscosity of SBO may be a limitation in some digital printing applications. Vegetable oils can be converted to their methyl ester with about a tenfold decrease in their viscosity (4). In this study, factors affecting the resistivity of methyl soyate (SBOMe) prepared from SBO by transesterification are reported.

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EXPERIMENTAL PROCEDURES

SBOMe was purchased from Interchem Environmental, Inc. (Kansas City, MO). Water and polar constituents were removed by passage through alumina according to Jensen *et al.* (5). Chemicals were reagent grade and purchased from Fisher Scientific (Pittsburgh, PA), Sigma (St. Louis, MO), and Aldrich (Milwaukee, WI).

Resistivity measurements were carried out with a Hewlett-Packard (Wilmington, DE) 4339 B high-resistance direct current meter equipped with a conductivity cell (Fisher Scientific #9,366) with a cell constant of 1.3. The following conditions were used to measure volume resistivity unless otherwise specified: 24°C, 50 V, charging time 120 s. Fifty readings were observed and averaged automatically by the instrument.

The effect of various substances on the resistivity was tested by dissolved them in alumina-purified soybean oil methyl ester (APSBOMe) at 24°C. To test for interactions of the substance with water, 1 drop of water (~0.05 mL) was mixed with 10 mL of the sample at 24°C for 30 min after the dry resistivity was read. The sample was centrifuged for 2 min to remove excess water, and the resistivity was measured.

RESULTS AND DISCUSSION

APSBOMe was charged with various voltages (up to 1,000 V) and times (up to 600 s) to determine the effects on the apparent resistivity. Figure 1 indicates that voltages greater than 25 V and charging times greater than 10 s gave consistent results. Potentials of 50 V and charging times of 120 s were chosen for the resistivities reported here.

As the temperature of APSBOMe decreased from 100 to –5°C, the resistivity increased logarithmically from 0.015 to 6.86 Tohms·cm (Fig. 2). Similar relations have been observed between viscosity and temperature (6) and are probably related to the heat of evaporation, that is, the energy required to separate molecules of a substance. The resistivity of APS-

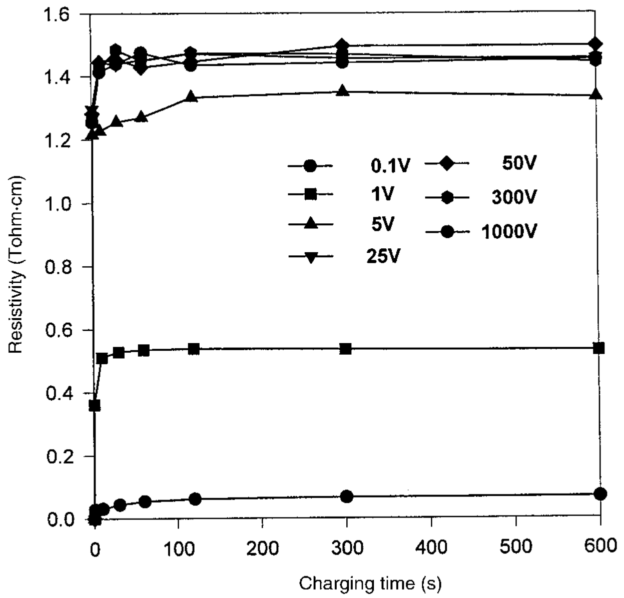

FIG. 1. The effects of voltage and charging time on the resistivity of alumina-purified soybean oil methyl ester.

BOMe is about 16-fold less than that of APSBO (1), a difference of about the same magnitude as the change in viscosity. Resistivity was not recorded below –5°C, the cloud point of the oil.

Oleic acid was added to APSBOMe to test the effect of FFA on resistivity. Oleic acid reduced resistivity about twofold at the level of 0.2% oleic acid. This is much smaller than the effect that FFA had on APSBO and may result from the smaller resistivity of APSBOMe relative to APSBO. Table 1 shows that resistivity increased with the additional FFA. A similar effect of FFA was noted with SBO (1), and was attributed to increased dimerization of the FFA as the concentration increased. When water was introduced, the resistivity of the sample containing 0.2% of oleic acid decreased about 100-fold to 0.0068 Tohms·cm.

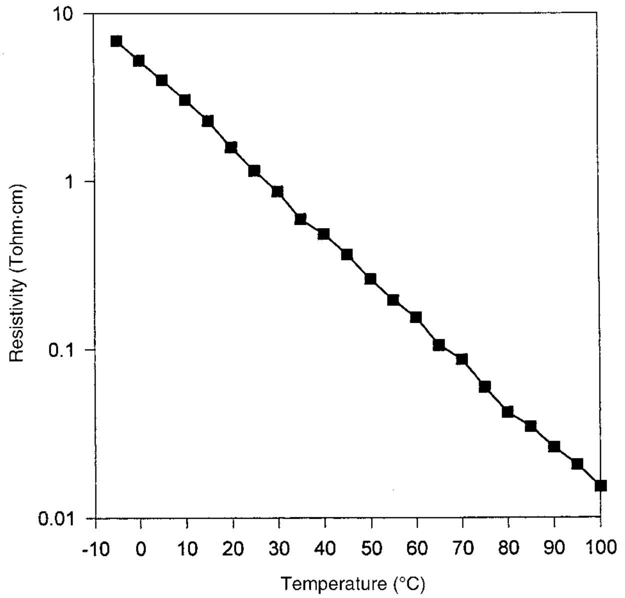

FIG. 2. The effect of temperature on the resistivity of alumina-purified soybean oil methyl ester.

Treatment of SBOMe with alumina to remove water and polar constituents resulted in an increase in the resistivity from 0.058 to 1.44 Tohm·cm. The introduction of 1 drop of water in SBOMe and APSBOMe lowered the resistivities from 0.058 to 0.0050 Tohm·cm and 1.44 to 0.015 Tohm·cm, respectively. This 99-fold drop for APSBOMe is much greater than the 3.25-fold drop in resistivity caused by the addition of water to APSBO. This may be caused by a greater solubility of water in methyl ester.

Phospholipids significantly reduced the resistivity when added to dry APSBOMe (Table 1). But when water was added to the samples containing phospholipids, the resistivities did not change very much even though water had been found to act synergistically with phosphatides in APSBO (1). Possibly, centrifugation was more effective in removing hydrated phosphatides from the APSBOMe because of its lower viscosity.

1-Monoolein, α-tocopherol, and β-sitosterol had less effect than phospholipids in dry APSBOMe (Table 1), but the resistivities of the samples containing 1-monoolein decreased more than those of the others with the addition of water. Because monoglycerides are good emulsifying agents, they may have stabilized emulsified water in APSBOMe. These effects paralleled those caused by the addition of these materials to APSBO (1).

Hydroperoxides are primary oxidation products of fats and oils. Lauroyl peroxide and *tert*-butyl hydroperoxide were introduced into APSBOMe to observe the effect of peroxides on resistivity. As shown in Table 1, diacylperoxide had little effect, but hydroperoxide lowered the resistivity about 2.5-fold in dry APSBOMe and about 6.6-fold in the presence of water.

Crude SBO contains about 40–50 ppm of carotenoids and 1–2 ppm of chlorophyll (7), and they are removed by alumina treatment. β-Carotene added to APSBOMe at 20 ppm reduced the resistivity from 1.44 Tohm·cm to 1.29 Tohm·cm (Table 1). The addition of water to β-carotene-containing APSBOMe gave little effect on resistivity over that of water alone.

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REFERENCES

1. Tekin, A., and E.G. Hammond, Factors Affecting the Electrical Resistivity of Soybean Oil, *J. Am. Oil Chem. Soc. 75*:737–740 (1998).
2. Tagg, H.F., *The Practical Measurement of Insulation Resistance*, Newnes Books, Feltham, England, 1968, pp. 17–35.

TABLE 1
Effects of Various Constituents on the Resistivity of Alumina-Purified Soybean Oil Methyl Ester

	Resistivity in Tohm·cm			Resistivity in Tohm·cm	
	Dry oil	Wet oil[a]		Dry oil	Wet oil[a]
Oleic acid (%)			Phospholipids (mg/kg)		
0	1.44	0.0148	0	1.44	0.0148
0.1	0.75	0.0070	100	0.0054	0.0039
0.2	0.69	0.0068	200	0.0033	0.0026
0.3	0.83	0.0074	300	0.0022	0.0017
0.4	0.88	0.0079			
0.6	1.03	0.0085			
0.8	1.09	0.0089			
1	1.18	0.0101			
1-Monoolein (mg/kg)			Lauroylperoxide (meq/kg)		
0	1.44	0.0148	0	1.44	0.0148
100	0.67	0.0009	10	1.24	0.0107
300	0.52	0.0008	30	1.19	0.0094
900	0.41	0.0004	50	1.18	0.0082
α-Tocopherol (mg/kg)			*t*-Butylhydroperoxide (meq/kg)		
0	1.44	0.0148	0	1.44	0.0148
250	0.875	0.0046	10	0.94	0.0044
500	0.705	0.0039	30	0.67	0.0035
750	0.669	0.0028	50	0.56	0.0022
1000	0.665	0.0025			
β-Sitosterol (mg/kg)			β-Carotene (mg/kg)		
0	1.44	0.0148	0	1.44	0.0148
250	0.761	0.0039	5	1.30	0.0144
500	0.66	0.0030	10	1.29	0.0129
750	0.59	0.0024	15	1.30	0.0139
1000	0.57	0.0019	20	1.29	0.0133

[a]Mixed with water for 30 min and centrifuged to remove excess water.

3. Lipscomb, T.G., II, Mineral Insulating Oil Manufacture and Safekeeping, in *Electrical Insulating Oils,* STP 998, edited by H.G. Erdman, American Society for Testing and Materials, Philadelphia, 1988, pp. 5–24.
4. Lawrence, A.J., and J.M. Deland, Industrial Uses for Soybeans, in *Practical Handbook of Soybean Processing and Utilization*, edited by D.R. Erickson, AOCS Press, Champaign, 1995, pp. 380–427.
5. Jensen, R.G., T.A. Marks, J. Sampugna, J.G.Quinn, and D.L. Carpenter, Purification of Triglycerides with an Alumina Column, *Lipids 1*:451–452 (1966).
6. Singleton, W.S., Properties of the Liquid State, in *Fatty Acids, Their Chemistry, Properties, Production and Uses,* 2nd edn., Part I, edited by K.S. Markley, Interscience, New York, 1960, pp. 499–607.
7. Taylor, R.D., Adsorbtive Purification, in *Proceedings of World Conference on Oilseed Technology and Utilization*, edited by T.H. Applewhite, American Oil Chemists' Society, Champaign, 1992, pp. 152–165.

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