Full Length Research Paper

An application of optical activity and Faraday Effect to promote food security: A case study of vegetable oils

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Abstract

The purpose of the study was to examine the relationship between the angle of rotation of the Vibration Plane and Calorific Value of Transparent Oils. Fourteen different types of vegetable oils were studied and three transparent mineral and one animal oil samples were investigated for the sake of comparison. For vegetable oils contaminated with impurities or expired, the cut-off angle ϕ was found to satisfy the relationship $\phi_{Vegi\,imp} = A_v + VHL$ **(1)** where A_v is the impurity concentration in the sample, V is the Verdet constant, H is the magnetization and L is the length traversed by the light in the sample. For vegetable oils without impurities and unexpired therefore suitable for human consumption, the cut-off angle obeyed the equation. $\phi = VHL$ **(2)** For transparent mineral oils the cut-off angle gave the relationship $\phi_{min\,eral} = A_{min} + VHL$ **(3)** where A_{min} is the constant that causes intrinsic circular birefringences responsible for optical activity in mineral oils. The calorific values of both mineral and vegetable oils were determined by using the equation $K = [(W_1 + W_2)\{t + n\,VI + (VI - V)_{/2}\}]/W$ **(4)** where W_1 is the weight of water in grams, W_2 is water value of the apparatus in grams and W is weight of oil sample, it is temperature rise during test, VI is the rate of temperature fall in degrees per minute at the end of the test and V is the rate of temperature rise in degrees per minute at the beginning of the test, n is the number of minutes between the ignition and attainment of the maximum temperature. The graph of angle of rotation β per unit current against calorific value of oils was plotted. A straight line graph of the relationship $y = 8.781x - 25.25$ was obtained. This technique is a potential method for designing an instrument that can be used to determine calorific values of transparent oils by using Faraday Effect.

Keywords: Angle of rotation, verdet constant, birefringences and Calorific value.

INTRODUCTION

Food security is the assurance of food availability in terms of both quality and quantity. Kyaruzi (1980) suggests that, this involves the following, (a) Land, (b) Labour, (c) Production, (d) Processing, (e) Storage, (f) Quality control, (g) Preservation, (h) Marketing and (i) Distribution.

In many parts of East Africa farmers produce food in large quantities for subsistence and for sale. Cash crops are sold cheaply because farmers lack:
(i) Technology for processing their produce,

(ii) Mechanisms for ensuring quality control for processed products, (iii) Facilities for storage, (iv) Transportation to the market Kyaruzi (1980). In addition there is no policy to cater for prices of agricultural product all over East Africa. Farmers lack awareness about foods which have high Calorific value Kyaruzi (1980).

This has resulted in malnutrition in East Africa each year, for example children suffer from kwashiorkor, and others lack calcium in their bodies. In some cases when vegetable oil of poor quality particularly that one with high

level of fats is consumed, high blood pressure may result from accumulation of cholesterol and other associated complications (Mucunguzi-Rugwebe, 2000).

Despite the health hazards associated with poor quality of vegetable oil, the rate of using oil as one of the ingredients in cooking has drastically gone up. There is need to improve on the quality of vegetable oils in order to suppress health hazards.

Oil industries in East Africa produce vegetable oils that do not meet international standards and so cannot compete on the world market with similar products from other regions. Because of poor methods, farmers get low returns from the sale of their produce (raw materials) because of the inferior technology used in vegetable oil quality control.

In vegetable oil industry, it is difficult to get pure oils from the methods of processing such as Solvent Extraction (SE) and Single Refinery (SR) Mucungizi-Rugwebe (2000). In the SE which is superior to SR the raw material is crushed and then mixed with petroleum product as an oil solvent. The mixture is distilled, and then purified oil is obtained as a distillate. SR is the classical approach technique in which Caustic Soda (NaOH) is used for preservation, bleaching and isolating oil from impurities. In this process the semi refined oil is obtained as a filtrate. Afterwards, semi refined oil is mixed with charcoal and the mixture is heated, and then filtered out to get pure oil.

Vegetable oils may contain impurities like: (i) Variety of particles (ii) Drops of foreign liquids (iii) Soap (iv) Sand (v) Wax, etc. The product often has oil fats, oil-moisture or oil-fats-mixture.

In the Uganda National Bureau of Standards the most used quality indices are chemical indices.

Optical Activity is an intrinsic property of molecular structure and is one of the best methods of obtaining structural information of a sample. Whenever the d.c. magnetic field is applied through a material (without birefringence) in the direction parallel to that of propagation of light, it will exhibit a phenomenon known as induced circular birefringence.

Mucunguzi-Rugwebe (2000) reports that, Hetcht, emphasizes that Faraday Effect can be used to analyse mixtures of hydrocarbons like vegetable oils, since each constituent has a characteristic magnetic rotation.

In experiments where Optical Activity and Faraday Effect is highly utilized it is clear that there exists a connection between the angle of rotation of the vibration plane and Calorific value of the oil tested Mucunguzi-Rugwebe (2000) . If this connection can be established, then the principle presents a new and novel method of an easy way to determine the calorific values of the different oil products in the oil industry.

The purpose of this work is to utilize Optical Activity and Faraday Effect technique to study the dependence of rotation angle on Calorific value of vegetable oils and some transparent mineral oils for the sake of comparison.

This relationship will be used as a tool to analyze oil quality in terms of its calorific value.

Farmers, oil consumers and the oil industry will be the beneficiaries as this project is geared towards protecting customer needs.

METHODOLOGY

Fourteen different samples of vegetable oils and three types of mineral oils were analyzed to determine the relationship between the rotation angles of the vibration plane per unit current β with their calorific values.

The calorific values of oils were determined by using bomb calorimeter as described in the Parr bomb calorimeter system arrangement in Figure 1.

Recommended steps necessary for safety precautions and ensuring complete combustion of the sample were followed with due care using the guidelines given in the manual "instructions for the 1341 Plain Oxygen Bomb Calorimeter, Parr Instrument Co. (Moline 1960).

Experimental lay out for determining (table1) calorific values of oils Parr bomb calorimeter system including a bomb, pail, jacket, cover, stirring motor and Beckmann thermometer. Support stands for the calorimeter cover and the bomb head. Ignition unit for the calorimeter, oxygen filling system, sample holder and fuse wire, 2000 ml volumetric flask and timer and an oxygen cylinder (Figure 1).

The stirrer was first turned using the hand to be sure that it rotated freely, and after that, it was rotated by a motor.

Then the "10cm fuse" terminals on the ignition unit were connected to the leads on the calorimeter jacket.

The temperature change per minute was recorded as water temperature slowly increased.

After the water temperature had become fairly constant for about four or five minutes, the bomb was ignited.   To ignite the bomb, the button on the ignition unit was pressed to fire the charge.

- The passage of current through the fuse wire ignited the sample.
- The temperature began rising after a short time delay.
- Recording temperature change per minute continued until the run was over.
- After a few minutes, the water temperature reached its maximum value.
- After this maximum value, the water temperature dropped at a slow, steady rate.
- Recording temperature change per minute continued for about 5 minutes.
- After the last temperature observation, the stirrer motor was stopped.
- All the recommended steps to open the calorimeter were followed with due care.
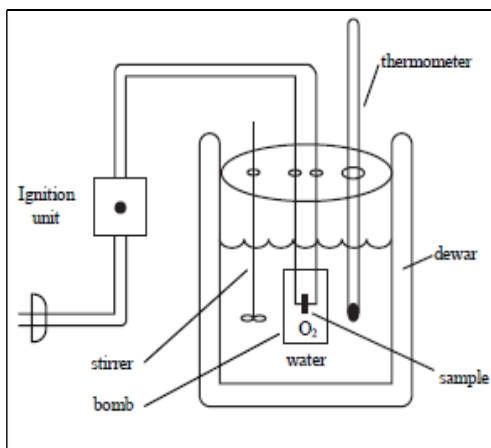- Any unburnt fuse wire was removed and weighed.

Figure 1: Schematic diagram of the bomb calorimeter system.

Table 1: showing Calorific values of vegetable oils from Mukwano Group of Industries

Type of vegetable oil	Calorific value in (kJ/kg)
Corn Oil	39,555
Sunflower Seed Oil	43,011
Fully refined Palm Olein + Sunflower Seed Oil	45,161
Fully refined Palm Olein	46,276

• The weight of the unburnt fuse wire was subtracted from the initial wire weight to obtain the net weight of the wire unburnt.

• The graph of temperature in 0C versus time in minutes was plotted for each sample of oil used.

The equation for radiation correction

$$\Delta t = nVI + \frac{(VI - V)}{2}$$ (1)

was used; where Δt is the temperature correction, n is the number of minutes between the ignition and the attainment of maximum temperature, VI is the rate of temperature fall in degrees per minute at the end of the test and V is the rate of temperature rise in degrees per minute at the beginning of the test.

Then, corrected rise in temperature

$$\Delta T = t + nVI + \frac{(VI - V)}{2}$$ (2)

where t is the temperature rise during test.

• Hence the calorific value of mineral or vegetable oils is given by

$$\left[(W_1 + W_2)\left\{t + nVI + \frac{(VI - V)}{2}\right\}\right] \Big/ W$$ (3)

where W1 is the weight of water in grams, W2 is water value of the apparatus in grams and W is weight of oil sample.

• Equation (3) was used to calculate the calorific value of the sample.

Experimental Arrangement for determining the set up of the equipment is shown in Figure 2.

The analyser, polarizer, sample holder, laser and the head sensor of the laser power meter were fixed on the optical bench using clamps (which were strongly fixed to avoid any change of position during the experiment). The laser beam was directed to pass through the centres of the polarizer, sample and analyser thus all these were at the same height.

The head sensor was adjusted from time to time to be in line with the beam because the beam kept on being rotated. The sample container was thoroughly with liquid soap to remove any stain along its walls and then properly dried with blotting paper.

One end of the container was closed with the lid leaving another end purposely for the container to be inserted in the hole through the hub of the coil frame work.

After inserting the sample container in the hub, the coil and container were positioned on a table in such a way that the open end of the container faced directly vertically upwards while the closed end rested on the table.
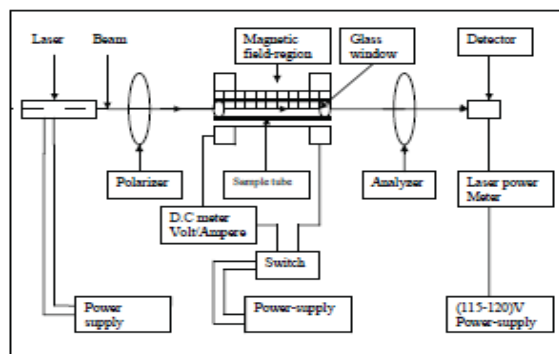
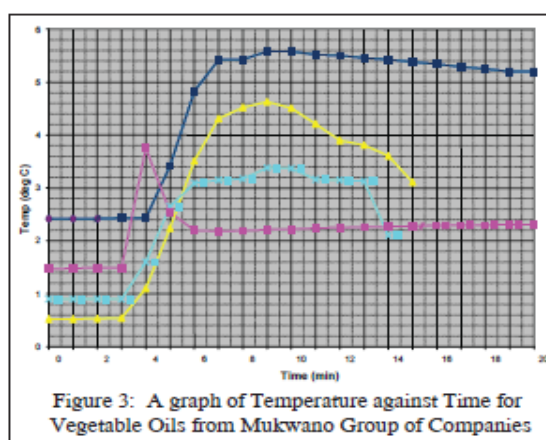Figure 2. Experimental Arrangement for determining Rotation Angle

Figure 3: A graph of Temperature against Time for Vegetable Oils from Mukwano Group of Companies

The sample was poured in the container after which the open end was closed.The coil containing sample holder as shown in the diagram was symmetrically and centrally fixed in its support which was firmly fixed on the optical bench.

Without d.c. magnetic field, the beam was directed through the sample and the angle j at which minimum irradiance Imin occurred was determined for each vegetable sample.

It was found that oils suitable for human consumption there cut–off angle fc was equal to cut-off angle for water aw.

However, if oil is contaminated or expired the cut-off angle f is different from aw.Then, the rotation caused by impurity concentration in the sample is given by

A = f - aw

The solenoid current was varied to change the magnetic field which consequently changed the angle of rotation f for oil suitable for human consumption to q.

The angle of rotation f due to application of d.c. magnetic field is obtained as the difference between two angles i.e. f = q – fc

For each sample a graph of angle f against current I was plotted and the angle b the angle of rotation per unit current i.e. for each oil sample was obtained.

RESULTS

In this section, results are presented starting with graphs (temperature versus time) (Figures 3-9) used to determine calorific values, the angle of rotation versus current and lastly a graph of angle of rotation b per unit current versus calorific values of the oils.

DISCUSSION OF RESULTS

It was observed that the calorific values of both vegetable and mineral oils lie in the range of 35.0 to 48.2 MJ/kg. It was noted also that kamura oil from Arua has the highest vegetable calorific value of 47.2 MJ/kg followed by groundnut oil from the same area with 46.9 MJ/kg. Groundnut oil from Tororo had a calorific value of 45.7 MJ/kg (Tables 3-7).

The range of vegetable oil Calorific is 39.00– 48.0MJ/kg as obtained from www.compenser.net (2011).

The caloric value of vegetable oils studied lie in the range of 47.025 – 39.555MJ per kg and these lie within the range of calorific values of vegetable oils found by other scholars.
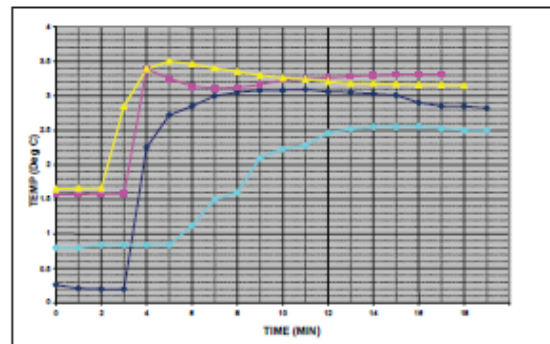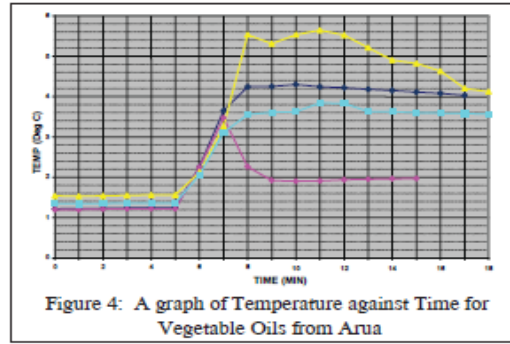
Figure 4: A graph of Temperature against Time for Vegetable Oils from Arua
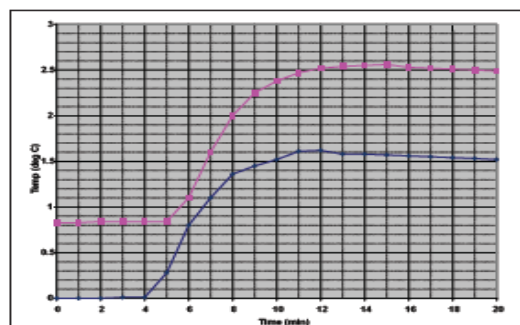
Figure 5. A graph of temperature against time for vegetable oils from Tororo

Table 2: Showing Calorific Value of vegetable oils from Arua

Type of vegetable oil	Calorific value in (kJ/kg)
Kamura Plant Oil	47,025
Sim sim Oil	45,480
Groundnuts Oil	46,830
Soya bean Oil	43,500

Table 3: Showing Calorific values of vegetable oils from Tororo

Type of vegetable oil	Calorific value in (kJ/kg)
Sim sim	44,500
Ground nuts	46,600
Soya bean	42,400
Sunflower Seed oil	42,900

Figure 6: A graph of temperature against time for Vegetable Oils from Bidco

Table 4: showing Calorific values of vegetable oils from Bidco

Type of vegetable oil	Calorific value in (kJ/kg)
Sunflower Seed Oil	43,025
Refined Oil from Bidco	46,380
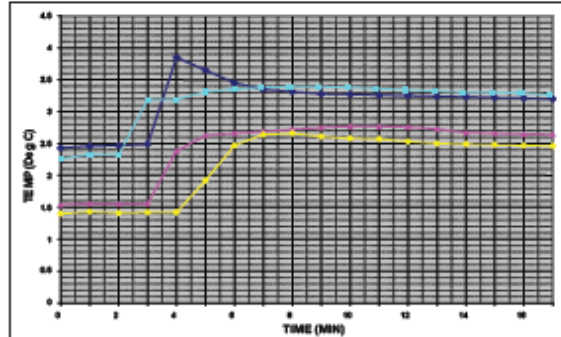
Figure 7: A graph of temperature against time for diesel from Jinja and for petrol and kerosene from Kampala

Table 5: Calorific values of mineral oils

Type of mineral oil	Calorific value in (kJ/kg)
Petrol	48,034
Diesel	43,839
Kerosene	34,998
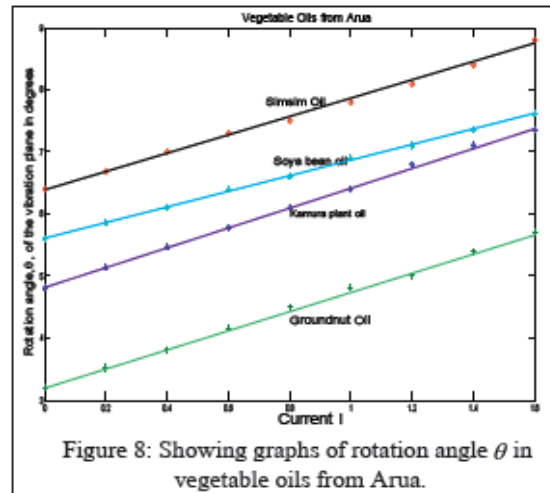
Figure 8: Showing graphs of rotation angle θ in vegetable oils from Arua.

Table 6: Angle of rotation per Unit current β in vegetable oils from Arua

Type of mineral oil	Angle of rotation per Unit Current β
Groundnuts Oil	15.8×10^{-1}
Kamara Plant Oil	16.4×10^{-1}
Soya bean Oil	12.6×10^{-1}
Simsim Oil	14.2×10^{-1}
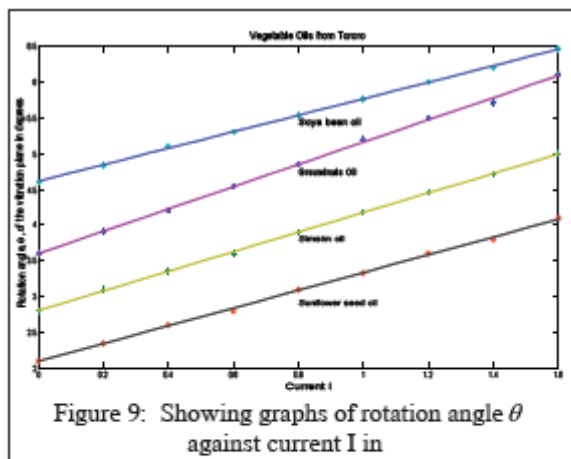
Figure 9: Showing graphs of rotation angle θ against current I in

Table 7: Rotation angle per unit current β in vegetable oils from Tororo

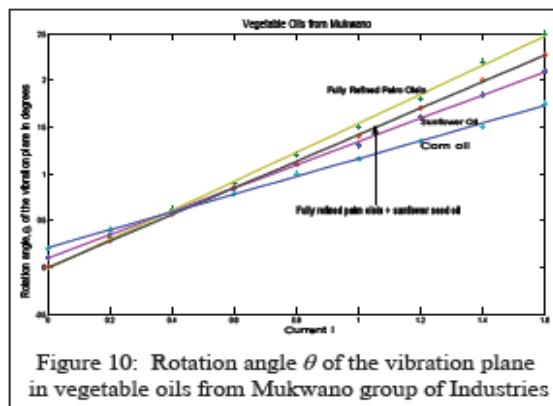| Type of Vegetable Oil	Rotation angle per Unit Current β
Groundnuts Oil	15.6×10^{-1}
Sim sim Oil	13.8×10^{-1}
Sun flower Oil	12.3×10^{-1}
Soya bean Oil	11.6×10^{-1}

Figure 10: Rotation angle θ of the vibration plane in vegetable oils from Mukwano group of Industries

Table 8: Rotation angle per unit current β in Vegetable Oils from Mukwano Group of Industries in Kampala

Type of Vegetable Oil	Rotation angle per Unit Current β
Corn oil	9.6×10^{-1}
Sunflower oil	12.4×10^{-1}
Fully Refined Palm Olein	15.4×10^{-1}
Fully Refine Palm Olein + Sunflower seed oil	14.1×10^{-1}

Also www.compuser.net (2011) reports that the clorific values of petrol and diesel are 48.0MJ/kg and 44.8MJ/kg and the ones obtained in this study are 48.03M/kg for petrol and 43.839M/kg for diesel which are also in agreement with those obtained by other researchers.

The results also show that kamura oil from Arua has the highest rotation per unit current β of 16.30 followed by groundnuts oil from Arua with 15.70. A plot of rotation angle per unit current β against calorific value gave a straight line graph given by the equation

$$y = 8.781x - 25.5$$

CONCLUSION

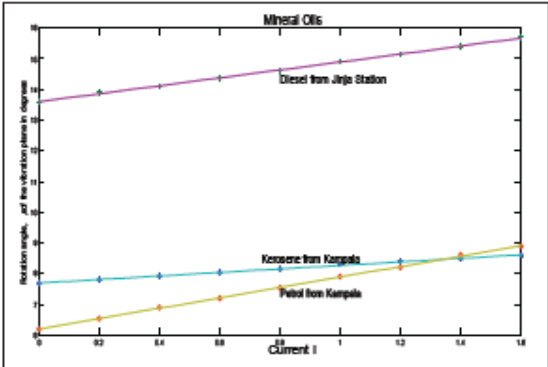The results show a good linear relation between calorific

Figure 11: Rotation of the angle θ in selected mineral oils

Table 9: Angle of rotation per unit current β in three mineral oils selected for comparison with Vegetable Oils

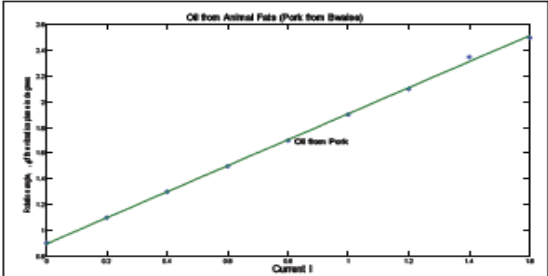| Type of Mineral Oil	Rotation angle per Unit Current β
Diesel from Jinja Station	12.8×10^{-1}
Petrol from Kampala	16.8×10^{-1}
Kerosene from Kampala	5.6×10^{-1}

Figure 12: Rotation angle θ in oil obtained from pork fats

Table 10: Rotation angle per unit current β in animal oils.

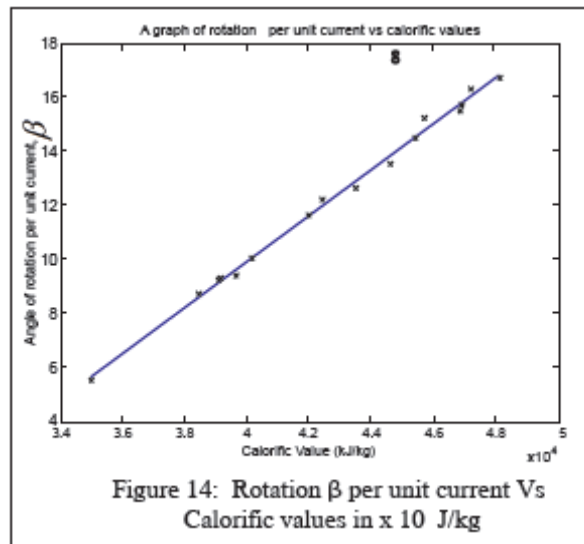| Type of Animal Oil	Rotation angle per Unit Current β
Pork oil	10.0×10^{-1}
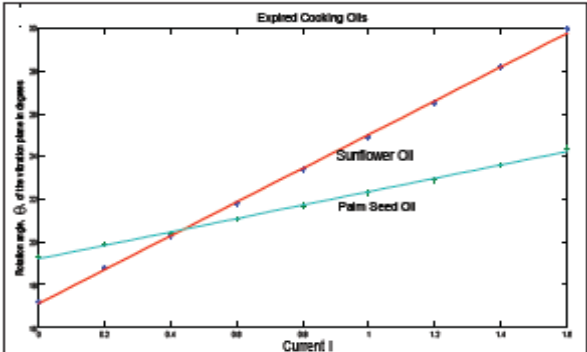
Figure 13: Rotation angle θ in expired Cooking Oils

Figure 14: Rotation β per unit current Vs Calorific values in x 10 J/kg

value and the angle of rotation per unit current (Figures 10-14)

This technique is a potential method for designing an instrument that can be used to determine calorific values of transparent oils using Faraday Effect.

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