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Study on Dielectric Property of Soyabean oil In "Deep-Fat-Frying"

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Abstract – Oils &Fats provide a concentrated source of energy. Like carbohydrates, they act as body fuel. They are also used to transport certain vitamins [A, E, D, K] around the body. Fats are stored in the body around the organs and muscles and under the skin, and here they maintain the body temperature and provide insulation. Fats are also used in the formation of sebum, the skin's natural lubricant. Carbohydrates and proteins that are not used up for energy is stored as fat. Every gram of fat provides 9 calories, more than double the amount provided by carbohydrates or protein. While a certain amount of fat is essential, excess fat is stored in the body contributing to weight gain. Diets high in fat often lead to obesity and are associated with disorders like heart disease and diabetes. Increased and diversified application of natural fats and oils have stemmed primarily from the advances which have been made in the knowledge of composition, structure and properties of these substances during present century.

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INTRODUCTION

It is an ideal coolant which is non-toxic and readily biodegradable fluid. These have longer insulation, thermal life and after use can be economically recycled after use. Oils &Fats provide a concentrated source of energy carbohydrates, they Like act as body fuel. They are also used to transport certain vitamins [A, E, D, K] around the body. Fats are stored in the body around the organs and muscles and under the skin, and here they maintain the body temperature and provide insulation. Fats are also used in the formation of sebum, the skin's natural lubricant. Carbohydrates and proteins that are not used up for energy is stored as fat. Every gram of fat provides 9 calories, more than double the amount provided by carbohydrates or protein. While a certain amount of fat is essential, excess fat is stored in the body contributing to weight gain. Diets high in fat often lead to obesity and are associated with disorders like heart disease and diabetes. Increased and diversified application of natural fats and oils have stemmed primarily from the advances which have been made in the knowledge of composition, structure and properties of these substances during present century. Vegetable oil is one of the alternatives which can be used as fuel in automotive engines either in theform of straight vegetable oil, or in the form of ethyl or methyl ester. Presently lot of research is being done in the following fields.

1. Research is being carried out on the changes in fatty acid percentages in vegetable oils by changing the genetic nature of flowers, fruits and plants.

2. The effects of the oils on different cooking media are also studied in Joint international congress expo on "Lipids, Fats & Oils- Opportunities and responsibilities in the new

It is an ideal coolant which is non-toxic and readily biodegradable fluid. These have longer insulation, thermal life and after use can be economically recycled after use. These transformers can be installed indoors, outdoors, on sideways, in parks without creating fire hazards. These have inherent superior overload capacity without suffering insulation damage; hence an withstand harmonic levels that exceed specific load range. EPA [Enviromental protection agency] of America has approved these Transformers. The parameters they test for use of any oil as dielectric coolant are fire and flash point, dissipation factor, dielectric breakdown, neutralization number, interfacial tension, viscosity, pour point, water content, conductivity, aquatic biodegradation, aquatic toxicity, fatty acid content, phenolic antioxidants and metals. So to use any vegetable oil as transformer coolant, study of dielectric properties and viscosity properties are important.

3. Dielectric studies of oils are also carried out as food oil sensor. The Food Oil Sensor [FOS] is designed to test the dielectric constant of fat. As oil undergoes thermal and oxidative breakdown, its dielectric constant increases. Oil should be replaced when its FOS reaches 5, during frying. The terms fats and oils are generally considered to refer to substances which have a similar chemical structure and which have the same

metabolism in the animal body. Fats are those substances which are solids at ordinary temperatures, while oils are liquids under similar circumstances. Thus what may be considered as a fat in one locality which is colder may be considered as oil in a warmer climate Oil molecules are triglycerides. Structurally, a triglyceride is the reaction product of one molecule of glycerol with three molecules of fatty acids to yield three molecules of water and one molecule of triglyceride.

DIELECTRIC STUDIES

Dielectric Measurements

The dielectric measurements in the present investigation were taken on The HP impedance analyzer4192A [as shown in Photograph-1] in the frequency range 100Hz to 10MHz in the temperature range 303K to 333K. HP Impedance Analyzer Capacitance measurements were made with HP Impedance Analyzer. The HP 4192 Meter is a fully automatic high performance test instrument used to measure a wide range of parameters .The measurement speed of the instrument is 29m/s; it has a very fast test quick recovery and got built in comparator. It can measure the capacitance to a high accuracy and wide measurement range, which allows making precise measurements at four frequencies ranges of 1 kHz, 10 kHz 100 kHz and 1 MHz. The two measurement display sections, capacitance and dissipation factor provide the direct read out of the parameters. The instrument has got two modes of measurement viz., normal mode and average mode; in normal mode operation, the instrument performs measurements at very high speed where as in the average mode it has short, medium or long range rate to average the measurement results. The second mode is adopted in the present measurements to have a high reliable and repeatable value than in the normal mode of the measurement. From the measurements of capacitance and dissipation factor values, dielectric constant and dielectric loss were calculated in the radio frequency range. Sample holder: The HP impedance analyzer with specially designed coaxial, cylindrical sample holder is used for measuring capacitance and dissipation factor of oils. Coaxial, cylindrical sample holder is shown in photograph-2. The sample holder is placed in a specially designed glass bottle. The glass container is a double walled so that through the two outlets present in the bottle, water from thermostatically controlled water bath can be circulated around glass container. So by circulating water around the glass container the temperature of the sample is maintained at required temperature.

EXPERIMENTAL

The dielectric parameters were measured at distributed frequencies between 100Hz and 10MHz.The system was calibrated and verified for the performance by testing with benzene and water samples. Then the measurement is made with oil in frequency range 100Hz to 10MHz first at room temperature 303K. The oil in the sample holder is heated by circulating water around sample holder. The constant temperature bath heats the sample oil under controlled conditions. The temperatures are measured with platinum probe attached to precision temperature indicator. The arrangement used is shown in the photographs land 2. The temperature of the circulating water through layers of sample holder has been maintained to accuracy of +/-0.05K by an electrically controlled thermostat. The oil sample is heated from 303K to 333K and readings are taken in intervals of 5 degree kelvin. The dielectric values are taken in the frequency range 100Hz to 10MHz. Experiment is done with Sunflower oil, Ricebran oil and Sunflower-Ricebran blends. Then the experiment is repeated with Soya bean oil, Palmolein oil and Soyabean-palmoleih blends. After finishing measurements for each sample, the oil sample was drained out from the sample holder and the sample holder as well as the bottle holding oil is cleaned, and dried at room temperature. The dielectric measurements of oils' were taken at 303K. The effect of temperature was evaluated at temperature intervals of 5K between 303K and 333K. The real part of the permittivity of the sample in the sample holder is obtained from the change in capacitance value of the sample holder due to the presence of sample material, using the following equation: Where a and b are the outside diameter of the inner conductor and inside diameter of the outer conductor respectively, h is the height of sample in the sample holder and AC is the change in the capacitance of the sample holder which is given by :

AC = *CP—C0* [3.2.2]

where Cp and C0 are the capacitances of the sample holder with and without sample respectively. Ln[b/a]/h is instrument constant. The b value is 1.2775cm, a value is 0.8274cm and h value is 4.241cm.The instrument constant is calculated to be 0.04448. AC is taken in pico farads. The loss tangent or dissipation factor D, for the sample material was derived from the capacitance and the dissipation factor measured for the sample holder with and without sample.

tan*8 = D= c p n p ~Lc'° Un°* [3.2.3] *cr-c0*

Loss factor s" was evaluated by using the equation

£ - s tan£ [3.2.4]

Comparison Value

we study the variation of the ultrasonic velocity and density with temperature. Variation of the ultrasonic velocity with concentration of Rice bran in Sunflower and Ricebran oil blends and Palmolein in Soyabean and Palmolein oil blends is studied. Gouw & Vultger (1), John N.Coupland & D.Julian McClements(3), McClements & Powey(2) have made study on ultrasonic velocities of individual oils and oils mixed with triglycerides in the temperature range 278K to 343K. They have given the linear fit values of ultrasonic velocities in these temperature ranges. So .in table 4.1.1 we have compared our values with their experimental values for individual oils.

Table 4.1.1: Comparison of experimentally determined Ultrasonic velocities of different oils with Literature Values:

Oil	Temp.	SV	IV	u(exp)	SV	IV	U(refl)	U(refl-Theor)
Sunflower	40C	193.56	137.91	1409.90	192	135.4	1411.0	1408.0
Soyabean	40C	193.07	130.01	1410.20	198	127.5	1404.0	1405.0
Palm	40C	198.1	58.86	1404.7	197	52.10	1399.0	1398.0
RB	40C	194.27	95.8	1410.16	184.00	115.00	1412.0	1402.0

Gouw and Vultger have given a method to find out the ultrasonic velocity of oil from Saponification and Iodine values. It is described in Chapter-2, Section-I, 2.1.1a. Equation to find out the ultrasonic velocity of oil from SV and IV values is given by equation 2.1.7. Using the IV and SV values of experimental oils, we calculated the ultrasonic velocities from the said equation theoretically and compared them with experimental values. Javanaud and Radhalkar (4) proposed a method to find the ultrasonic velocity of oil from ultrasonic velocity values of simple triglyceride using equation 2.1.12, described in chapter 2 Section-1,2.1.1a. We used the said equation and calculated the ultrasonic velocities theoretically and compared it with experimental values. Similarly McClements and Powey (3) proposed some values for ultrasonic velocities of simple triglyceride at 343K and used modified Wood's equation shown in equation 2.1.14a. We calculated the ultrasonic velocity values of oils and there blends at 343K. We extrapolated the u-t graph and found the u values for our oils at 343K and compared them with theoretical values The u values of different simple triglycerides are given by Me Clements and Powey (3) at 343K and at 313K by Gouw and Vultger (1). Using the knowledge of ultrasonic velocities of simple triglycerides proposed by them, we proposed the ultrasonic velocities of each simple triglyceride in temperature range 303K to333K. Considering the oil as a mixture of simple triglycerides, the proposed values are used and the ultrasonic velocity of the oil is calculated from the proportions of simple triglycerides present in the oil. The ultrasonic velocity.is calculated using the formula

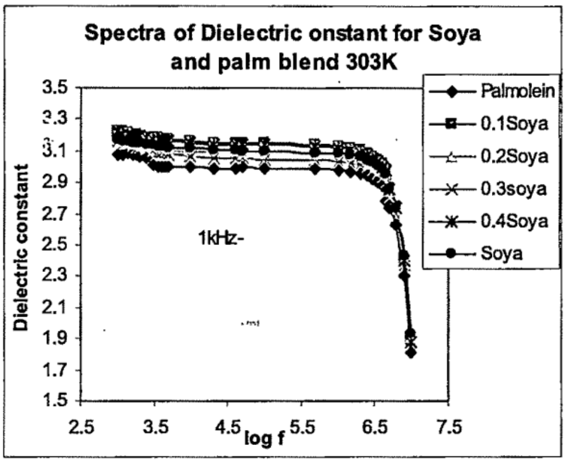
« = (4-1.1) ***i=l***

where P; is the weight proportion of simple triglyceride present in the oil. Above equation is similar to the generalized equation of Hustad etal given in paper of Javanadu and Radhalkar (4). The theoretical values are compared with experimental values and **%** of error is also calculated. These values are shown in the tables of next sections. The proposed u values for simple triglyceries at different temperatures are listed in table 2.1.1.

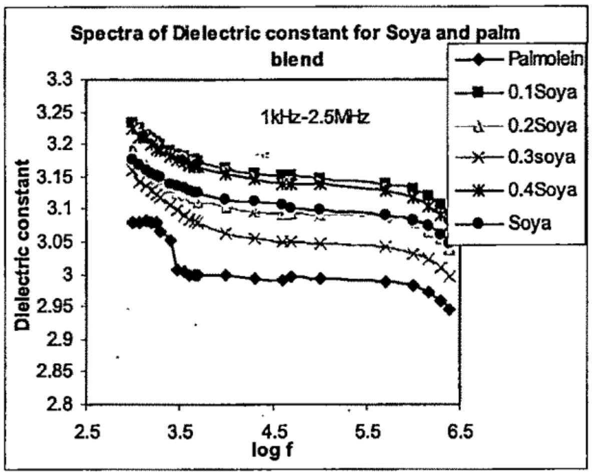
Dielectric permittivity and Dielectric losses of Soyabean oil and Palmolein oil blends

Measurement of Dielectric constant and Dielectric loss factor for Palmolein oil and Soya bean oil blends are carried out with impedance analyzer in the frequency range 100Hz to 10MHz, in temperature range 303K to 333K. The concentrations of Soya bean oil blended with Palmolein oil is varied from 0% to 100% by weight. The results are shown in the form of graphs and tabular forms. The values obtained experimentally are co pared with the data available in reference papers. When the two oils are blended together, saturates **%** is decreasing and unsaturates % is increasing in the blend with increase of Soyabean percentage. In particular Linoleic group in the blend is increasing and Oleic, Palmitic groups are decreasing in the blend. So when Soyabean is blended with Palmolein, we are converting modified oil type to more Linoleic-Palmitic-low linolenic type than the Oleic-linoleic type. Graphs 5.3.1 to 5.3.4 indicate the changes in dielectric constant values with frequency for different Soyabean+Palmolein oil blends at room temperature.

Graph 5.3.1



Graph 5.3.2



When temperature is raised the dielectric values of all blends except 0.8Soya are lying in between the values of Soyabean and palmolein oil values. This means the dielectric values of blends are taking lesser values than soyabean oil unlike at room temperature. So increase of orientation polarization created by mixing Soyabean oil to Palmolein oil at room temperature (which gives higher dielectric value to blend) is reduced due to heating of blend up to 313K. We may say similar trend is observed at 323K from graphs 5.3.9 to 5.3.10 Dielectric permittivity and Dielectric losses of individual oils The objective of our present study is to study the changes in the dielectric properties of oils under controlled heating of oil from 303K to 333K in the frequency range 100Hz to 10MHz. Since edible oils are now used as dielectric fluids in transformers, it is possible that the temperature of the environment gradually increases from 303K to 325K in tropical region. Then it may be useful to study the dielectric properties of oils under gradual heating of oil in different frequency ranges. But most of the studies are carried out after using oils or oil blends as frying mediums for different periods. In our present study, we investigated the changes in Dielectric constant and loss factors while heating oil under controlled conditions from 303K to 333K instead of Frying. Most of the research is focused on oleic acid rich and linoleic acid rich oils like sunflower, Safflower, Olive, Soya bean etc oils and find the dependence of dielectric property on unsaturated fatty acids. But recently Ricebran oil is used as health oil in food industry. It is rich in oleic acid, linoleic acid as well has considerable amount of Palmittic acid (unsaturated). Similarly Palmolein oil is rich in Palmitic acid. So we studied the variation of dielectric properties with oils rich in Palmitic acid along with Sunflower oil and Soyabean oils rich in unsaturated fatty acids. Food industry introduced many blended oils in market to improve the health quality of edible oils. So we also studied the' dielectric properties of the blends of Ricebran and Sunflower oils and Soya bean and Palmolein oil to find there dependence on constituent fatty acids. The experimental procedure for measurement of Dielectric constant and loss factors is described in Chapter 3 section 3. We studied the variation of Dielectric constant and loss factors for Ricebran oil, Sunflower oil, Ricebran and Sunflower blends, Soyabean oil, Palmolein oil, Soyabean and Palmolein oil blends in the temperature range 303K to 333K and frequency range 100Hz to 10MHz.

RESULT AND DISCUSSION

The dielectric constants of all oils and their blends are independent of frequency at room temperature from 500Hz to 4MHz and then there is dielectric dispersion at higher frequencies according to Debye's equation. When oils temperature is raised from 303K to 308K the dielectric constant value is decreasing from 3.1 to 2.6 in general. But at raised temperature the dielectric constant values are increasing with frequency in kHz range. Then it is taking constant values for few kilo hertz and decreasing in megahertz range due to dielectric dispersion. When the oil is heated, the dielectric constants decreased with increase of temperature from 308K to 318K as given by HuLizhi etal. After 318K there is slight increase in dielectric values at certain frequencies. The dielectric losses are minimum in frequency range from 10 kHz to 8 MHz at room temperature for all oils and oil blends. When oil is heated the dielectric losses are showing peaks at two frequencies in frequency range 1 kHz to 100 kHz. These peaks attribute to relaxation times. All oils and their blends have two different relaxation times at higher temperatures. The relaxation time is increasing with temperature. The dielectric losses are increasing at temperatures 313K and 318K in the frequency range 1 kHz to 100 kHz for Sunfloweroil. The dielectric losses are almost zero up to 1.6 kHz and minimum in frequency range from 10 kHz to 3 MHz at room temperature for all oils and their blends. There are few negative dielectric losses to Ricebran oil at 323K. The dielectric constant is increasing when temperature rose from 308K to 313K instead of general decrease Soyabean oil. Also the plateau region of dielectric constant in kHz range is reducing for Soyabean oil when temperatures rose from room temperature. So the dielectric constant of Soyabean oil is not constant with respect to frequency at higher temperatures. The "dielectric losses for Soyabean oil are slightly higher at 328K and 333K. The dielectric constants of palmolein oil slightly increased at 318K and 323k instead of decrease as indicated by HuLizhi. The changes in dielectric losses of Palmolein are showing small amounts of positive values in MHz range unlike other oils. In the temperature range under study, the dielectric constant values of Ricebran oil are higher than the other three oils.. Palmolein oil has smallest dielectric constant compared to the other three oils. So orientation polarization may be large in ricebran oil. Palmolein oil has smaller dielectric constant compared to the other three oils. May be the polar nature of palmolein oil molecules is less. Soyabean oil and Sunflower oil which are having almost equal amounts of Linoleic content are having same dielectric constant values at all temperatures and frequencies.

Ricebran oil and Palmolein oil showed two relaxation times. Soyabean oil arid Sunflower oil are showed single relaxation time. The dielectric constant values and Dielectric loss values are increasing slightly once they are heated from 303K to 308K, then the values decreased with increase of temperature. The Ricebran oil can be used as transformer oil where larger dielectric constants and lower dielectric losses are needed. The dielectric values of RB10%+SF 90%, RB40+SF60%, RB70%+SF30%, RB 80%+SF 20% blends are having dielectric values lesser than the individual oils. This means by blending the ricebran oil'and Sunflower oil in this ratio, the polarity of triglyceride molecules is decreasing or causing lower orientation polarization and hence lower dielectric values. When we blend ricebran oil with sunflower oil the dielectric constants of blends are lesser than ricebran oil values and nearer to Sunflower oil. So unsaturated part increase due to blending is decreasing the dielectric values. The dielectric constants of blends are influenced by the dielectric constant of Sunflower oil (i.e., unstaurtaion) rather than the ricebran oil. So to reduce dielectric constant of Ricebran oil, we can blend it with Sunflower oil.

As previous researchers mentioned , dielectric values of adulterated oils are lesser than the individual oils,RB80%+SF20% oil blend is having dielectric value lesser than the individual oils. Hence dielectric spectroscopy can be used for finding the adulteration of oils or the blending of oils in different percentages. But it is difficult to differentiate when oil with larger% of unsaturates are mixed with the oils having similar %of unsaturates as mentioned by HuLizhi etal(2010). Some of the oils like RB20%+SF80% are showing negative dielectric loss values in frequency range 5 kHz to 6MHz. As the temperature is increasing the plateau regions in dielectric spectra are shrinking. The dielectric losses are more for blends than the individual oils at higher temperatures. So it may be suitable to use pure oils than the blends for low dielectric losses. All the blends are showing two relaxation peaks in dielectric loss spectra just like the individual oils. The dielectric constant of blends is higher than the dielectric constant of individual oils by blending Soyabean oil to Palmolein oil for some blends. This means by blending Soyabean oil to Palmolein oil, its orientation polarization is increasing at room temperature. But when these blends are heated to 313K and 323K, the dielectric values are lying between the individual oil values. This means the additional orientation polarization introduced due to blending is reduced due to kinetic energy increase created by heating.But 0.8Soya blend is still having higher dielectric value than individual oils after heating also. This means it is attaining some permanent polarity due to blending. The dielectric constants of blends are influenced by the dielectric constant of *»u Soyabean oil (i.e., imstaurtaion) rather than the Palmolein oil. So to increase dielectric constant of Palmolein oil, we can blend it with Soyabean oil. The dielectric losses are more for Soya+Palmolein blends than the individual oils. So it may be suitable to use pure oils than the blends for low dielectric losses.

CONCLUSION

Ultrasonic Studies

1. Modified Rackett equation can be used to calculate the densities of oils and oil blends theoretically with percentage of errors less than 1%.

2. Ultrasonic velocities of oils and oil blends can be calculated by using Javanaud-Radhalkar method, McClements-Powey method with the values proposed by them and the author. Error percentages are less than 0.5%. .'•4U

3. The expansion coefficient values for Sunflower oil are high between temperatures 318K to 323K.

4. Density of sunflower oil is varying non-linearly with temperature for Sunflower oil. The increase in molar volume with temperature is more after 318K for Sunflower oil. From molar-sound velocity values, we can say there is no association between Sunflower oil molecules.

5. The change in density with temperature for ricebran oil is non-linear. Decrease in density is more after 318K. This may be due to presence of 22% of Palmitic in it whose melting point is 333K. But change in ultrasonic velocity with temperature is linear.

6. The expansion of ricebran oil is increasing with temperature may be due to presence of considerable amount of Palmitic content in its triglycerides..

7. There may be slight association between Ricebran molecules at higher temperatures as seen from Rao's constant.

8. The change in density with temperature for Soyabean oil is nonlinear. The expansion of oil is more at room temperature rather than at higher temperatures. Expansion is minimum at 318K.

9. There is no association between soyabean oil molecules up to 328K. From increase in Molar sound velocity we can say there may be some association after 328K.

10. Density of Palmolein oil is changing non-linearly whereas the change in ultrasonic velocity is linear with respect to temperature for Palmolein oil.

11. The thermal expansion of Palmolein oil is almost same at all temperatures but with a rise at 328K. This may be due to presence of 50% of Palmitic content in its triglyceride molecules. So we may conclude that the oils with large amounts of saturates do not have larger and varying expansions than oils with poly unsaturates but expansions will increase from 328K.

12. Molar volume of Palmolein oil is rising sharply after 328K which is the melting point of Palmitic acid.

13. There is no association between Palmolein oil molecules as can be observed from Molar sound velocity values.

14. The density of Ricebran oil is more compared to other three oils. Palmolein oil has lesser density than other three oils namely SF, RB, Soyabean oils. The decrease in density with temperature is steeper for Ricebran oil in comparison to other oils. The change in density with temperature for Palmolein oil is less. The reason may be presence of 50% of Palmitic content in Palmolein which are closely packed due to straight chain structures.

15. The Molar volume of Soyabean is higher than other oils, may be due to presence of large % of Linoleic and Linolenic contents and minimum for Palmolein oil may be due to presence of large amount of palmitic content.

16. The ultrasonic velocities of Sunfloweroil, Soyabean oil are almost same due to larger % of Linoleic content in them.

17. The densities and ultrasonic velocities of palmolein oil are less when compared to other three oils. The reason may be the presence of Palmitic as major content. This leads to lesser mass and larger inter molecular free lengths due to straight chains of palmitic part in Triglycerides.

18. The expansion coefficients of Palmolein oil is less compared to other three oils. Reason may be due to presence of 40% of Palmitic content in it.The expansion coefficients of ricebran oil are increasing with temperature. The expansion coefficients of Sunflower are changing with temperatures. By observing the expansion values and dielectric values at higher temperatures, we may say there are some phase changes in the oil at temperatures 318K and 328K.

19. The adiabatic compressibilities. of Ricebran and sunflower oils are almost same.

20. Variation of Molar sound velocities with temperature for four oils indicates that Sunflower oil and Soyabean oil with more Linoleic content are behaving as non-associated liquids. Whereas Ricebran oil and Palmolein oil which are having considerable amounts of Palmitic content are showing slight association at temperatures greater than 323K.

21. By blending the Ricebran oil in different proportions to Sunflower oil, the decrease in density with temperature is less compared to individual oils except 0.3RB+0.7SF! So we can conclude that the blended oil molecules are closely packed rather than individual oil molecules.

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