# Viscosities and Densities of Hydrogenated Peanut Oils

FRANK C. MAGNE and HELMUT WAKEHAM
Southern Regional Research Laboratory,[1] New Orleans, Louisiana

INFORMATION concerning the viscosities and densities of vegetable oils and hydrogenated vegetable oils is valuable in the design of processing equipment and in the development of extended applications of these oils in the industry. A systematic study of the variations of viscosity and density with iodine value and temperature, similar to that recently published for cottonseed oils (15), is here reported for peanut oils.

The viscosities and densities of four peanut oils were included in an early survey of the physical characteristics of over fifty vegetable oils by Crossley and Le Sueur (4) in 1898. They observed the decrease of viscosity with increasing iodine value, a relationship later confirmed by several others (7, 10, 14). Numerous values for isolated peanut oil samples were subsequently reported (8, 12, 13, 14, 16) and some limited investigations of the effect of temperature on specific gravities and viscosities of peanut oils were described later (1, 2, 7, 9, 11). As yet, however, no measurements of these physical properties for hydrogenated peanut oil have been published.

Two groups of oil samples were investigated. Group A (see Table I) consisted of peanut oils obtained from peanuts of different varieties grown at experiment stations in different parts of the South, so selected that the iodine values of the oils would cover as wide a range as possible. These oils were extracted from the finely ground kernels in a large Soxhlet apparatus using Skellysolve F as the solvent. The excess of solvent was distilled off first at atmospheric pressure and finally under a vacuum with a slow stream of purified nitrogen passing through the oil. The resulting oils had free fatty acid values between 0.1 and 0.3 percent and were refined by the A.O.C.S. refining-loss method using 12° Bé alkali. They were filtered to remove foots and alkali and finally bleached with 6% fuller's earth according to the A.O.C.S. method.

The oils in Group B were prepared in this laboratory by hydrogenation of a commercial alkali-refined and bleached peanut oil. The original oil had an iodine value of 82.4 and was included among those investigated.

Iodine value, free fatty acid contents, and melting and solidification points of the oils used are shown in Table I. Iodine values were obtained by the Wijs method. Free fatty acid contents as oleic acid were determined by the official method of the American Oil Chemists' Society. The melting and solidification points were determined on samples cooled in sealed capillaries for 24 hours before measuring in a melting-point apparatus similar to that described by Hershberg (6). For temperatures above room temperature the modification suggested by Graff (5) was employed to give steady heating; a cooling bath surrounding the melting point apparatus was used for the lower temperatures.

THE viscometers used were of the Ostwald type as modified by Zeitfuchs (17), and the technique employed was essentially that described by Craxton (3), except that a thermostatically controlled oil bath was used to maintain the temperature of the viscometers with an accuracy of 0.1° C. The mercury regulators were of the metastatic, pre-set type and could be rapidly interchanged when a new bath temperature was desired.

TABLE I

Properties of Peanut Oils Used in Viscosity and Density Determinations.

| Sample No. | Wijs iodine value | Melting point | Solidification point | Free fatty acid |
|---|---|---|---|---|
| Group A | | °C. | °C. | Pct. |
| 1 | 101.4 | 3.0 | —1.8 | 0.10 |
| 2 | 98.8 | 2.4 | —1.8 | 0.08 |
| 3 | 96.1 | 3.0 | —0.8 | 0.08 |
| 4 | 90.6 | 2.8 | —0.5 | 0.08 |
| Group B | | | | |
| 5 | 82.4 | 11.5 | +8.0 | 0.12 |
| 6 | 65.7 | 30.5 | 17.5 | 0.14 |
| 7 | 51.0 | 43.8 | 40.2 | 0.10 |
| 8 | 37.3 | 52.7 | 46.2 | 0.07 |
| 9 | 24.5 | 60.1 | 51.7 | 0.10 |
| 10 | 13.4 | 63.3 | 49.3 | 0.08 |
| 11 | 4.5 | 65.1 | 52.5 | 0.08 |
| 12 | 0.9 | 65.5 | 60.2 | 0.05 |

Precautions were taken to insure accurate viscosity determinations at all temperatures. The calibration constants of the viscometer tubes were determined with standard-viscosity oils supplied by the National Bureau of Standards. An individual viscometer was used for each oil, the runs being completed in the shortest possible time (about 15 minutes at the high temperatures) that would permit attainment of temperature equilibrium and determination of flow time. As in the investigation on cottonseed oils (15), viscometers were removed from the bath immediately after the determination to minimize possible thermal decomposition and polymerization of the peanut oils at the temperature of the bath.

Densities of the oils were measured by the pycnometer method in the same bath as used for the viscosity determinations.

Experimentally determined densities (*italics*) and viscosities in centipoises are shown in Table II.

The densities of hydrogenated peanut oils were plotted against the iodine values for each temperature to give a family of smooth isotherms from which densities were read off for hypothetical oils of 0, 20, 40, 60, 80, and 100 iodine values. These densities were then plotted as density *versus* temperature for each of the hypothetical oils to give the family of curves shown in Figure 1. Densities of peanut oils with various degrees of unsaturation may be read directly from this chart by interpolation.

[1] This is one of four regional research laboratories operated by the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

TABLE IIA

Experimental Densities *(Italics)* and Viscosities of Peanut Oils (Group A).

| Sample No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Iodine value | 101.4 | 98.8 | 96.1 | 90.6 |
| Temperature | | | | |
| 24.85° C. | 59.41 | 60.33 | 61.17 | 63.39 |
| | *0.9117* | *0.9113* | *0.9112* | *0.9099* |
| 65.3° C. | 14.91 | 15.08 | 15.15 | 15.63 |
| | *0.8849* | *0.8849* | *0.8847* | *0.8831* |
| 86.3° C. | 9.28 | 9.43 | 9.39 | 9.65 |
| | *0.8714* | *0.8710* | *0.8711* | *0.8700* |
| 118.3° C. | 5.21 | 5.28 | 5.30 | 5.35 |
| | *0.8510* | *0.8506* | *0.8504* | *0.8492* |
| 155.7° C. | 3.13 | 3.17 | 3.16 | 3.19 |
| | *0.8269* | *0.8268* | *0.8268* | *0.8255* |
| 179.9° C. | 2.39 | 2.44 | 2.43 | 2.47 |
| | *0.8115* | *0.8109* | *0.8107* | *0.8095* |
| 211.6° C. | 1.79 | 1.78 | 1.79 | 1.81 |

An equation relating the density and temperature for a peanut oil of given iodine value was calculated from the data in Table II and found to be:

$$d_2 = d_1 - 0.000646\ (t_2 - t_1).$$

In this equation $d_1$ and $d_2$ are densities corresponding to centigrade temperatures $t_1$ and $t_2$, respectively. Calculated densities for any second temperature obtained by means of this relationship from a known density for a peanut oil were found to agree with experimental values within about 0.1 percent. The mean coefficient of cubical expansion for peanut oil was calculated to be 0.000764 per degree centigrade over the temperature range 30°-200° C.

THE experimental viscosity data in Table II were plotted to obtain a family of curves of viscosity *versus* temperature for oils of different iodine values. From these curves viscosities were read off for every 10° C. interval of temperature for each oil and the resulting data were plotted as viscosity *versus* iodine value to give a family of smooth isotherms as shown in Figure 2.

Table III is a comparison of some of the published values for the viscosities of peanut oils at different temperatures with values obtained by interpolation of the data graphed in Figure 2. The agreement shown in this table would seem to indicate that the data here reported may be used in determining the viscosity of any refined or hydrogenated peanut oil

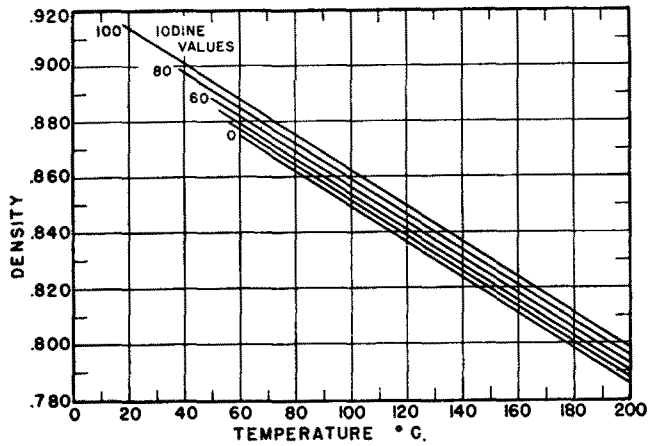


FIG. 1. Densities of hydrogenated peanut oils.

of which the iodine value is known. The generality that at a given temperature the viscosity decreases with increasing iodine value is here confirmed for the case of peanut oils.

An empirical equation by Walther relating viscosity and temperature for a mineral oil has also been applied successfully to fatty oils (7). The equation is

$$\text{loglog}\ (v + 0.8) = m\ (\log T_1 - \log T) + \text{loglog}\ (v_1 + 0.8)$$

in which v and $v_1$ are kinematic viscosities at absolute temperatures T and $T_1$, respectively. (Absolute viscosity is equal to the kinematic viscosity multiplied by the density.) The average of the values of

TABLE III

Comparison of Published Viscosities With Data From Figure 2.

| Author | Iodine value | Temp. °C. | Published value (Centipoises) | Observed (Centipoises) |
|---|---|---|---|---|
| Kaufmann and Funke (7) | 92.4 | 30 | 48.83 | 49.0 |
| | 92.4 | 40 | 33.12 | 33.2 |
| | 92.4 | 50 | 23.70 | 23.8 |
| Boekenoogen (1) | 89 | 30 | 49.7 | 50.2 |
| | 89 | 40 | 33.8 | 34.0 |
| | 89 | 50 | 24.2 | 24.2 |
| Bhattacharyya (2) | Approx. | 37.8 | 35.6** | 34.8 |
| | 100* | 51.7 | 22.4 | 21.5 |
| | 100 | 68.3 | 14.8 | 14.0 |
| | 100 | 79.4 | 10.4 | 10.8 |
| | 100 | 96.1 | 7.56 | 7.75 |

* Estimated from the density.
** Calculated from kinematic viscosity in Redwood seconds and densities estimated from Figure 1.

TABLE II-B

Experimental Densities *(Italics)* and Viscosities of Peanut Oils (Group B).

| Sample No. | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|
| Iodine value | 82.4 | 65.7 | 51.0 | 37.3 | 24.3 | 13.4 | 4.5 | 0.9 |
| Temperature | | | | | | | | |
| 24.85° C. | 62.80 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | *0.9090* | | | | | | | |
| 66.1° C. | 16.57 | 17.99 | 18.46 | 19.66 | 19.96 | 20.45 | 21.13 | 21.17 |
| | *0.8826* | *0.8797* | *0.8773* | *0.8753* | *0.8742* | *0.8731* | *0.8724* | *0.8715* |
| 104.4° C. | 6.99 | 7.42 | 7.70 | 7.99 | 8.07 | 8.18 | 8.34 | 8.41 |
| | *0.8570* | *0.8544* | *0.8523* | *0.8506* | *0.8495* | *0.8485* | *0.8476* | *0.8469* |
| 125.7° C. | 4.95 | 5.21 | 5.37 | 5.53 | 5.65 | 5.65 | 5.76 | 5.76 |
| | *0.8439* | *0.8411* | *0.8387* | *0.8370* | *0.8359* | *0.8351* | *0.8340* | *0.8339* |
| 160.4° C. | 3.05 | 3.19 | 3.21 | 3.31 | 3.36 | 3.36 | 3.41 | 3.42 |
| | *0.8214* | *0.8188* | *0.8166* | *0.8151* | *0.8140* | *0.8127* | *0.8119* | *0.8115* |
| 202.4° C. | 1.96 | 2.02 | 2.02 | 2.08 | 2.08 | 2.09 | 2.12 | 2.13 |
| 203.4° C. | *0.7934* | *0.7906* | *0.7885* | *0.7868* | *0.7858* | *0.7848* | *0.7841* | *0.7836* |

constant $m$ calculated from the data in Table II was found to be 2.724. Using this constant, viscosities can be calculated for any temperature with an accuracy of about 5 percent or better from the viscosity of the oil at a given temperature.

A comparison of the density and viscosity characteristics for cottonseed oils (15) and peanut oils shows striking similarities between oils of the same iodine value (Table IV). This agreement is not surprising in view of the known likeness in the composition of these two oils. It emphasizes the fact that certain physical properties of a vegetable oil may be correctly inferred from the same properties of another vegetable oil of similar chemical characteristics, a fact which may be of considerable help in designing processing equipment for an oil which has not been thoroughly studied.

TABLE IV

Comparison of Density and Viscosity Characteristics of Cottonseed Oil and Peanut Oil.

| Characteristic | For cottonseed oil | For peanut oil |
|---|---|---|
| **Density at 100° C.** | | |
| For oils having iodine value of 100 | 0.8675 | 0.8622 |
| For oils having iodine value of 50 | 0.8570 | 0.8550 |
| Temperature density coefficient $d_2=d_1-k(t_2-t_1)$ k | 0.000638 | 0.000646 |
| Mean coefficient of cubical expansion, 30°-200° C. | 0.000764 | 0.000764 |
| **Viscosities (centipoises)** | | |
| For oils having iodine value of 100 | | |
| Viscosity at 50° C. | 23.5 | 22.7 |
| Viscosity at 100° C. | 7.10 | 7.18 |
| Viscosity at 200° C. | 1.96 | 1.96 |
| For oils having iodine value of 60 | | |
| Viscosity at 50° C. | 29.5 | 27.8 |
| Viscosity at 100° C. | 8.05 | 8.26 |
| Viscosity at 200° C. | 2.03 | 2.07 |
| Walther constant $m$ (Relating temperature and viscosity) | 2.805 | 2.724 |


## Acknowledgment

The authors are indebted to the personnel of the several experiment stations in the South which submitted the peanut samples from which the oils in Group A were prepared, and to R. O. Feuge, M. Caravella, M. F. Stansbury, D. H. Petty, T. H. Hopper, and E. L. Skau of this laboratory for their interest and cooperation in this work.


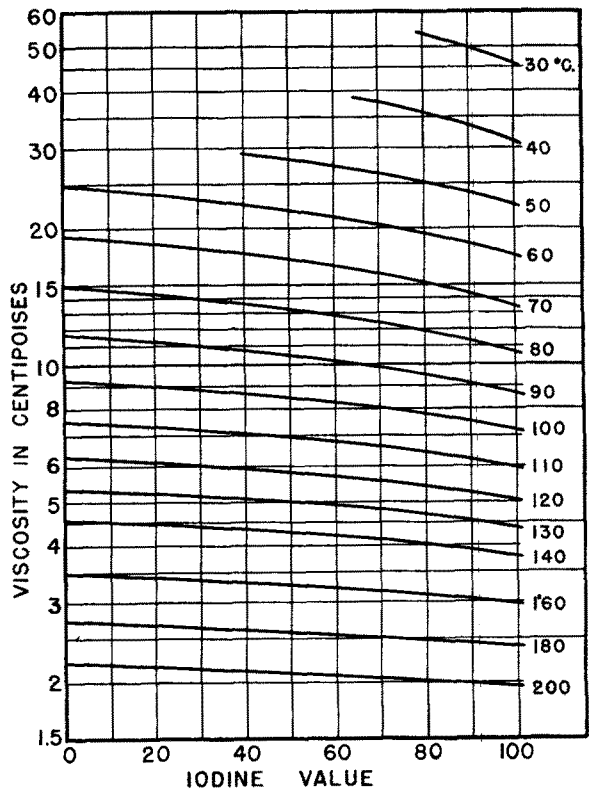


FIG. 2. Viscosities of hydrogenated peanut oils.


LITERATURE CITED

1. H. A. Boekenoogen, Chem. Weekblad, *34*, 759 (1937).
2. G. N. Bhattacharyya, Ind. J. Phys., *10*, 403 (1936).
3. F. C. Craxton, Ind. Eng. Chem., Anal. Ed., *14*, 593 (1942).
4. A. W. Crossley and H. R. Le Sueur, J. Soc. Chem. Ind. *17*, 989 (1898).
5. M. M. Graff, Ind. Eng. Chem., Anal. Ed., *15*, 638 (1943).
6. E. B. Hershberg, *Ibid.*, *8*, 312 (1936).
7. H. P. Kaufmann and S. Funke, Fette und Seifen, *45*, 255 (1938).
8. L. Margaillan and H. Reybaud, Chimie and industrie, Special No. 896 (Apr. 1934).
9. F. A. Medina and A. Clemente, Univ. Philippines Natural and Applied Sci. Bull. *4*, No. 1, 61 (1934).
10. G. B. Ravich, Acta Physicochim. U.R.S.S., *6*, 205 (1937).
11. A. R. Rescorla and F. L. Carnahan, Ind. Eng. Chem., *28*, 1212 (1936).
12. H. Schrader, Pharm. Zentralhalle, *75*, 689 (1934).
13. P. Slansky and L. Kohler, Kolloid Z., *46*, 128 (1928).
14. J. L. Strevens, J. Soc. Chem. Ind., *33*, 109 (1914).
15. H. Wakeham and F. C. Magne, Ind. Eng. Chem., *36*, 568 (1944).
16. C. H. Wright, J. Soc. Chem. Ind., *26*, 513 (1917).
17. E. H. Zeitfuchs, Nat'l Petroleum News, *31*, 2621 (1939); Proc. 9th Mid-Year Meeting Am. Petroleum Inst., Sec. III, Refining, *20*, 104 (1939).


# An Application of the Barcroft-Warburg Apparatus to the Study of Antioxidants in Fats*


JULIUS J. NAGY, FRANK C. VIBRANS, and H. R. KRAYBILL

**Research Laboratory, American Meat Institute, University of Chicago**


FOR some years the Research Laboratory of the American Meat Institute has been investigating the keeping quality of lards with and without the addition of various antioxidants that have been submitted for examination. The active oxygen method (AOM) (1) was used extensively. More recently tests have been made also with the Barcroft-Warburg constant volume manometric apparatus as described by Johnston and Frey (3).

This paper gives the results of studies by the two methods on the effect of d-isoascorbyl esters of fatty acids** alone and in combination with soybean lecithin on the keeping time of lard. When 0.01 to 0.10 per cent of ascorbyl esters were added to lard. the keeping times as determined by the Barcroft-

* Presented before the Division of Agricultural and Food Chemistry at the 105th Meeting of the American Chemical Society, Detroit, Michigan, April 13, 1943.

** Furnished by The U. S. Eastern Regional Research Laboratory.