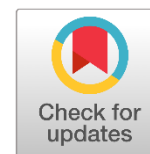




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Electrochemical Effect of Omega 3 Fatty Acid in Milk at Different Temperatures by Cyclic Voltammetry

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ABSTRACT

In this study, a new method to determine the extent effect of chemical interference between omega 3 fatty acid (fish oil), and milk solution (lactose) was used by electrochemistry procedure through oxidation-reduction of electric current peaks. The different temperature factors and their effect on the oxidation peak of omega-3 in the milk medium were applied to determine the values of activation energy (E_a^*) and other thermodynamic values were calculated, such as enthalpy (ΔH^*), free energy (ΔG^*), and entropy (ΔS^*). The results of the analysis showed that there is only one reduction peak of omega 3 fatty acid in milk, which proves that fish oils with lactose milk have an effective antioxidant effect on the body of the organism in addition to the benefits envisaged by these oils. Temperature is the main action to destruction of milk proteins above 50 °C, in addition to the effect of omega-3 on the milk as well.

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1. Introduction

Previous studies were carried out in the electrochemical field on the effect of ascorbic acid on omega-3 as shown in Fig.1 (Radhi, et al., 2015) and its positive effect on inhibiting lead contamination (Radhi, et al., 2016). Studies are continuing in the field of electrochemistry to discover the important effects on the blood composition of various chemical and pharmaceutical compounds (Radhi, et al., 2017; Radhi & Al-Mulla, 2015; Radhi, et al., 2018; Radhi, et al., 2010; Abdul-Amir, et al., 2017).

Lactose or milk sugar has a structure as shown in Fig.2 is a disaccharide made by combining one unit of galactose and one unit of glucose. Milk sugar is naturally present in milk and makes up between 1.5% and 8% by weight of milk. It can be extracted from milk solids (both grades, sweet milk solids and sour milk solids) that remain after cheese is manufactured (Machado, et al., 2000).

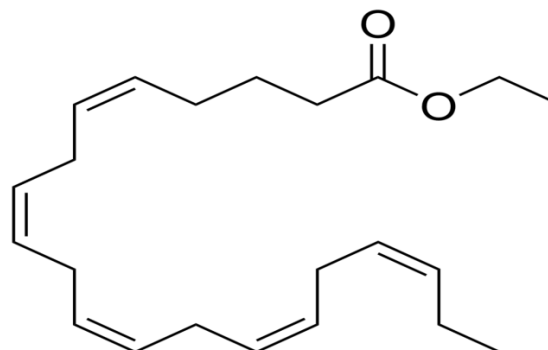


Fig. 1. Omega 3 fatty acid structure

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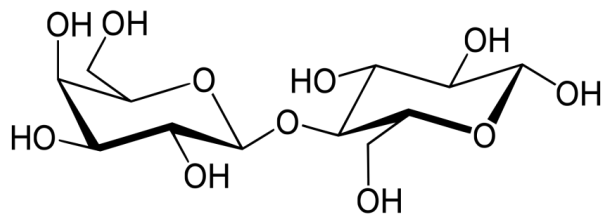


Fig. 2. Lactose structure

The compound of omega-3 is a fatty acid can be found in fish, and it is very important substance which response for produce of many compounds that save the balance of many vital process. It is an unsaturated fatty acid with the chemical formula $C_{20}H_{30}O_2$, with five double bonds, one of which is on carbon number 3 of the methyl end of the chain, and therefore it is an omega-3 acid. Omega-3, symbolized ω -3, is a double-linked polyunsaturated fatty acid that is usually obtained from salmon, and is also found in other marine and river fish. It is effective in lowering cholesterol. And resistance to infections in the body, and works on the integrity of the brain. It was found the fish oil from different sources such as sardines, salmon, mackerel and tuna, soybeans, raisins, walnuts, linseed, and extracted oils from them, and also olive oil (Weintraub, 2014).

The naturally product can be occurred in an immune-modulating nutrients such as omega-3 polyunsaturated fatty acids, citrus pectin, and milk-derived exosomes in preventing intestinal septal inflammation. In the existing evidence, the molecular reaction of these bio nutrients in the intestinal has been applied in animal diets (Sundaram, et al., 2022).

2. Materials and Methods

Materials

Milk solution was used in the study from the market, Omega-3 was received from the California Gold Nutrition, USA. Different chemical compounds and solvents were used was provided from Merck, Germany. Deionized water was used in all experiments.

Methods

Instrumentation

Potentiostat type EZstat from company NuVant Systems Inc. (USA) was used in the current study. Glassy carbon electrode (GCE), Ag/AgCl (3 M KCl) and a platinum wire (1 mm diameter) were used as working electrode, reference and counter electrode, respectively. All electrodes immersion in 10 ml of milk in voltammetric cell as shown in Fig.3.

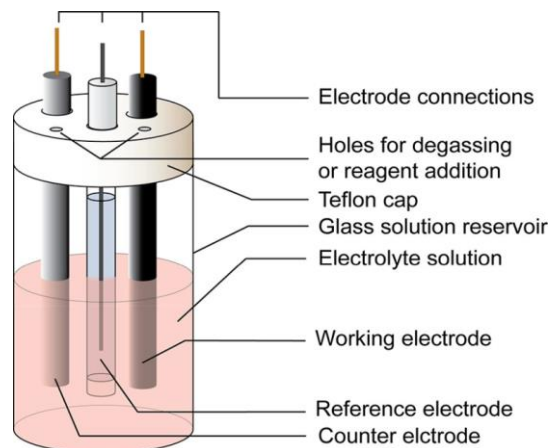


Fig. 3. Cyclic voltammetric cell

Procedure

15 mL voltammetry cell was used to place 10 mL of electrolyte (milk), then all electrodes were immersed in the milk and connected into a potentiostat with personal computer to show the results of cyclic voltammogram (Zwyea, et al., 2020; Kareem, et al., 2021) as shown in Fig. 4.

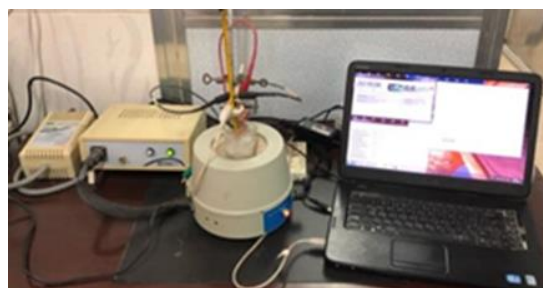


Fig. 4. Cyclic voltammetry set up

3. Results and Discussion

Omega-3 in milk medium was studied in cyclic voltammetric method at different temperatures from 30 to 70 °C to find the electrochemical properties of the redox current peaks. The oxidation peak current of the interference of milk with omega-3 as fish oil at +500 mV has been enhanced gradually at different temperatures as shown in Fig. 5. This phenomena indicates that the electrocatalytic effect of temperature changes appeared when use milk with fish oil especially at high temperature causes a bad interferences in the body (Radhi, et al., 2014; Radhi, et al., 2015).

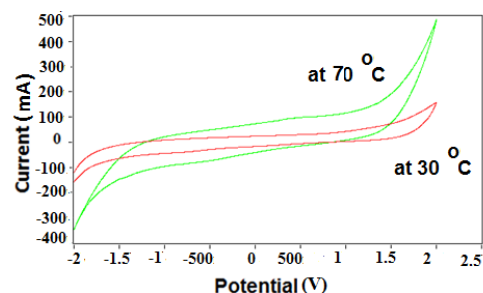


Fig. 5. Cyclic voltammogram of omega-3 in milk medium on GCE at different temperatures (30-70 °C) [at scan rate of 0.1 V sec⁻¹]

Effect Different Temperatures on Mix of Milk and Fish Oil

The activation energies (E_a^*) of the oxidation current peak for the mix of milk and fish oil that appeared in the cyclic voltammogram at 500 mV in different temperatures (30-70 °C) was determined. Table 1 shows the values of the oxidation (I_{pa}) current peak which enhanced with increasing the temperatures.

Table 1

Different temperatures (30-70 °C) of Ln (I_{pa}) oxidation current peak at +500 mV for the mix of milk and fish oil

| T (°C) | T(°K) | 1/Tx10 ⁻³ | Ln(I_{pa}) |
|--------|-------|----------------------|----------------|
| 30 | 303 | 3.3 | 3.669 |
| 31 | 304 | 3.289 | 3.728 |
| 32 | 305 | 3.279 | 3.77 |
| 33 | 306 | 3.267 | 3.795 |
| 34 | 307 | 3.257 | 3.833 |
| 38 | 311 | 3.215 | 3.85 |
| 40 | 313 | 3.195 | 3.85 |
| 42 | 315 | 3.175 | 3.892 |
| 46 | 319 | 3.135 | 3.926 |
| 48 | 321 | 3.115 | 3.949 |
| 50 | 323 | 3.096 | 3.998 |
| 52 | 325 | 3.077 | 4.036 |
| 54 | 327 | 3.058 | 4.108 |
| 56 | 329 | 3.039 | 4.117 |
| 58 | 331 | 3.021 | 4.153 |
| 60 | 333 | 3.003 | 4.162 |
| 62 | 335 | 2.985 | 4.24 |
| 63 | 336 | 2.976 | 4.286 |
| 64 | 337 | 2.967 | 4.316 |
| 65 | 338 | 2.958 | 4.329 |
| 66 | 339 | 2.945 | 4.369 |
| 67 | 340 | 2.941 | 4.407 |
| 68 | 341 | 2.932 | 4.443 |
| 69 | 342 | 2.923 | 4.477 |
| 70 | 343 | 2.915 | 4.483 |

Calculation of Activation Energy (E_a^*)

Activation energy was determined using Arrhenius equations (Tan & Goh, 2008; Bao, et al., 2009):

$$\sigma = \sigma_0 \exp(-E^*/RT) \dots\dots\dots(1)$$

$$D = D_0 \exp(-E^*/RT) \dots\dots\dots(2)$$

where σ / D refer to conductivity / diffusibility

while σ_0 / D_0 represent standard conductivity / the initial diffusibility

$$I_p = \exp(-E_a^*/RT) \dots\dots\dots(3)$$

Where:

I_p : Current peak (μA)

E_a^* : Activation energy (kJ/mol).

R: Ideal gas constant (8.314 J/mol.K).

T: Temperature in K.

Fig. 6 shows the relationship between the oxidation peak current of the mix of milk and omega-3 (fish oil) against the different temperatures to determine the activation energy from equation 3. The value of activation energy (E_a^*) for the fish oil in milk medium is [15.8190 KJ mol⁻¹ K⁻¹]

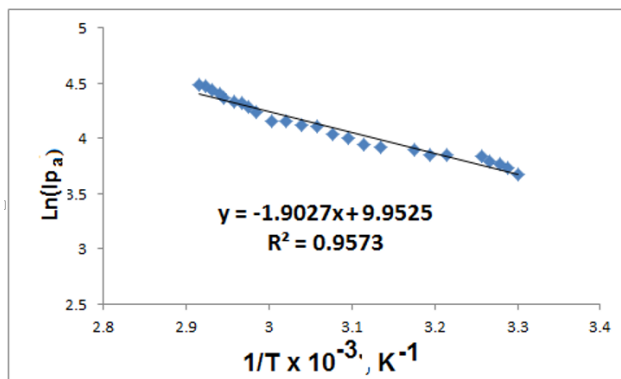


Fig. 6. Relationship between the Ln(I_{pa}) and 1/T of Omega fatty acid milk in blood medium

Functions of Thermodynamic (ΔH^* , ΔG^* , ΔS^*) of Fish in Oil Milk

From the derive many equations of thermodynamic equations with Eyring equation activation energy equation to determine each values of ΔH^* , ΔG^* , and ΔS^* (Atkins & de Paula, 2006; Chapman & Cowling, 1990; Hosamani, et al., 2012):

$$\Delta G^* = \Delta H^* - T\Delta S^* \dots\dots\dots(4)$$

where

ΔG^* is the Gibbs energy of activation

ΔH^* is the enthalpy of activation

ΔS^* is the entropy of activation

$$E_a^* = \Delta H^* + RT \dots\dots\dots(5)$$

In general, a reaction proceeds faster if E_a^* and ΔH^* are small. Conversely, if E_a^* and ΔH^* are large, the reaction rate is slower.

$$\Delta G^* = -RT \ln(k h / T k_B) \dots\dots\dots(6) \text{ Eyring equation}$$

$$\Delta H^* = \Delta G^* + T\Delta S^* \dots\dots\dots(7)$$

where gas constant $R = 8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$, Boltzmann constant $k_B = 1.381 \times 10^{-23} \text{ m}^2\cdot\text{kg}\cdot\text{sec}^{-2}\cdot\text{K}^{-1}$, and Plank constant $h = 6.66 \times 10^{-34} \text{ J}\cdot\text{sec}$. with multiplier of temperature T (K) [18-20].

In this work, the parameters of thermodynamic factors of omega-3 in milk solution as an electrolyte were found from the equations 4, 5, and 6. The results illustrated that the oxidation reaction of omega-3 has been processed in milk solution at variable temperature that make as the law of "Gibbs Helmholtz free energy", also depend on the changing of enthalpy different (ΔH^*) as shown the results in Table 2. This oxidation reaction was happened in nonspontaneous process when the estimate the free energy (ΔG^*) is positive value and "enthalpy change (ΔH^*)" is positive value too, these reaction may be happened with reversible process of [cathodic current peak]. In other results of entropy different (ΔS^*) which showed a negative value (Essa & Hoidy, 2020) as it is illustrated in table 2.

Table 2

Values of activation energy E_a^* , and thermodynamic functions (ΔH^* , ΔG^* , and ΔS^*) of oxidation peak current for omega 3 fatty acid in milk

| E_a^* , I_{pa} | ΔH^* , I_{pa} | ΔG^* , I_{pa} | ΔS^* , I_{pa} |
|--------------------|-------------------------|-------------------------|-------------------------|
| 15.819 | 12.761 | 65.333 | -2.664 |

Reliability and Stability Study

In the electrochemistry with cyclic voltammetry study need to be checked the correct cyclic voltammogram through experiments that give stable voltammogram through the work by scanning for ten times to find the overlapping of the voltammogram to reach high precision of the results. Fig. 7 shows the reliability in high stability in the voltammogram, so we can depended to the results as in the experiments especially at different temperatures (Essa & Hoidy, 2020).

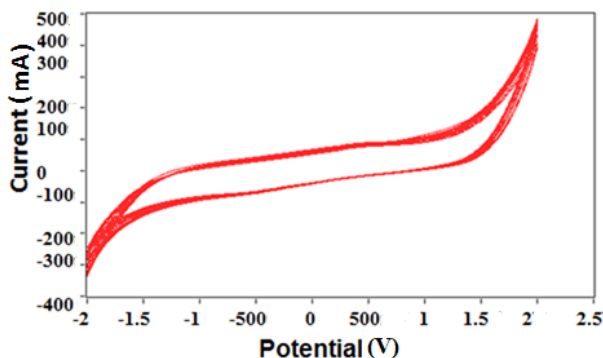


Fig. 7. cyclic voltammogram at ten scanning of fish oil in milk medium on GCE as working electrode and Ag/AgCl as reference electrode at scan rate 0.1 Vsec⁻¹

4. Conclusion

The effect of omega -3 on milk composition was studied at different temperatures by cyclic voltammetry. In order to learn about what happens from oxidation and reduction reactions when mix fish oil with milk, the oxidation reaction of the milk by fish oil was obtained by this study, which caused a change in its composition when the mixture was heated. By conducting mathematical calculations of the activation energy (E_a^*) value and the thermodynamic values of entropy (ΔS^*), enthalpy (ΔH^*) and free energy (ΔG^*), it was found that the interaction between the composition of omega 3 fatty acid and milk occurs at high temperatures in the oxidation process and is considered an oxidizing factor in the composition of milk. Therefore, it is advised not to drink hot milk after eating fishmeal, because it contains omega.

Competing Interests

The authors had no competing interests.

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