International Journal of Science, Environment and Technology, Vol. 2, No 6, 2013, 1318 – 1326

ISSN 2278-3687 (O)

A STUDY ON VISCOSITY, SURFACE TENSION AND VOLUME FLOW RATE OF SOME EDIBLE AND MEDICINAL OILS

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Abstract: The paper presents data on viscosity, surface tension and volume flow rate of some edible and medicinal oils. The study is based on the simple experimental setup developed in Biophysics Laboratory of Nizam College, Hyderabad. The rheological parameters of oils have a direct relationship with some fatty acids that constitute the triglycerols. Further, the rheological parameters characterize oils of plant origin. The study suggests that any environmental influences; compositional, structural and physiological alterations; storage period can be reflected significantly in the rheological properties of oils extracted from plants and animals.

Keywords: Viscosity, Surface Tension, Volume flow Rate, Oils of plant origin, Capillary viscometer, Saturation of Oils.

1. Introduction

Oil is any substance that is in a viscous liquid state at ambient temperatures and is of both hydrophobic and hydrophilic nature. Edible oil means the triglycerides and diglycerides of animals or plant origin. The oil which has therapeutic value is called medicinal oils. Edible oils are simply fats that are liquid at room temperature. The fats are derived from vegetable or animals. Dietary fat is necessary for the energy. Most dietary fat take the form of triglycerides. There are three types of fatty acids - saturated, mono unsaturated and poly unsaturated. The type depends on the number of double bonds in a molecule. The extent of saturation or unsaturation has practical importance for use of fats for health and food applications.

Sukumar Debnath et al [1-2] investigated the impact of blending of frying oils on viscosity and heat transfer coefficient at elevated temperatures. Rodenbush et al [3-4] studied relation between density and viscosity, and gave new empirical formula. Fasina et al [5-6] predicted temperature dependence of viscosity of vegetable oils from fatty acid composition. Timms [7] presented physical properties such as density and specific heat of oils and mixtures of oils. Shankland and Dunlop [8-9] introduced some correlations for capillary viscometers at 20^0 C and 1 atm.

*Received Nov 4, 2013 * Published Dec 2, 2013 * www.ijset.net*

In the present investigation, rheological properties such as coefficient of viscosity, surface tension and volume flow rate of several edible and medicinal oils are studied.

2. Materials and Methods

In the present study, *Ten* edible oils and *Fifteen* medicinal oils were selected, which were of plant origin. These oils are easily available in the market. Most of the oils selected are commonly used as food or medicine. Care was taken to have oils understudy in the pure form. The oils are extracted from seeds, leaves, twigs, buds, fruits, bark and grass.

For the determination of rheological parameters such as coefficient of viscosity, surface tension and volume flow rate of edible and medicinal oils, capillary viscometer was used, developed in Biophysics Research Laboratory, Nizam College, Hyderabad, based on the theory proposed. The advantage of this viscometer is besides being simple and accurate; it measures viscosity and surface tension of oil at a stretch. The theoretical aspects of the viscometer were mentioned elsewhere [10].

2. 1. Experimental

The viscometer is a simple glass capillary tube of length of about 30 cm with inner radius of 0.05 cm was marked with two preset points A and B and is clamped to be held vertical in a mechanical arrangement as shown in Fig. 1. To measure the time flow of oil a digital watch of L. C. 0.1 sec. was used.

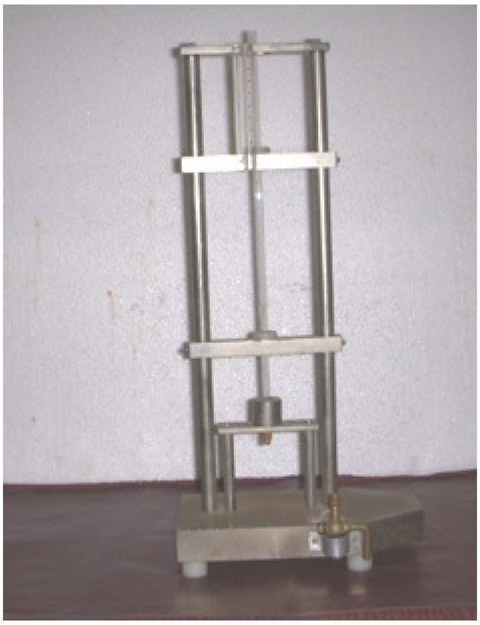

Fig.1. Viscometer

The distance between A and B is 10 cm. The column of oil sample about 1 to 8 cm in length was sucked into the capillary tube. The capillary tube was clamped vertically as shown in Fig. 1. The vertical clamping of the capillary tube with sample will set the oil column into one-dimensional motion. The flow of oil column in the capillary tube was controlled by closing and opening the upper end of the tube by right hand thumb. At the beginning of the experiment, meniscus of column was set above the point A. The timer was switched on the moment the meniscus of the oil column just touches mark A. The timer was switched off at the moment the meniscus just reaches the mark B. The timer records the time (t) of the sample which traveled a fixed distance of 10 cm. The velocity was calculated as 10/t cm/sec. For different lengths (L) of the oil column the time of travel (t) was recorded and velocity (V) was calculated.

A plot was drawn between L^{-1} on X - axis and V on Y- axis. The plot is a straight line with negative intercept on Y-axis which confirms the theory. The intercept and slope of the straight line were measured. Viscosity and surface tension of the sample were calculated from the intercept and slope of the straight line, knowing radius of the capillary tube (R) and angle of contact (θ) of the sample with the capillary wall. Radius of the capillary tube (R) was measured using a traveling microscope of L.C 0.001 cm. The angle of contact was measured by keeping a circular scale marked in degree behind the capillary tube and viewing the meniscus of the sample through traveling microscope. It is not possible to measure angle of contact very accurately and hence it is approximated to 30^0 for oil samples.

Coefficient of viscosity (η) is calculated using the relation,

$$\eta = \frac{R^2 \rho g}{8V_0}$$

Volume flow rate (Q) is computed from the relation,

$$Q = V_0(\pi R^2)$$

Surface Tension (T) is determined using the relation,

$$T = \frac{4\eta \tan\alpha}{R\cos\theta}$$

where R: Radius of the capillary tube; ρ: Density of oil; g: Acceleration due to gravity; V_0: Maximum velocity; α: Slope of the straight line, drawn between velocity (V) on Y – axis and 1/L on X – axis; θ: Angle of contact.

A computer program was written in C language for the calculation of coefficient of viscosity, volume flow rate and surface tension using the values of L and t.

Table 1: Data on Viscosity, Volume flow Rate and Surface Tension of Edible Oils

Sample Code	Scientific Name	Common Name	Viscosity (poise)	Surface Tension (dyne/cm)	Volume Flow Rate (x10 $^{-3}$ cm^3/sec)
GRN	Arachis hypogaea	Groundnut Oil	0.345 ± 0.014	9.99 ± 0.51	6.63 ± 0.29
SEM	Sesamum indicum – Limn	Sesame Oil	0.365 ± 0.005	9.42 ± 0.61	6.34 ± 0.04
OLV	Olea europofalinne	Olive Oil	0.437 ± 0.010	10.00 ± 0.66	10.00 ± 0.66
SNF	Helianthus annus	Sunflower Oil	0.360 ± 0.009	7.39 ± 0.31	7.39 ± 0.31
CCT	Cocosnukifera	Coconut Oil	0.229 ± 0.065	17.84 ± 0.59	7.76 ± 0.03
PAM	Elaeisguneesis Jacq	Palm Oil	0.428 ± 0.022	5.71 ± 0.47	5.35 ± 0.26
MST	Brassia nigra Koch	Mustered Oil	0.423 ± 0.005	19.81 ± 1.35	5.30 ± 0.04
CTS	Gossypium herbaceum	Cotton seed Oil	0.353 ± 0.002	24.13 ± 0.42	6.44 ± 0.02
SYB	Glycine soja	Soyabean Oil	0.368 ± 0.011	18.36 ± 1.25	6.52 ± 0.25
SAF	Earthamos tincturious	Safflower Oil	0.294 ± 0.017	10.43 ± 0.32	7.90 ± 0.47

Table 1 reveals the data on coefficient of viscosity of 10 commonly used edible oils. The value of coefficient of viscosity for oils varies from 0.229 to 0.437 poise. It is observed that olive oil has the highest viscosity i.e., 0.437 followed by Palm oil (0.428 poise) and Mustard oil (0.423 poise). It is to be notice that Sesame oil, Sunflower oil, Soya Bean oil have almost same value of coefficient of viscosity which ranges from 0.360 to 0.368 poise. It is found that Groundnut oil and cotton seed oil have viscosity 0.345 poise and 0.353 poise respectively. It is interesting to note that Coconut oil has least viscosity i.e. 0.229 poise where as viscosity of Sunflower oil is 0.294 poise.

Table 1 presents the data on surface tension of Edible oils. The surface tension varies from 5.71 to 24.13 dyne/cm. It is found that Cottonseed oil possesses highest surface tension value 24.13 dyne/cm. It is to be noted that Groundnut oil, Olive oil, Safflower oil and sesame oil have almost same value of surface tension. The value of Palm oil and Sunflower is found to be 5.71 and 7.39 dyne/cm. respectively. The surface tension of Coconut oil, Soya Bean oil and Mustard oil is found in the range of 17.84 to 19.81 dyne/cm.

Table 1 gives the data on volume flow rate of 10 edible oils. The volume flow rate of commonly used Edible oils under study is found to be in the range of $5.30 \times 10^{-3} cm^3/sec$ to$10.00 \times 10^{-3} cm^3/sec$. It is interesting to note that Olive oil has highest volume flow rate. Groundnut, Coconut and Safflower oils have values in the range $7.39 \times 10^{-3} cm^3/sec$ to $7.90 \times 10^{-3} cm^3/sec$. The lowest volume flow rate is observed in Mustard oil and Palm oil i.e. $5.30\ and\ 5.35 \times 10^{-3} cm^3/sec$ respectively.

Table 2: Data on Viscosity, Volume flow Rate and Surface Tension of Medicinal Oils

Sample Code	**Scientific Name**	**Common Name**	**Viscosity (poise)**	**Surface Tension (dyne/cm)**	**Volume flow Rate ($x10^{-3}$ m^3/sec)**
ALM	Prumus Amygdalus	Almond oil	0.438 ±0.018	8.46 ± 1.00	4.82 ±0.16
CLV	Eugenia Caryophyllus Myrtaceace	Clove oil	0.066 ±0.006	5.80 ± 0.72	4.68 ±0.05
ECT	Eucalyptus Globullus	Eucalyptus Oil	0.337 ±0.033	7.33 ± 1.49	6.91 ±0.07
NEM	Azardichta Indicajuss	Neem Oil	0.177 ±0.003	7.91 ± 1.03	1.30 ±0.02
PST	Pistaciavera	Pistachio Oil	0.351 ±0.023	7.06 ± 1.03	6.76 ±0.06
PPS	Papaveraceae	Poopy seed Oil	0.304 ±0.023	12.24 ± 1.07	7.61 ±0.69
GRD	Lagenaria Siceraria	Bottle Gourd Oil	0.416 ±0.001	6.55 ± 0.26	5.56 ±0.01
NTG	Myxistica Fragraws Houtt	Nutmeg Oil	0.097 ±0.003	8.86 ± 2.00	… 24.10 ±0.60
WLN	Genus Juglans	Walnut Oil	0.296 ±0.002	4.97 ± 0.34	8.02 ±0.05
CIN	Cinnamonum Zeylanicum	Cinnamon Oil	0.041 ±0.001	23.04 ± 0.07	61.00 ±0.30
LMNG	Cymbopogon Flexuosus	Lemon grass Oil	0.321 ±0.005	9.23 ± 0.68	76.90 ±0.54
GRL	Allium Sativum Linnaeus	Garlic Oil	0.092 ±0.004	10.91 ± 1.04	2.60 ±0.03

CTR	Ricinus Commonis	Castor Oil	3.115 ±0.053	14.89 ± 1.12	0.70 ±0.12
BCS	Negella Satva	Black cumin seed Oil	0.308 ±0.009	28.49 ± 1.73	7.70 ±0.25
LIN	Linumusitalissimum Linaceae	Linseed Oil	0.254 ±0.005	12.79 ± 2.49	8.69 ±0.20

Table 2 gives the data on coefficient of viscosity of medicinal oils, which varies from 0.041 to 3.114 poise. The viscosity of Castor oil is very high (3.114 poise) when compared to other medicinal oils under investigation. It is to be noted that Almond oil and Guard oil have viscosity 0.438 and 0.416 poise respectively. It is found that Eucalyptus oil, Pistachio oil, Poppy Seed oil, Lemon Grass oil and Black Cumin Seed oil have coefficient of viscosity in the range of 0.304 to 0.351 poise, whereas Walnut and Linseed have 0.296 to 0.253 poise. The value of Neem oil is found to be 0.177 Poise. Clove oil, nutmeg oil, cinnamon oil and Garlic oil have significantly low viscosity, which ranges from 0.0413 to 0.0965 Poise. Among all the selected medicinal oils cinnamon has lowest viscosity.

Table 2 reveals the data on surface tension of medicinal oils. The surface tension of medicinal oils varies from 4.968 to 28.49 dyne/cm. It is observed that Black Cumin Seed oil has highest surface tension (28.49 dyne/cm). The value of surface tension of Cinnamon oil is found to be 23.04 dyne/cm. It is to be noted that Poppy seed oil, Castor oil and Linseed oil have surface tension values in the close range. Garlic oil and Lemon grass oil have surface tension as 10.913 and 9.23 dyne/cm. It is interesting to note that Eucalyptus oil, Neem oil and Pistachio oil possesses surface tension values in the close range. The surface tension of Almond oil and Nutmeg oil is observed to be 8.46 and 8.86 respectively. For Clove oil, bottle Gourd oil and Walnut oil, it is found to be in the range of 4.97 to 6.55 dyne/cm.

Table 2 presents data on volume flow rate of medicinal oil under investigation. The values vary from $7.68 \times 10^{-2} cm^3/sec$ to $7.04 \times 10^{-4} cm^3/sec$. The volume flow rate of Castor is found to be $7.04 \times 10^{-4} cm^3/sec$, which is the lowest value among all the medicinal oils under study. This parameter of Almond oil, Neem oil, Poppy Seed oil, Gourd oil, Walnut oil, Black Cumin Seed oil and Linseed oil ranges from $1.303\ to\ 8.687 \times 10^{-3} cm^3/sec$. It is interesting to note that volume flow rate lies in the range of $2.413\ l10^{-2}\ to\ 7.686 \times 10^{-2} cm^3/sec$for Clove oil, Eucalyptus oil, Nutmeg oil, Cinnamon oil, Lemon Grass oil and Garlic oil.

4. Discussion

The most striking feature of the biological or organic fluids such as oils is the *Biorheology*, which can be regarded as a branch of *biomechanics* related with the tubes of different diameters and dynamics of fluid under mechanical forces. The important parameters involved in *Biorheology* are:

1. Coefficient of viscosity
2. Volume flow rate
3. Dynamic surface tension

In order to measure the above rheological parameters, a capillary viscometer is constructed in the laboratory. The advantage of the viscometer is of two folds:

1. There exist different techniques to determine surface tension and viscosity. But no technique is available in the literature, which can measure both surface tension and viscosity at a stretch. This viscometer does the job. The viscometer, designed in the laboratory, measures the rheological parameters in less time with greater accuracy.
2. The second advantage of this viscometer is with respect to the quantity of the sample for the test. It is difficult, if not impossible, to get the biofluids in large quantity. This viscometer requires the sample of about 1 cc for the investigation.

Viscosity is a physical property, which represents the tendency of a fluid to undergo deformation when subjected to a shear stress. The deformation rate is determined by the intermolecular force, which provides the force to balance the applied shear force. In fact, viscosity is a material constant representing the propensity for a collection of fluid molecules to externally applied stress. In the case of a pure liquid consisting of simple molecules, viscosity is thought to be an intrinsic property and its value is dependent on the temperature of the fluid alone. For more complex fluids, such as solutions of macromolecules and cell suspensions, viscosity may contain more than one constant and generally shows a complex dependence on an additional number of parameters, such as type of solvent or concentration, molecular weight, conformation of solutes or suspended material. Nevertheless, even in these more complex cases, viscosity is ascribed to the intrinsic properties of the fluid itself.

Viscosity of edible and medicinal oils of the present investigation reveals large variation (from 0.041±0.0014 to 3.115±0.053) with respect to the type of oil. The viscosity of Caster oil is very high, while Cinnamon oil has the lowest value. The significant variation in viscosity of selected oils can be attributed to degree of saturation of fatty acids present in oils. It is interesting to note from viscosity data of oils that the viscosity is high for the oils extracted from seeds, when compared to the oils extracted from other parts of the plant (bud, twig, leaves, bark etc).

Surface tension is exclusively a molecular phenomenon. Hence, one should take into account various forces that act between the molecules of liquid. There are two types of intermolecular forces:

1. Force of attraction between the molecules of two different materials known as *adhesive force*.
2. Force of attraction between the molecules of same liquid known as *cohesive force*.

If a film of fluid is considered, the molecules inside will experience a resultant downward force. Work has to be done against the downward cohesive force in order to bring a molecule from within the liquid to the free surface. Consequently potential energy of the molecule increases. This means potential energy of the free surface is greater than that of any other layer of the liquid, since any mechanical system tries to come back to a state of minimum potential energy. The free surface of the liquid also tries to the same and in the process, a contraction in the area takes place. As a result, the free surface always experiences a tension, which is nothing but *surface tension* of the liquid. The surface tension of a liquid depends on the nature of media in contact with the surface.

It is evident from the data on Surface tension of edible and medicinal oils that it is significantly low, compared to other organic liquids. This parameter is more or less the same in both the types of oils (edible and medicinal).

Volume flow rate is a vital parameter in fluid dynamics. Its variation with respect to type of oil is note worthy. It is interesting to note that the value of volume flow rate lies in a very wide range as far as different medicinal oils are considered. This is not the case with edible oils. This aspect may perhaps be attributed to degree of saturation and also the presence of other organic compounds apart from triglycerides.

5. Conclusions

1. Viscosity of edible oils is more than that of medicinal oils, except Castor oil which possesses highest value, where as Cinnamon oil has lowest value of among the oils investigated.
2. Coefficient of viscosity can be a potential parameter to detect adulteration in oils.
3. Viscosity is high for the oils extracted from seeds, when compared to the oils extracted from other parts of the plant (bud, twig, leaves, bark etc).

4. Surface tension is significantly low, compared to other organic liquids. This parameter is more or less the same in both the types (edible and medicinal) of oils.
5. Volume flow rate of oils appears to be significant in characterizing edible and medicinal oils.

Acknowledgement

One of the authors (NS) is thankful to Head, Department of Physics, Nizam College (Autonomous), Osmania University, Hyderabad for providing facilities of Biophysics Research Laboratory.

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