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**FULL LENGTH ARTICLE**

# Experimental Investigation of Thermal Conductivity and Specific Heat and Thermal Degradation of Vegetable Oils For A Range Of Temperature

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**ABSTRACT**

*In the present scenario there is a growing need for the innovative heat transfer fluids. Thermophysical properties of the fluids like thermal conductivity, viscosity,specific heat, are important to understand the transport process during heat transfer, in various processes of heating and cooling. These transport properties in combination with thermodynamic properties play an important role in the design of heat exchangers, designing of oil burners and combustion chambers etc.Vegetable oils are the ones which are widely used as industrial heat transfer fluids. In the present work two sets of vegetable oils namely sunflower oil and corn oil are studied and their properties are determined experimentally from a temperature range of 25$^0$C to 80$^0$C it has been observed that thermal conductivity of sunflower oil decreases from 0.168 to 0.162 W/mk and for corn oil thermal conductivity decreases from 0.167 to 0.153 W/mK. Thermal degradation and specific heat were studied using the TGA and DSC instrument. Specific heat was studied in the range 35$^0$C to 120$^0$C for sunflower oil specific heat varies from 2.244 to 2.491 KJ/kg K for corn oil specific heat varies from 1.673 to 1.918 KJ/kg K.*
**Keywords:** Thermal conductivity, Specific Heat, sunflower oil,corn oil and thermal degradation.

## INTRODUCTION

Heat transfer is a basic and very important topic that deals with energy. Heat transfer processes are encountered in a large number of engineering applications. It is essential for thermal engineers to understand the principle of thermodynamics and heat transfer and be able to employ the rate equation that govern the amount of energy being transferred. Vegetable oils are for the most part utilized for cooking and singing of sustenance's and snacks. In both applications, the oils are subjected to lifted temperatures in the scope of 35 to 180°C. The ideal configuration of heating and cooling frameworks for cooking and singing, and the fun-damental understanding of cooking and browning forms require that the thermo-physical properties of the real fixings included, (for example, vegetable oil) in these procedures be known.[1-3] Two of the critical thermophysical properties are viscosity and specific heat. The estimating and determination of pumps and pipes for handling the hot oil additionally require that the viscosity of the oil be known. It has been settled that temperature affects the viscosity of liquid items with viscosity for the most part diminishing with increment in temperature. Several analysts have reported the viscosity of vegetable oils at room temperature. Studies have likewise been completed on the impact of temperature on the viscosity of a few vegetable oils at temperatures less than 110°C and at temperatures between 150–180°C. The authors did not find any reported study on the viscosity of vegetable oils at temperatures between 110–150°C. Moreover, these studies that have been carried out on temperature effect on viscosity of vegetable oils have been carried out at different temperature ranges. Although thermal properties values are often not available with sufficient reliability and sometimes are not available at all. This is true for both gaseous and liquids, but in the case of liquids, a peculiar factor must be stressed the absence of a rigorous theory of the liquid state comparable to the ones commonly used for the solid state or for the gaseous state. The theoretical formulation used for the liquid state are poor in terms of there practical use. The apparatus is designed and fabricated according to the guarded hot plate principle [4]. The guarded hot plate method has been recognized by scientists & engineers in U.S.A., West Germany, Scandinavian Countries., and U.S.S.R. In India most of the developers aredependable and reproducible for the measurement of thermal conductivity of insulting material. It is a steady state absolute method suitable for material which can be laid flat between two parallel plates & can be adopted for loose fill materials which can be filled between such plates. Used guarded hot plate method is a steady state techniques perform a measurement when the temperature of the material measured does not change with time. This makes signal analysis straight forward .and it requires well engineered experimental set up. The unsteady state methods or transient methods are very costly and experiments can be carried very quickly since there is no wait for steady state condition and moreover mathematical analysis of the data in general more difficult. Therefore the guarded hot plate method which is very cost effective and absolute method. In the present study the work undertaken to measure the thermal conductivity of low and heavy viscous locally available liquids.

## EXPERIMENTAL SET UP

### Thermal Conductivity

The essential parts – the hot plate, the cold plates, the heater assembly, thermocouples & the specimens in position are shown in the Fig 1.For the measurement of thermal conductivity (k) what is required is to have a one dimensional heat flow through the liquid, an arrangement has been made to maintain the faces at constant temperature & some metering methods are applied to measure the heat flow through a known area. To eliminate the distortion caused by edge losses in uni-directional heat flow, the central plate is surrounded by guard ring which is separately heated . Temperatures are measured by calibrated thermocouples either attached to the plates or to the hot & cold faces liquid. The heater plate is surrounded by a heating ring for stabilizing the temperature of the primary heater & prevents heat loss readily around its edges . The primary & guard heater are made up of mice sheets in which is wound closely spaced Nichrome wire & packed with upper &lower mica sheets. These heaters together form flat together with upper & lower brass (or any other good conducting material) plate & rings from the heater plate forming the heater plate assembly.[5] Thermocouples no 1&2 measures the hot face temperature at the upper & lower central heater assembly copper plates. Two more thermocouples are used to check balance in both the heater inputs. Testing liquid is held in between the heater & cooling unit of the apparatus. Thermocouples No. 5 & 6 measures the inlet and outlet temperature of the cooling jacket. (Fig 2.1) shows The heater plate assembly together with cooling plate & the testing liquid held in the plate on which circular grooves has been made. The whole assembly held in position by three vertical stands & nuts on a base plate are as shown in the assembly. The cooling chamber is a composite assembly of grooved aluminum casting & aluminum cover with entry & exit adapters for water inlet & outlet.

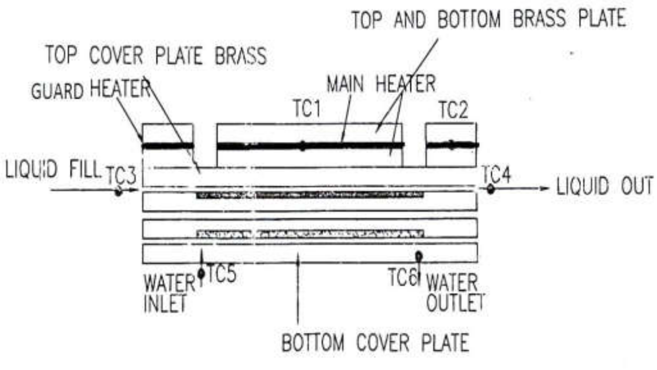



**Fig.2.1. Guarded hot plate method experimental set up**

**Fig.2.2. Guarded hot plate method experimental set up**

Thermal conductivity of liquid has to be computed using Fourier law of conduction

$Q = -KA_m \times (dT / dX)$

$K = Q/ A_m \times (T_h - T_c)$ Watts/m- ºc

Where,

K = Thermal Conductivity of sample watts/m-ºc

Q = Heat flow rate in the specimen, Watt

$A_m$ = Mean area for heat flow, $m^2$.

$T_h$ = Hot plate temperature ºc.

$T_c$ = Cold plate temperature, ºc.

**Specific Heat**

Specific heat of both the vegetable oil samples tested in the study increased linearly with increase in temperature from 35–120°C .[6]The percent increase in specific heat was about 17% within this temperature range. Therefore, more heat will be required for a unit change in temperature per unit mass of a food that is cooked or fried with oil. The heat capacities of the sunflower oil were determined from the data obtained by DSC. The calculations were based on implementation of the temperature program. The oil samples were heated at a rate of 5 $^0$C min-1 up to 30 $^0$C during five minutes. Then, they were heated at a rate of 10 $^0$ Cmin-1 up to 120 $^0$C during five minutes. The following ratio was used to calculate the heat capacities.[7-9]

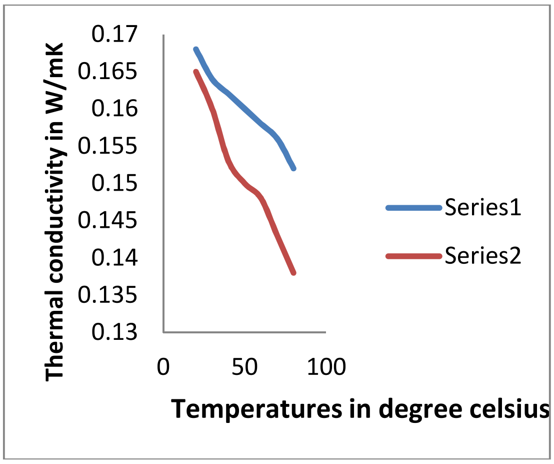
where c0 and c are the specific heat of the reference material and of the sunflower oil, respectively; m0 and m refer to the mass of samples and of the reference material, respectively, and S1, S2 and S3 are the thermal displacements of the DSC in relation to the blank, reference and sample, respectively (Kasprzycka-Guttman et al., 1995).

**Thermal degradation**

The study of thermal degradation of sunflower oils was carried out by thermogravimetric measurement. For this purpose the oils were heated to 190 $^0$C for periods of 0.5, 4.0 and 8.0 h.[10] The sunflower oils were heated in a 500 mL flask with a surface diameter of about 4 cm that was exposed to air. Afterwards, TG/DTG curves were obtained in a Shimadzu TGA-50 thermobalance in air (20 mLmin- 1) at a heating rate of 5 $^0$ Cmin-1 with the objective of verifying of influence the frying time and temperature on the thermal stability of sunflower oils.

## RESULTS AND DISCUSSION

As in the case vegetable oils thermal conductivity decreases as temperature increases as shown in figure 3.1 due to the fact that density gradient will exists, this will create a buoyancy force that will opposes by viscous resistance of the fluid and thermal non equilibrium will results leading to decrease in thermal conductivity.[11-12] And there is not easy exchange of protons between the molecules. For both set of vegetable oils the specific heat has been postulated that the increase as shown in figure 3.2 specific heat of materials with increase in temperature is because of expansion of a substance during heating. Some of the heat being provided is therefore used to furnish the work required for the expansion of that material against the surroundings. Similar increase in specific heat with increase in temperature has been obtained for various food and biological materials.



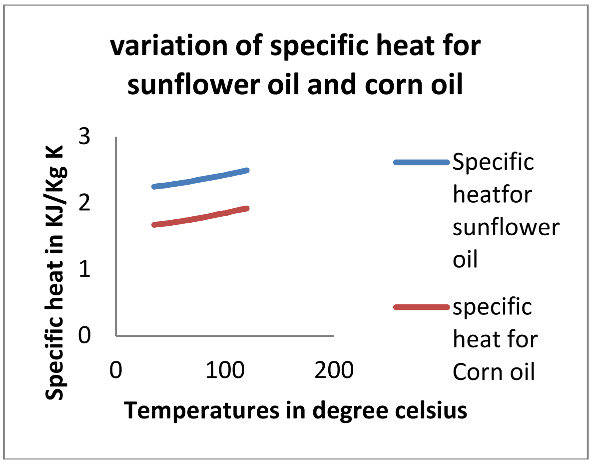




**Fig. 3.1. Variation of Thermal conductivity vs. Temperature** **Fig. 3.2. variation of Specific heat vs. Temperature**

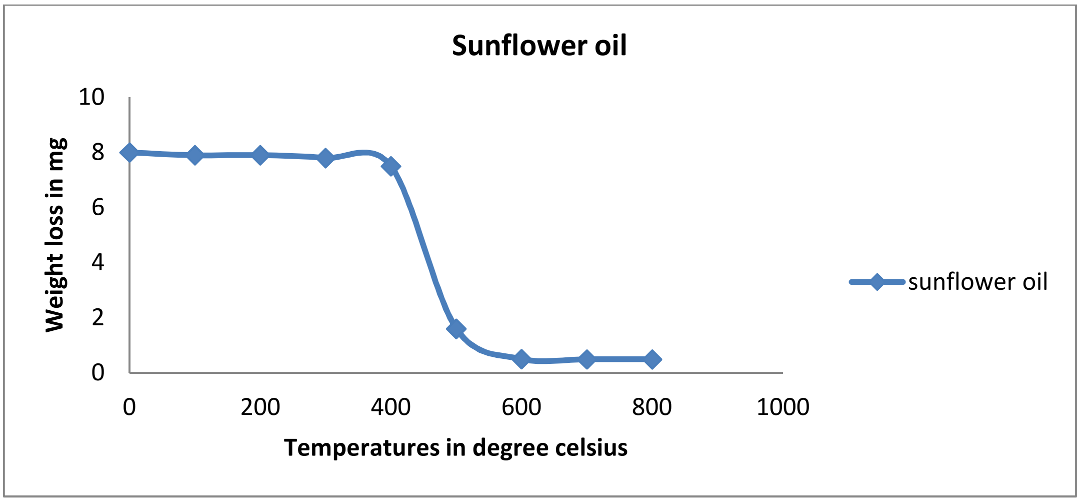



**Fig. 3.3. Thermal degradation vs. Temperature for sunflower oil**

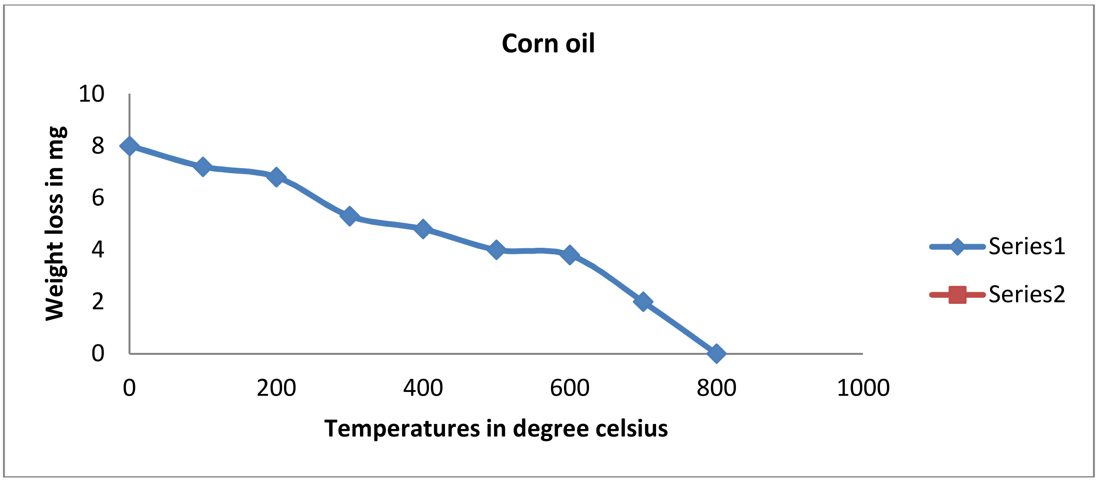



**Fig. 3.4. Thermal degradation vs. Temperature for corn oil**

The thermal decomposition profiles for the sunflower oils have similar characteristics, as can be observed in Figs.3.3 and 3.4, where all the non isothermal TG/DTG curves have three thermal decomposition steps in the range of 230 to 550 $^0$C, with no residue remaining at 8000 $^0$C. Thermal decomposition of these oils occurred in three stages, related to the decomposition of polyunsaturated, monounsaturated and saturated fatty acids, respectively. In relation to the thermal decomposition steps, it was observed that the first step (230 to 380 $^0$C) corresponds to the decomposition of the polyunsaturated fatty acids. During heating, the triglycerides, which form 96 to 98% of the edible oils, produce volatile compounds, which are constantly removed by vapor generated during heating. These products (dimers, trimers, polymers) are formed principally by thermal reactions of unsaturated fatty acids, such as linoleic acid.

The first step is the most important for the thermal stability of edible oils, because this is the step where decomposition of the unsaturated fatty acids begins. On the basis of the temperature at the beginning of thermal decomposition, it can be established that sunflower oil A, containing the antioxidants citric acid and vitamin E, had a higher thermal stability than that observed for sunflower oil B. Thus, it can be verified that the thermal stability of sunflower oils is dependent on the composition of the fatty acids, as it is influenced by artificial antioxidants. The beginning of oxidation in edible vegetable oils is characterized by absorption of oxygen through the fatty acid chain, subsequently forming the oxidation product as peroxides. This behavior is generally identified by an increase in the initial mass of the sample.[13] For the sunflower oil samples analyzed in air, a small gain in mass in the DTG curve for oil B was observed (Fig. 3.3), indicating that the process of thermal decomposition involved the absorption of oxygen as well as the liberation of volatiles.[14] This was not observed for sunflower oil A (Fig. 3.3), where the reaction resulted only the liberation of volatiles.

## CONCLUSION

Thermal conductivity was measured for different locally available vegetable oils at atmospheric temperature and pressure. The apparatus represents a flexible tool for measuring the thermal conductivity of vegetable oils with good accuracy. The results obtained highlight an interesting point that for sunflower oil thermal conductivity decreases from 0.168 to 0.162 W/mk and for corn oil thermal conductivity decreases from 0.167 to 0.153 W/mK. which matches well with the theoretical value. Specific heat was studied in the range $35^0$C to $120^0$C for sunflower oil specific heat varies from 2.244 to 2.491 KJ/kg K for corn oil specific heat varies from 1.673 to 1.918 KJ/kg K.

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