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The Effect of Impurity Concentration on Activation Energy Change of Palm Oil and a its Application to Identify an Adulterated Palm Oil

[1]Dikko A. B., [2]Alkasim A., [3]Ahmed A. D.
[1,2,3]Department of Physics, Modibbo Adama University of Technology, Yola, Nigeria

Abstract: *A pycknometer and a rotational viscometer were used to measure the density and viscosity respectively of pure palm oil and various concentrations of adulterated palm oil at 313 K. From the measured values of density and viscosity, activation energy changes arising from various concentrations of impurity in palm oil were calculated. The activation energy change of palm oil increased linearly as the concentration of impurity in palm oil increased. This most probably is due to the increase in intermolecular attractive force between the impurity and palm oil molecules. Due to the linear relationship between the impurity concentration and the activation energy change of palm oil, a simple mathematical expression was developed for the identification of an adulterated palm oil.*
Keywords: *Activation energy change, Adulteration, Concentration, Impurity, Palm oil, Turkey oil*

I. Introduction

Palm oil [1] is an edible vegetable oil derived from the mesocarp of the fruit of the oil palms, primarily the African oil palm Elaeis guineensis and to a lesser extent from the American oil palm Elaeis oleifera and the maripa palm Attalea maripa [2]. Palm oil is naturally reddish in color because of a high beta-carotene content. It is not to be confused with palm kernel oil derived from the kernel of the same fruit [3], or coconut oil derived from the kernel of the coconut palm (Cocos nucifera). The differences are in color and in saturated fat content. Palm mesocarp oil is 41% saturated, while Palm Kernel oil and Coconut oil are 81% and 86% saturated respectively [4].

Palm oil is one of the few highly saturated vegetable fats and like other vegetable oils, palm oil contain no significant amounts of cholesterol [5]. Palm oil is a common cooking ingredient in the tropical belt of Africa, Southeast Asia and parts of Brazil. Its use in the commercial food industry in other parts of the world is widespread because of its lower cost and the high oxidative stability of the refined product when used for frying [6], [7].

The use of palm oil in food products has attracted the concern of environmental activist groups; the high oil yield of the trees has encouraged wider cultivation, leading to the clearing of forests in parts of Indonesia in order to make space for oil-palm monoculture. This has resulted in significant acreage losses of the natural habitat of the orangutan, of which both species are endangered; one species in particular, the Sumatran orangutan, has been listed as critically endangered [8]. In 2004, an industry group called the Roundtable on Sustainable Palm Oil (RSPO) was formed to work with the palm oil industry to address these concerns [9]. Additionally, in 1992, in response to concerns about deforestation, the Malaysian Government pledged to limit the expansion of palm oil plantations by retaining a minimum of half the nation's land as forest cover [10], [11].

During these last ten years adulterated vegetable oils become more and more present at low cost in many markets of developing countries. These adulterated vegetable oils resulted in fraudulent substitution practices in which inferior quality edible oil is mixed into superior quality edible oil. All fields of human nutritional activities in developed and developing countries are concerned by fraudulent substitution practices many years ago. Thornton (1968) reported that the first case of fraudulent substitution in food products namely in meat industry was recorded in thirteenth century A.D. at Florence in Italy. While considering the quality of food products from industrial origin, several analytical techniques have been developed to fight against fraudulent substitution practices [12], [13], [14].

One of the most recent powerful methods to fight against fraudulent substitution practices because of its specificity is the fingerprints methods. These methods consist of selecting a known compound or a marker as qualitative and quantitative target to assess authenticity and inherent quality. The evaluation of this compound in its entirety, so-called fingerprints is widely used for authentication and quality control [12], [13], [14].

The worldwide economy stipulated nowadays requires that developing countries acquire or develop more and specific production tools for efficient quality control, falsification repression and production standardisation. Quality control of vegetable oils is one of the many problems to be solved in developing countries exposed to various internal and external falsifications of consumer goods. Unequivocal or specific identification of food products in general and vegetable oils in particular remains a challenge as well as on the economic, food and sanitary point of view. Numerous identification and quality control methods of vegetable oils are developed in the literature: conventional methods based on the determination of acid index, ratio of unsaturated to total fatty acids content, saponification index, iodine index, refraction index, triacylglycerol determination [17], [18], [19], [20], [21].

The coupling of Gas Chromatography (GC) with Mass Spectrometry (MS) has resulted in separation and identification of various volatile compounds in foodstuffs [22], [23]. These many volatile compounds currently called aroma, are considered as a key characteristic in many quality control and identification methods of food products by new electronic nose sensing technique of identification of vegetable oils [24], [25], [26]. Food adulteration, the act of adding or mixing something inferior, harmful, useless and unnecessary substance to food; and food item may be considered as adulterated if its nature and quality are not up to the standard.

The discovery of synthetic colours and flavours has made it any fat can be made to look like ghee and customers may easily be cheated. Til oil and coconut oil are often mixed with groundnut or cottonseed oil as the latter are cheaper. Mixing of palm oil with soybean oil is a common practice among dishonest trader for more profits, which will cause a change in it viscosity. In the drying oil industries, the process of heat-bodying, blowing and other methods for modifying oils, cause large changes in viscosity [27]..

These methods require sophisticated equipments or machines, and are time consuming. The aim of the present study was to develop a rapid and simple method of identifying adulterated palm oils.

II. Materials And Method

Samples of palm oil were obtained from extraction industries at Ikot Ekpene and Abak, and vegetable oil (Turkey oil) were obtained from Yola main market in Nigeria. These samples were collected and stored in a container in its pure state and carefully sealed in clean and well labeled sample bottles. These samples were subsequently transported to the laboratory for the adulteration tests and measurement of some physical parameters. Various measured volumes of Turkey oil were added to a fixed volume of pure palm oil for density and viscosity measurements. The density and viscosity were measured using a pycknometer and a rotational viscometer respectively with an accuracy of 3 parts in 10^5 for density and 0.001 Ns m^{-2} for viscosity at 313 K.

Using the measured data of viscosity of pure palm oil and adulterated palm oil, the change in activation energy, ΔE_a arising from different concentrations of the impurity (Turkey oil) in the palm oil at constant temperature was calculated using equation (1) [28].

$$\Delta E_a = K_B T \ln\left(\frac{\mu_2}{\mu_1}\right) \tag{1}$$

Where μ_1 is the viscosity of pure palm oil, μ_2 is the viscosity of the palm oil adulterated with Turkey oil, T is the absolute temperature, and K_B is the Boltzmann constant.

III. Results And Discussion

Measured values of various concentrations of turkey oil (adulterant) in palm oil and the corresponding change in activation energies are given in table 1. It can be observed from Figure 1 that the change in activation increased linearly with increase in concentration of the impurity (Turkey oil) in palm oil. The increasing values of activation energy change show that there is a moderate attraction between solute (Turkey oil) and solvent (palm oil) molecules. The increase of values with concentration shows increase in intermolecular forces due to non increase in thermal energy of the system.

Table 1 Activation energy change of palm oil with impurity concentration

Percentage concentration of Turkey oil in Palm oil	Activation energy change, ΔEa (meV)
0	0
5	7.885
10	15.374
15	21.849
20	28.974
25	35.853
30	43.124
35	49.322
40	56.453
45	63.645
50	70.234

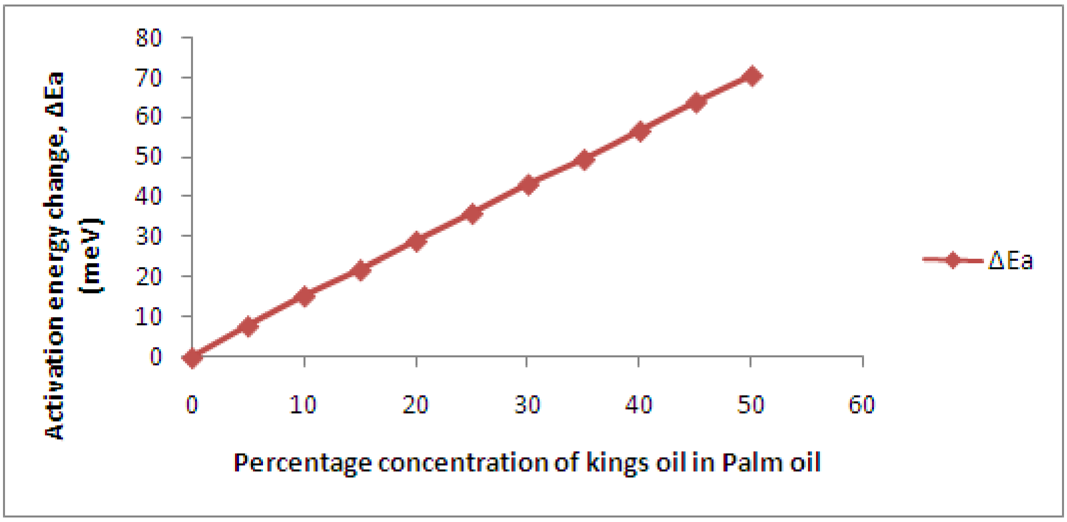

Fig. 1 Variation of activation energy change of palm oil with impurity concentration in the mixture

The linear relationship between the concentration of impurity and the change in activation energy of the solvent can be represented by the equation as

$$\Delta E_a = SC_{imp} \tag{2}$$

Where ΔE_a is the change in activation energy of palm oil, C_i is the concentration of impurity in palm oil, S is the value of the slope of the graph in Figure 1. Equation (2) and equation (1) can be combined and simplified as

$$C_{imp} = K_B \frac{T}{S} \ln\left(\frac{\mu_2}{\mu_1}\right) \tag{3}$$

Equation (3) can serve for any binary liquid mixture provided the values for the parameters on the right hand side are determined for that liquid mixture. However, the particular palm oil studied in this paper, T = 313 K, S = 1.143 x 10^{-3}, μ_1 = 0.614 pa.sec. To determine the concentration of impurity in any suspected adulterated palm oil μ_2 is obtained at T = 313 K and employing equation (3), the percentage volume concentration of the impurity, C_{imp}, is calculated.

IV. Conclusion

The activation energy change of palm oil increased as the concentration of impurity in palm oil increased. This most probably is due to the increase in intermolecular attractive force between the impurity and palm oil molecules. It can be assumed that an adulterated palm oil can take more time to be digested in the stomach than pure palm oil. Due to the linear relationship between the impurity concentration and the activation energy change of palm oil, a simple mathematical expression was developed for the identification of an adulterated palm oil.

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