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Effects of volume fraction of palm kernel shell nanoparticles on the pH and electrical conductivity of Ethylene Glycol (EG)/deionised water

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Abstract
Comprehensive research has been carried out on the synthesis of nanofluid produced from metals, nonmetals and their various oxides. But, little or no work has been carried out using bio-based nanoparticles. The need for the use of bio-based nanoparticles in nanofluids research is important to reduce over-dependence on toxic nanoparticles. Bio-based materials like palm kernel shell (PKS) constitute environmental waste, its conversion to useful products for engineering application will go a long way in solving environmental problems. In this paper, nanoparticles was produced from Palm kernel shell (PKS) using a ball-milling machine. The PKS nanoparticles with an average size of 200 nm were dispersed in a mixture of ethylene glycol (EG)/ deionised water (50:50) base fluid up to 1.5% of the volume fraction (0.3%, 0.6 %, 0.9 % 1.2 % and 1.5%). The pH and electrical conductivity of PKS–deionised water and EG (50:50) were investigated for temperature ranging from 30 to 70◦C. The obtained results showed that the pH and the electrical conductivity increased as the volume fraction of the PKS nanoparticle was increased from 0.3 to 1.5%. However, the pH decreased with an increase in the temperature while the electrical conductivity increased with an increase in the volume fraction and temperature. This shows the effects of palm kernel shell nanoparticles and temperature on the PH and electrical conductivity of the palm kernel shell nanofluid. The experimental results shows the effects of palm kernel shell nanoparticles and temperature on the pH and electrical conductivity of the palm kernel shell nanofluid.

Keywords: Nanofluid; palm kernel shell, ethylene glycol; pH; electrical conductivity.

1. Introduction

Fluids are always used as heat transporters in heat transfer equipment. Examples of Sectors where heat transfer fluids are used include cooling systems in the transportation industry, heating and cooling systems in buildings, heating and cooling systems in industries and other processing plants. In all these applications, the thermal conductivity of heat transfer fluids plays a very important role in the development of energy-efficient heat transfer equipment. No doubt, industries have a strong need to develop advanced heat transfer fluids with higher thermal conductivities than are presently available. Despite reasonable previous research and development efforts put on heat transfer enhancement, few important improvements in cooling capabilities have been limited because of the low thermal conductivity of conventional or regular heat transfer fluids. Many years ago, a new kind of heat transfer fluid called nanofluid was introduced which was developed by suspending nanoparticles in conventional or regular heat transfer fluids. Choi used nanoparticles suspended in a conventional heat transfer fluid and proposed that the addition of nanometer size particles into the base fluid increased the thermal conductivity and enhanced the heat transfer rate of nanofluid.

Later on, various applications of nanofluids were found in electronic cooling components (Singh et al., 2006), transportation (Nelson et al., 2009), industrial cooling (Kulkami et al., 2009), heating buildings and reducing pollution (Buongiorno et al., 2008). The rheological properties of nanofluids show their good and maximum utilization of heat-transfer equipment that involves flow, such as in car radiators (Peyghambarzadeh et al., 2011), heat pipes (Zamzamian et al., 2011), refrigeration and air-conditioning systems. Nanofluids have displayed higher thermal conductivity (Chandrasekar et al., 2010) and specific heat capacity (Raud et al., 2017), (Nieh et al., 2014) as a result of containing nanoparticles. From the conducted literature survey, so many research works have been carried out on nanofluid using metallic and non metallic oxides but little work has been carried out using bio-materials.

However, due to high cost, availability and toxic effect of metals and their oxides during preparation and usage, it becomes important to explore the usability of a bio-friendly and low-cost agricultural material such as palm kernel shell (PKS) nanoparticles. The use of this material will go a long way in solving the problem of toxicity associated with metals and their oxides and also bio-materials will reduce the danger that the agricultural waste is risky to our environment. Therefore, preparation of a palm kernel shell nanofluid which is a novel heat transfer fluid by dispersing palm kernel shell nanoparticles in the base fluid has been proposed. The effects of volume fractions of palm kernel shell nanoparticles on the pH and electrical conductivity of the nanofluid will also be experimentally investigated in this study. The significance of this study is to develop a novel nanofluid using bio material nanoparticle (palm kernel shell) and also to experimentally investigate the PH and electrical conductivity of the nanofluid developed to enable us ascertain their practical applications.

2.0 Material and methods

The materials used for the laboratory experiment are Palm kernel, Powdered Sodium Hydroxide (NaOH), Ethylene Glycol and Deionized water, RADWAG AS 220-R2 Sensitive weighing scale(10mg – 220g), ball mill, GAUTRACK POTCH Oven, GAUSTING GT225 Impact Grinder (ball miller)

2.1 Preparation of nanoparticles from palm kernel shell

Bio-based materials such as palm kernel shell constitute environmental waste in some quarters and its conversion to useful products for engineering application will go a long way in solving environmental problems. In this study, the top-down approach was used to synthesize nanoparticles from palm kernel shell using a ball-milling machine. Ball mills are one of the earliest machineries utilized as a method of mineral grinding. Ball mill machine is a kind of grinding machine that is used to grind and blend numerous types of materials into fine powder Palm kernel shells were placed into bucket filled with water to a level such that it will be completely submerged. The bucket was covered to prevent air from entering it; the soaking lasted for two weeks. After the two weeks, the palm kernel shells were removed from the water and washed with fresh water and sundry for two weeks to remove the absorbed water at constant temperature.

The sun-dried palm kernel shells will then be oven-dried in a temperature range of 50–70◦C for 24 hours to ensure that the residual moisture will be completely removed. The dried palm kernel shells were feed into the container of the ball-milling machine. After that, the milling container was placed on the rotating base of the ball mill. We ensured that the container was securely fastened to prevent accidents. We started the ball mill and allowed it to rotate at a certain speed. The rotation causes the milling media inside the container to collide with the material, breaking it down into smaller particles. The ball mill was allowed to run steady for two days to obtain palm kernel shell nanoparticles.

The palm kernel shells were crushed thoroughly into very fine particles. 400g of the crushed bio materials shells particles was measured and passed through a thick cotton fabric with a pore size of about 200 nm, of which the nanoparticles was separated from other particles of palm kernel shells larger than 200nm . During the separation process, the nanoparticles pass into a container while particles larger than the cotton fabric's pore size are trapped on the fabric. The separation process was carefully done to ensure that particles obtained after separation are within the size range (<200nm).The obtained palm kernel shell nanoparticles were characterized using scanning electron microscope (SEM) to show the particle size and morphology of the nanoparticles.and X-ray diffraction (XRD) to determine crystal structure (Anthony et al., 2022). Nanoparticles obtained were washed using caustic alkali (NaOH) of 0.5M to remove impurities such as oil, which would affect the nanofluid mixture. After washing with NaOH, the nanoparticles became basic. Hence, it was neutralized using Sulphur acid of 0.2M. pH indicator papers were used to test for the pH value of the nanoparticle during neutralization until the nanoparticles became neutral. .

2.1.1Preparation of various volume fractions of nanofluids

A ‘two-step’ method was used in the preparation of nanofluid from the fabricated bio-material nanoparticles since it is better method out of the two common methods in use (Amaechi and Ogonna, 2022), (Anthony et al., 2022). In this method, nanoparticles are initially produced in the form of dry powder and then dispersed in the basefluid. The commonly employed equipments for dispersing nanoparticles in the basefluid are magnetic stirrers, ultrasonic bath, homogenizers, high-shear mixers, and bead mills. Unlike the one-step approach, the two-step approach is more commonly used to fabricate nanofluids due to its lower processing cost.

A known mass of the palm kernel shell nanoparticles corresponding to a predetermined volume concentration were measured and mixed with a binary mixture of Ethylene Glycol (EG) and deionised water (base fluid) in a ratio of 50:50 .Volume fractions of nanofluid obtained ranged from 0.3%-1.5%, with five (5) samples of nanofluid formed for each bio materual nanoparticle. This was achieved using a mathematical model equation to calculate the weight of base fluid (ethylene glycol/ de-ionized water) and nanoparticles required to achieve various volume fractions

$$Volumetric\ \ fraction, \varphi \times 100 = \frac{\frac{M_P}{\rho_P}}{\frac{M_P}{\rho_P}+\frac{M_{bf}}{\rho_{bf}}} \qquad (1)$$

Where Mp is the mass of the nanoparticle, ρ is the density of the nanoparticle, M_{bf} is the mass of base fluid and ρ_{bf} is the density of the base fluid.

Therefore, $Volumetric\ fraction, \varphi \times 100 = \frac{V_P}{V_P+V_{bf}}$ (2)

Where V_p is the volume of nanoparticle. V_{bf} is the volume of base fluid.

The density of the nanoparticles (ρ) was determined by measuring the mass of the nanoparticle for a given volume. 1.78 grams of the nanoparticle was determined using a weighing balance as the mass of the nanoparticle for 5 ml. of the nanoparticle, of which the density of the nanoparticle was calculated using equation 3

$$\rho_p = \frac{\text{mass}}{\text{volume}} \qquad (3)$$

After mixing the various weighed samples of nanoparticles with a measured volume of base fluid to achieve different volume fractions from 0.3%-1.5%, magnetic stirrer containing a magnetic stirring bar is used to stabilize the nanofluid mixtures for about 90 minutes for each volume fraction. This is to ensure proper mixing of the two phases of the mixture. All samples of the nanofluid were stored in a test tube.

The bio-materials nanofluids were prepared by dispersing or pouring different volume fractions (0.3%, 0.6 %, 0.9 % 1.2 % and 1.5%) of palm kernel shell nanoparticles into the base fluid. The nanofluids samples were homogenized by using an ultrasonic sonicator continuously for 40 minutes and the samples were observed for dispersion and stability

2.1.1.1 Experimental measurement
Measurement of PH

PH (potential of hydrogen) is a measure of the acidity or alkalinity of a solution. It is determined by the concentration of hydrogen ions in the solution. PH is typically measured on a scale from 0 to 14, where 0 represents strong acidity, 7 is neutral, and 14 indicates strong alkalinity. In this work, the pH was measured using a Jenway pH meter (model 3510). The pH meter consists of of a pH probe or electrode, which is dipped into the solution being texted, and a meter that displays the pH value

Measurement of electrical conductivity

Electrical conductivity, also known as specific conductance, is a measure of a materials ability to conduct an electrical current. The measurement of electrical conductivity can be done using various methods, depending on the sample type and the required precision. In this work, the electrical conductivity was measured using a EUTECHCON700 conductivity meter. A conductivity meter, also known as a conductance meter, is an electronic device designed for precise electrical conductivity measurements. A pair of conductivity electrodes was immersed in the sample solutions, and the meter measures the electrical conductance between the electrodes. The meter provides a direct reading of electrical conductivity in S/m.

3.0 Results and Discussions

Effect of temperature and volume fraction on PH of PKS nanofluid with Deionize water/EG (50:50) Base Fluid.

Figure 1 shows the influence of temperature and volume fraction of nanoparticles on the pH values of the PKS–deionized water/EG nanofluid for various volume fractions. The pH of the base fluid is in the mild acidic range and varies between 4.8 and 6.2. The pH of the base fluid reduced with an increase in temperature in a similar manner reported by Konakanchi *et al* (2015) on the pH of PG–water, 60:40 base fluid. Although the addition of PKS nanoparticles to the base fluid gave a higher pH value compared to the base fluid, increasing the temperature showed a continual decrease in the pH value.

The temperature increase influences the pH of any solution due to the dissociation of the weak acids' and bases' groups and splitting of water component into H+ and OH−. It could also be seen from figure 1 that the pH of the nanofluid increased as the volume fraction is increased up to a point corresponding to where counterion condensation effects set in at 0.3%. At this point, the rate of increase of pH reduced as the volume fraction increased. A similar phenomenon of counterion condensation relating to electrical conductivity and pH of nanofluids was observed previously by Adio *et al*, (2015). It could be seen from the results of the experimental investigation carried out in this work that PH of nanofluid increase with increase in nanoparticles volume concentration and decrease with an increase in temperature (13)

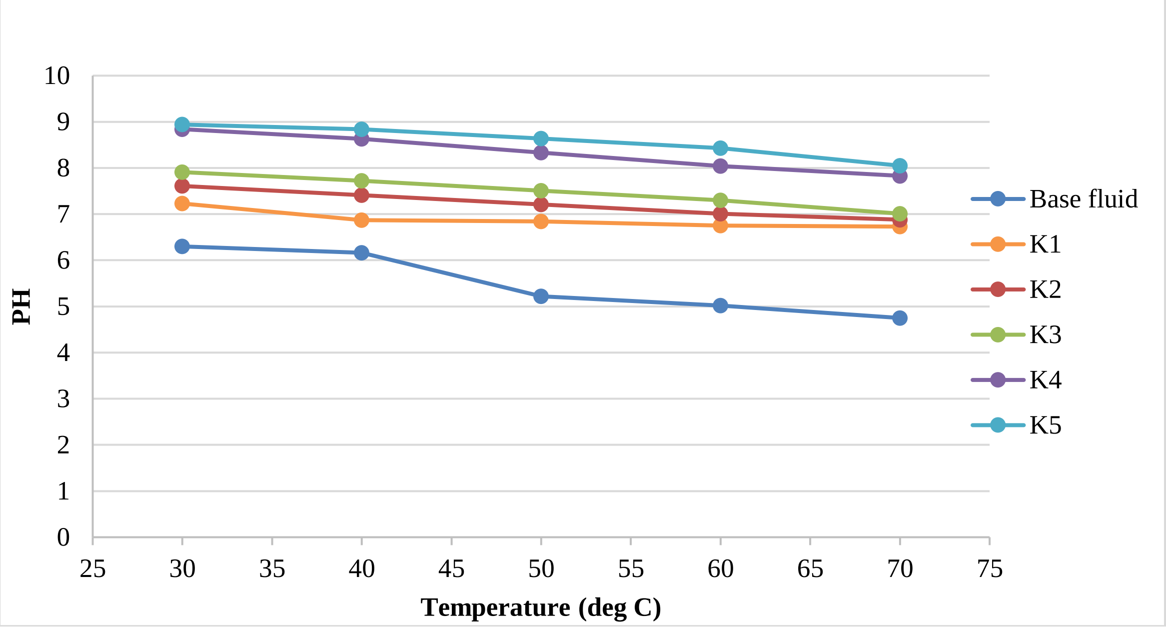

Figure 1: Effect of temperature and volume fraction on the PH of PKS–water/EG (50:50) nanofluids

The effects of temperature and volume fraction on the electrical conductivity of the PKS–deionize water/EG-based nanofluid were investigated at various volume fractions, and the result is shown in figure 2. The electrical conductivity of the base fluid was between 20.03 and 80.30 µS cm−1 when the temperature was increased from 30 to 70^0 C. This represents a 60% increment at the temperature of 70^0C. Deionized water is a polar liquid in the binary mixture (water and EG), which tends to dominate the ionization process that occurs in the suspension. The addition of PKS nanoparticles into the base fluid showed an increment in the value of the suspension and increasing the temperature also gave a corresponding increase in the electrical conductivity values. As the volume fraction was changed from 0.3 to 1.5%, there is an obvious enhancement in the electrical conductivity as shown in figure 2. The enhancement due to the volume fraction increase is more than the temperature increase. This shows that the effect of nanoparticles concentration on electrical conductivity of nanofluids is more than the temperature effect. . It could be seen from the results of the experimental investigation carried out in this work that electrical conductivity of nanofluid increase with increase in nanoparticles volume concentration and temperature (13)

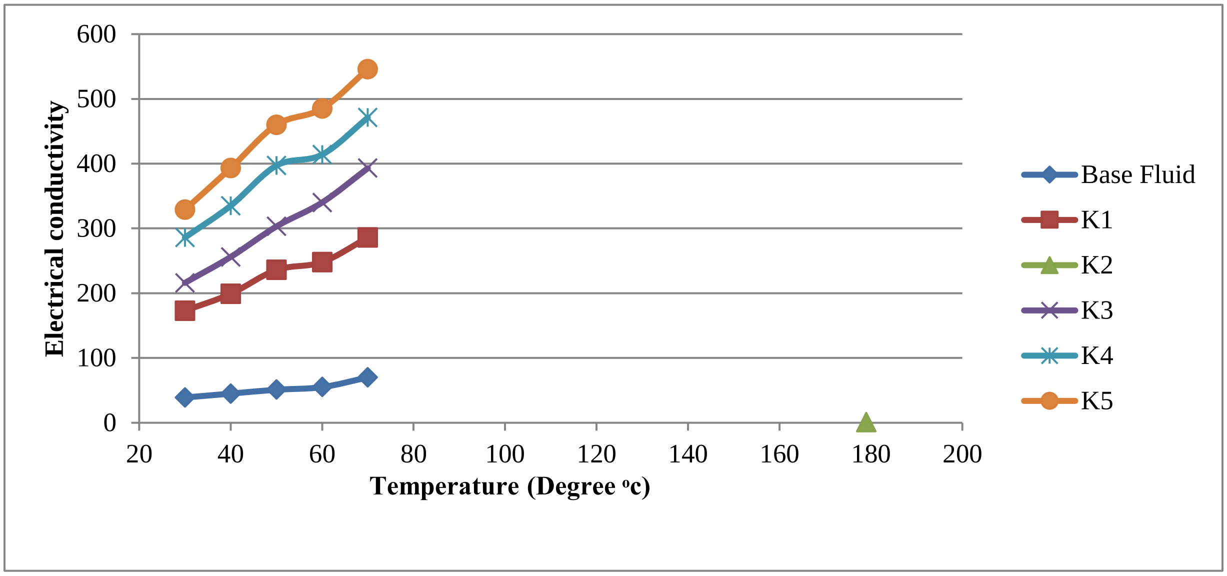

Figure 2: Effect of temperature and volume fraction on the electrical conductivity of PKS–water/EG (50:50) nanofluids

4.0 Conclusion

In this paper, a bio material nanoparticles was produced from a PKS using a ball-milling machine at room temperature. The PKS nanoparticles has an average size of 200 nm and were dispersed in an EG/water (50:50) mixture to produce a nanofluid with the volume fraction ranging from 0.3 to 1.5%. No surfactant was added to the sample before, during and after the preparation. The thermophysical properties such as electrical conductivity and pH response to volume fraction were studied for a temperature range of 30–70^{0}C. The pH and electrical conductivity increased with increasing volume fraction of the PKS nanoparticles.

The pH of nanofluid reduced with an increase in temperature while the electrical conductivity increased with temperature increase. This showed the effects of temperature and nanoparticles volume fraction concentration on the PH and electrical conductivity of palm kernel shell nanofluid. Some of the limitations of nanofluid which limits their practical applications which this present study has addressed are cost of production of nanofluid, stability of nanofluid, toxicity and homogeneity of nanofluid. This study has revealed the PH and electrical conductivity properties of nanofluid which can be utilized in various industrial applications such as heat transfer enhancement, sensing applications, energy storage and electrokinetic applications. The unique electricval conductivity and PH properties of nanofluids offer opportunities for innovation in various fields, ranging from thermal management to sensing and energy storage.

5.0 Recommendation

The need for the use of bio-based nanoparticles and bio-based nanofluids is important to mitigate over-dependence on toxic synthetic nanoparticles. This idea is also in line with renewable and sustainable developmental goals. This calls for more research on the use of bio-material nanoparticles for the production of bio-material nanofluids for industrial applications

Nomenclature

K_1= 0.3% Volume fraction of nanofluid
K_2= 0.6% Volume fraction of nanofluid
K_3= 0.9% Volume fraction of nanofluid
K_4= 1.2% Volume fraction of nanofluid
K_5 = 1.5% Volume fraction of nanofluid

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