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The Derivation of Silica from Coconut Husk Ash: Preliminary Study

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Abstract

Coconut husk is widely known as agricultural waste that can be burned and transformed into coconut husk ash (CHA). Conversion coconut husk into an ash becomes an environmentally alternative by turning the waste to resources. These wastes can give a bad impact to the environment if managed in the wrong way because it can release gaseous to the atmosphere. This project aims at different chemical treatments by using acid treatment and alkali treatment to produce silica by using coconut husk ash. The silica will be going through the characterization by using Fourier-transform Infrared Spectroscopy (FT-IR) and Field Emission Scanning Electron Microscope (FESEM). Currently, researchers are working to reduce the cost of utilizing high quality silica by extracting silica from agricultural waste. Silica obtained is easier to produce and more environmentally friendly. The silica is required to be produced as it is important in this country because it can be used in an industry as a catalyst, construction and many more. This is because the utilization of silica nowadays is increasing, hence coconut husk ash consists of silica components which can be produced after going through several treatment processes and the amount of waste can be reduced at a time. Aside from that, silica has a variety of applications compared to other chemical substances.

1. Introduction

Cocos nucifera, also known as a coconut, is one of the famous palm trees in this country. People also call it a 'tree of life' or 'the tree of a thousand uses' [1]. Coconut is a common fruit that is used in the food industry. Each part of coconut has its own function and can be used in another industry too. It can be used as a building material, handicraft, and many more. Coconut husk consists of mineral elements such as sodium oxide, magnesium oxide, aluminum oxide and others [2, 3]. To avoid the coconut from contributing to pollution, their husks are used to produce silica for industrial usage. Silica are mostly made up from quartz and sand as raw materials. The use of this material has to go through various difficult processes in the production of silica such as crushing and grinding the materials and separating them based on size. Using this raw material is highly expensive due to their high melting point [4]. However, this project used coconut husk as raw materials and was burned at different temperatures from 500 °C to 700 °C. To produce silica, the CHA undergoes acid and alkali treatment. This project is easier to handle but requires a long time period to complete the process since it produces only a small amount of silica for a big amount of CHA. The waste can be reduced by extracting the silica from coconut husk ash. Coconut husks are mostly burned or disposed of in the landfill which may contribute to environmental issues and

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pollution. Malaysia is a major agricultural service producer which creates at least 168 million tons of biomass each year [5]. This includes rice husks, coconut stem fibers, sugarcane waste and oil palm. Sustainable energy sources can be encouraged by the government by converting coconut husk into a silica. To sum up, using coconut husk as a raw material can give benefits to various industries since it can reduce harm.

2. Methodology and Materials

Coconut husks procured from local stores underwent a thorough cleaning process and were dried in an electric oven at 120°C to eliminate impurities and moisture. The fibers were meticulously separated from the outer husk layer and stored in a drying box to shield them from environmental impurities and moisture. These purified coconut fibers were then placed in an alumina crucible and exposed to temperatures of 500°C, 600°C, and 700°C for 2 hours in an electric furnace. This process aimed to produce CHA.

The process continued with chemical treatment. In the acid treatment, 20 mL of 2.5M sulfuric acid (H_2SO_4) was mixed with coconut husk ash in a beaker. A hotplate magnetic stirrer was used to continually stir the fluid until it reached 50°C for one hour. Following the leaching procedure, the residue was washed several times with distilled water to remove any remaining excess acid content in the ash. The solution was then filtered. The ash residue was dried in an oven for two hours at 70°C to obtain white powdered silica.

For the alkali treatment, 20 mL of 2.5M NaOH was mixed with coconut husk ash. The mixture was heated to 100°C for one hour while being continuously stirred to dissolve the silica in coconut husk ash and produce sodium silicate. The solution was filtered using ashless filter paper. After allowing the filter to cool, it was carefully titrated with 2.5M of H_2SO_4 while being continuously stirred. The extra impurities were removed by repeatedly cleaning and filtering using deionized water. The precipitate obtained was dried in an electrical oven to create amorphous silica.

After the silica was completed, it was characterized using Field Emission Scanning Electron Microscopy (FESEM) and Fourier Transform Infrared Spectroscopy (FTIR). The overall methodology described was shown in the diagram in Fig. 1.

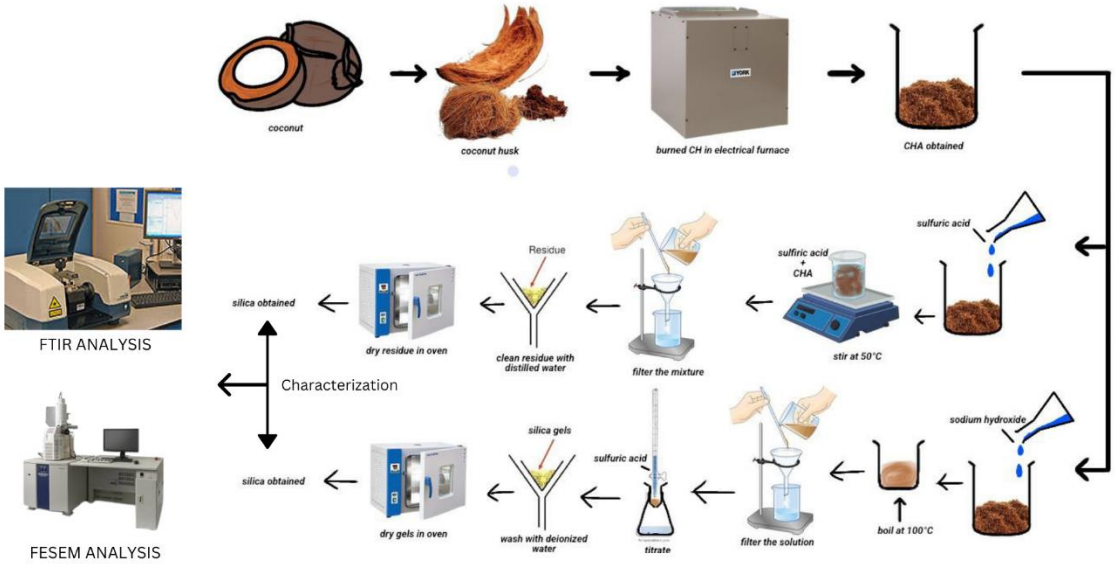

Fig. 1 *Flow diagram of overall methodology*

3. Results and Discussion

The synthesis of silica from coconut husk ash using an extraction method, which is acid treatment and alkali treatment has been done. The result of silica obtained from comparison between acid treatment and alkali treatment. The results comparison is observed by undergoing the characterization process. By using FESEM, the result of analyzing the morphological structures or microstructures of the sample is obtained. Furthermore, by using FT-IR, the result of identifying the chemical bond in a molecule sample by producing an infrared absorption spectrum is identified. The production of silica by using this method proved that coconut husks can help to recycle waste products and turn them into eco-friendly products, which is silica. By doing this project, environmental pollution such as air pollution, water pollution and other related environmental problems could be reduced.

3.1 Fourier-transform Infrared Spectroscopy (FTIR)

Based on the FTIR spectra curves illustrated in Fig. 2, three distinct spectra corresponded to the temperatures of 500 °C, 600 °C, and 700 °C. Each temperature exhibited different functional groups, as discerned from the spectra. At 500 °C, the bonds identified were C-H and C-C, indicating the presence of hydrocarbons and carbon-carbon bonds typically associated with the thermal decomposition of organic compounds at this temperature. At 600 °C, the detected bonds included C-H, O-H, and C-O. The presence of O-H and C-O bonds suggested the formation of hydroxyl groups and carbon-oxygen bonds, indicating partial oxidation and the formation of oxygen-containing functional groups due to the decomposition of organic matter and partial oxidation processes. At the highest temperature of 700 °C, the observed bonds were C-H, C-C, and C-O. This combination indicated the persistence of residual hydrocarbons (C-H), carbon-carbon bonds (C-C), and carbon-oxygen bonds (C-O), reflecting further oxidation processes at this elevated temperature.

However, the primary element of interest in this study was silica. Functional groups related to silica were not found at any of the three temperatures after the acid treatment. The absence of silica element in this treatment could be attributed to potential errors or carelessness during the experimental procedure, possibly due to students not meticulously following the outlined steps. Additionally, other factors might have contributed, such as environmental conditions affecting the coconut husk ash, which was stored for an extended period before testing. Consequently, the acid treatment may not have produced silica due to various factors that were not adequately managed, including the proper storage of the silica to prevent contamination. Thus, to prevent this situation from occurring the sample must be stored in the desiccator [5].

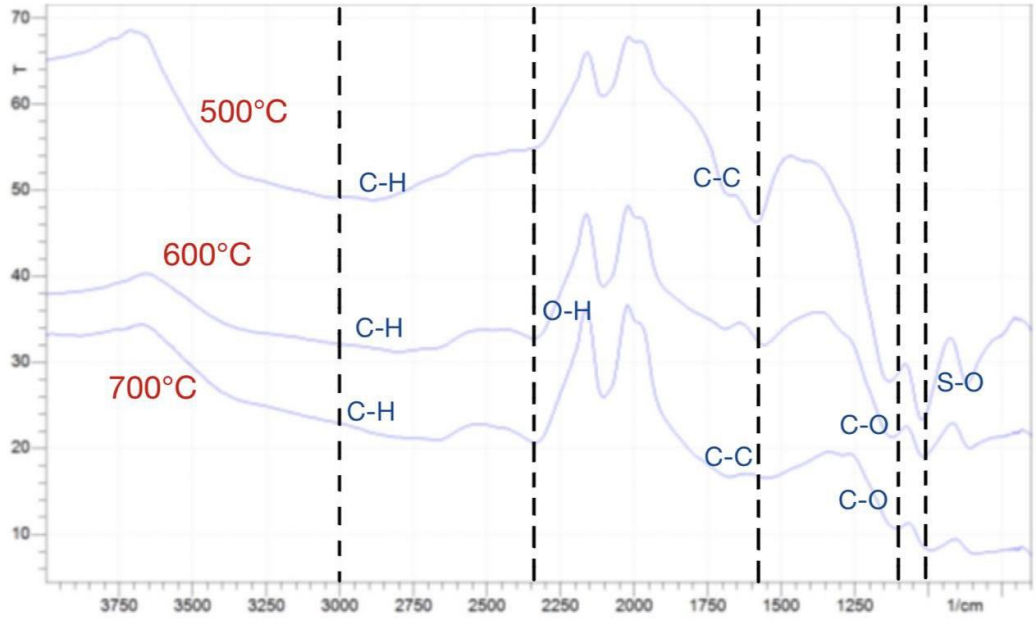

Fig. 2 *FTIR analysis after acid treatment*

Based on Fig. 3, the FTIR spectra curves depict three distinct temperatures: 500°C, 600°C, and 700°C. Each spectrum exhibited different functional groups at these temperatures. At 500°C, the bonds identified were C-H, Si-OH, and Si-O, indicating the presence of hydrocarbons and silica-related functional groups which potentially useful in catalytic and anodic applications [6], [7]. This suggests that silica was successfully produced at this temperature. At 600°C, the detected bonds were C-H and C-O, indicating the presence of hydrocarbons and carbon-oxygen bonds, but no silica-related functional groups were observed. At 700°C, only the C-H bond was present, again indicating hydrocarbons but no evidence of silica.

Silica was present at 500°C, as indicated by the Si-OH and Si-O bonds. However, at 600°C and 700°C, no silica-related functional groups were detected, suggesting that the conditions at these higher temperatures were not conducive to the formation or preservation of silica. Commonly, the functional group of Si-O and Si-OH exist at wavenumber 1050 to 900 cm^{-1} and 450 to 500 cm^{-1} [5].

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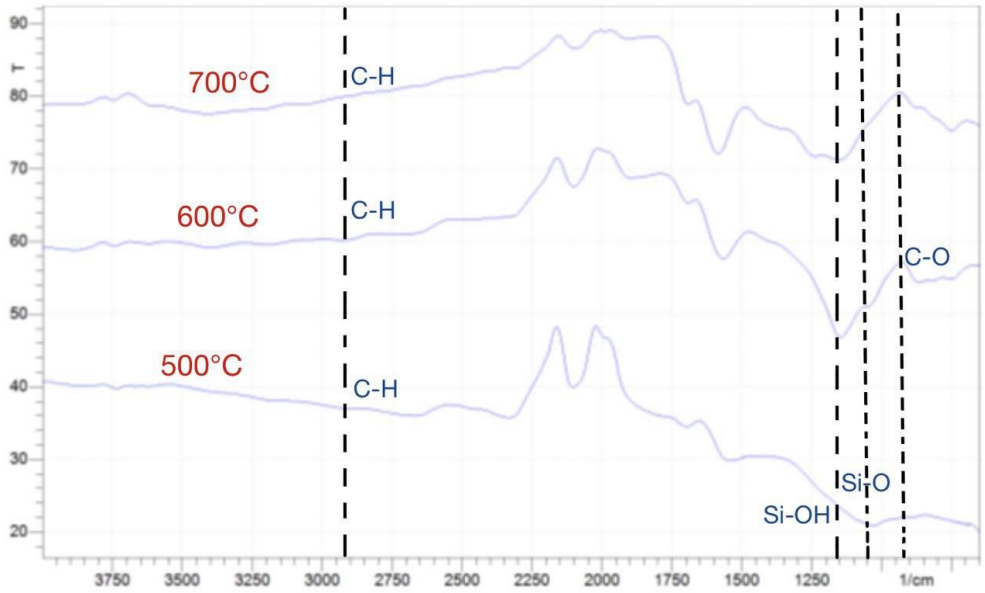

Fig. 3 *FTIR analysis after alkali treatment*

3.2 Field Emission Scanning Electron Microscope (FESEM)

Figure below shows the result obtained from acid treatment. Fig. 4(a) shows the samples with a layered morphology and various thin sheet-like structures. This layer's surface seems uneven and rough, which might be because of the material's inherent characteristics or the method in which the sample was prepared. Cracking and layer separation are caused by large gaps and spaces between layers. Variations in layer thickness also point to non-uniformity in the sample, which might be the product of mechanical processing or synthesis. A few possible elements could be a kind of carbon, like activated carbon and silicon and its compounds, like silicon dioxide (SiO_2) which often appears flaky and layered. This structure is common to materials created by chemical synthesis or exfoliation, and it may be used as fillers in composite materials or for applications like catalysis requiring a large surface area.

Observation of Fig. 4(b) with a characteristic layered and flaky structure can be seen in these pictures. This sample would contain hydrogen which is often present in organic materials. Elements like iron (Fe), calcium (Ca), potassium (K) also can be seen in this image due to the process of characterization. The sample has a lot of thin, overlapping sheets with distinct edges and rough surfaces. A large variety of sheet sizes displaying a coarse microstructure are part of the layered morphology. The rough texture and small cracks and fractures between the layers' point to mechanical stress or breaking, which may have occurred during sample preparation or may just be a natural characteristic of the material. A complicated internal structure is shown by the non-uniformity in the layer's thickness and the spaces between them.

The sample has a highly layered and fractured structure shown in Fig. 4(c). Numerous thin, sheet-like structures are seen in the pictures and these structures overlap and linked to provide a rough and complex texture. This layer appears rough on the surface and has a unique shape. This layer also has sharp edges [4]. It can be said that this sample contains metal oxides. The material may have had a reaction as a result of its inherent characteristics or due to sample preparation, as indicated by the existence of fractures and spaces between the layers. A non-uniform and varied internal structure is a result of these properties. The product's possibility for use in industrial applications is high due to variations in flakes' size and thickness [8].

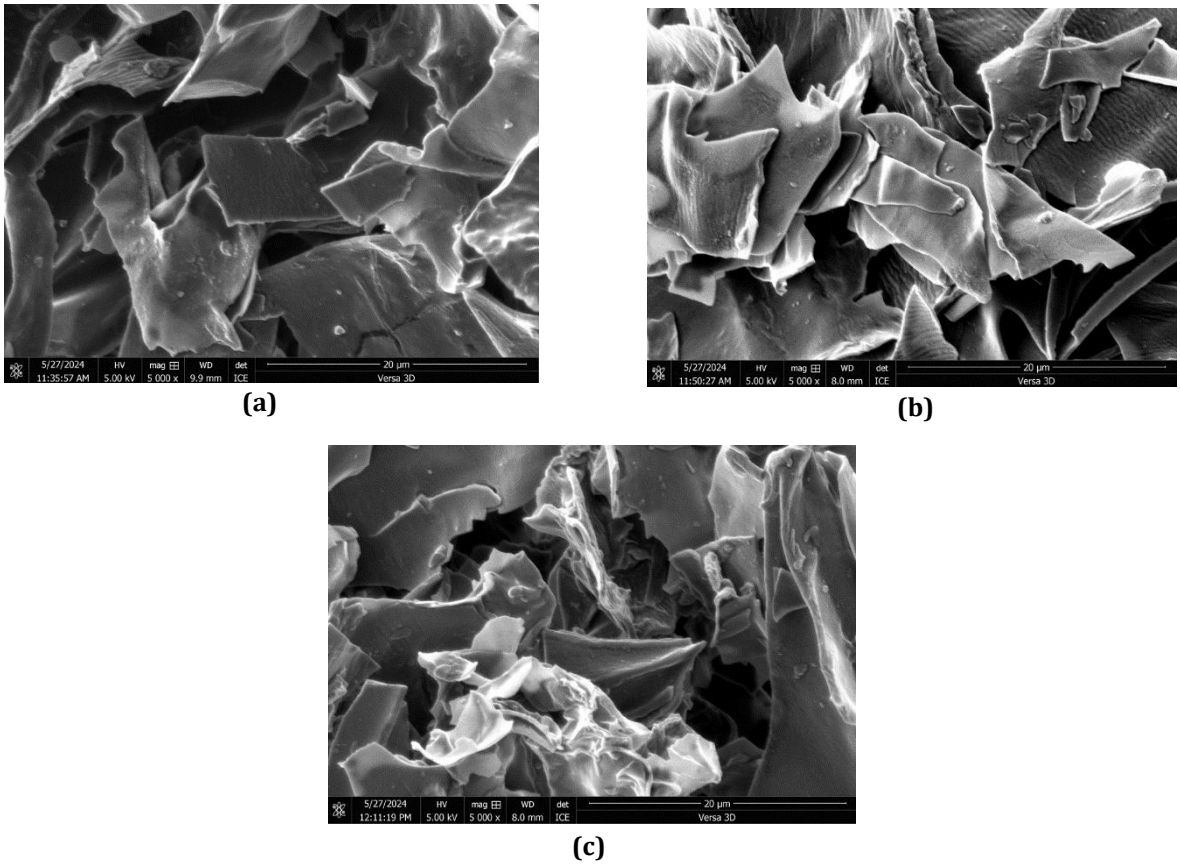

Fig. 4 *FESEM images of CHA at (a) 500 °C; (b) 600 °C and (c) 700 °C after acid treatment*

The photos showed that the CHA's elements were irregularly sized, suggesting that the temperature had no effect on the CHA's element sizes during the 500–700°C temperature range[9]. On contrary, the sample showed in Fig. 5(a) is a sharp edge with a flat surface and shows that there are elements of crystalline materials in this sample[4]. Various thin sheet-like structures can be seen due to their characteristic from how the sample is prepared. Sample does not have a lot of layer surface and has a large gap with other structures. Cracking and layer produce separation are caused by large gaps and spaces between layers. The non-uniform size structures are produced because of the reaction between materials with chemicals in the preparation of the sample.

From the Fig. 5(b), it can be observed that the layer of the sample is thicker than the 500°C alkali treatment sample. The edges of the structures have fewer sharp edges, and more layers are produced. A large variety of sheet sizes displaying a coarse microstructure are part of the layered morphology. The surface looks quite rough and uneven probably due to the reaction that occurred during its preparation. The complex structure is indicated by the non-uniformity of the shape and thickness of the layers and the spaces between them.

The surface of the structure is bigger and wider in Fig. 5(c). The resulting vertices are not sharp and do not have a large number of vertices. There is a combination of thick structures and also thin structures layered on top of each other. The surface of the feather-like structure is rough and uneven. It can be said that this sample contains graphene or graphite oxide because it has sheet-like structures. The material may have a response due to inherent characteristics or due to sample preparation, as indicated by the existence of layers and relatively close spaces between other layers.

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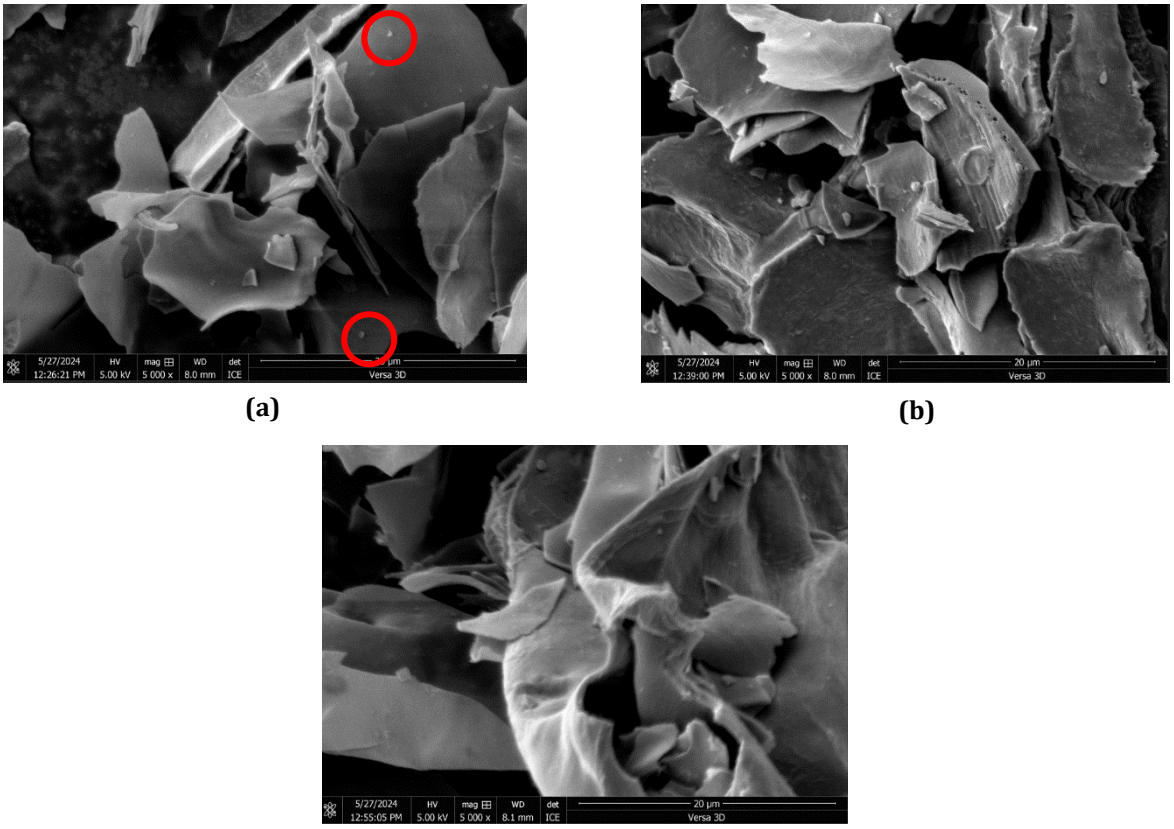

Fig. 5 *FESEM images of CHA at (a) 500 °C; (b) 600 °C and (c) 700 °C after alkali treatment*

4. Conclusion

As a conclusion for this project, it can be proven that silica can be produced from waste materials in the environment. The resulting waste does not necessarily need to be thrown away but can be used for other purposes and contribute to reducing pollution. While the initial results may not meet our expectations, further investigation and optimization are warranted. The observed variations could be attributed to factors such as experimental conditions, measurement techniques, or sample handling procedures. Future research should focus on refining the process and addressing any sources of variability. Then, this project also taught us to work together in dealing with problems that arise during the process so that undesirable things do not happen because this silica process is basically very simple and does not take long to complete.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nurul Nazaitul Nabila Nasrudin, Nursyaqeena Saffiya Mohd Rodzi;* ***data collection:*** *Nurul Afifah Ismail;* ***analysis and interpretation of results:*** *Nurul Nazaitul Nabila Nasrudin, Nursyaqeena Saffiya Mohd Rodzi, Nurul Afifah Ismail;* ***draft manuscript preparation:*** *Nurul Nazaitul Nabila Nasrudin, Nurul Afifah Ismail. All authors reviewed the results and approved the final version of the manuscript.*

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