Preparation and characterisation of mango bark and mango leaf nanoparticles

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Abstract. Nanoparticles are the simplest form of structures with sizes in the nanometre range (<100 nm). Suspended nanoparticles (non-bio) in base fluids (nanofluids) increase the heat transfer properties of the base fluids. However, addition of nanoparticles to the base fluid increases viscosity as well as pressure drop. It is also expensive to produce non-bio nanoparticles. Thus, mango barks and leaves were used to produce bio nanoparticles due to their natural characteristics that might lower viscosity of the nanofluid. The mango bark and mango leaf were collected and dried under hot sun to remove moisture content until constant weight achieved. Then, the materials were crushed and sieved to obtain finest powder followed by wet grinding for 1 hour at 800 rpm using FRTSCH Planetary Micro Mill PULVERISETTE 7 premium line. The particles size was determined using FESEM and particle size analyser machine. The bulk density of the nanoparticles was determined by experiment. The obtained results showed that the mango barks have lost total weight of 504g (63%) after 8 days of drying. Meanwhile, mango leaves have lost total weight of 606g (78%). The bulk density of mango bark nanoparticles is 2505.00kg/m³ and mango leaf nanoparticles is 2108.00kg/m³. From image analysis using FESEM, the average size of mango bark nanoparticles is around 102 nm and mango leaf nanoparticles was around 132 nm. From particle size analyser, the average fineness of mango bark nanoparticles measured by intensity was 125.5nm and mango leaf nanoparticles was 206.1nm. In conclusion, the mango bark and mango leaf nanoparticles can be synthesised by wet grinding method.

Keywords. Nanofluid; Nanoparticle; Physical properties; Density; Moisture content.

1. Introduction
Nanoparticles are materials with one or more components that have at least one dimension in the range of 1 to 100 nm [1]. A nanometer is one-billionth of a meter- a distance equal to two to twenty atoms (depending on what type of atom) laid down next to each other. The tiny size of nanoparticles results in some useful characteristics, such as an increased surface area. This made suspensions of nanoparticles possible because the interaction of the particle surface with the solvent is strong enough to overcome differences in density to form nanofluid [2]. Suspended nanoparticles in different base fluids can alter the heat transfer and fluid flow characteristics of the base fluids [3]. Nanofluids widely used in various applications such as electronic, biomedical, automotive, heat transfer, and oil production applications [4-6].
The raw materials used to produce bio nanoparticles can be obtained from plant parts such as barks, roots and leaves [7-9]. Meanwhile, the raw materials used to produce Non-bio nanoparticles can be obtained from metallic and non-metallic materials such as zinc, copper, silver, titanium oxide, silicon dioxide and aluminium oxide [10]. The synthesis of nanoparticles is mostly by ball milling, chemical vapor deposition, plasma arcing, electrodeposition, sol-gel synthesis, and the use of bio nanoparticles [11-12]. These methods can be divided into two approaches (top-down and bottom-up). Top down method usually produces nanoparticles by crushing the raw materials into nano-size powder. In the bottom-up methods, nanoparticles can be produced using chemical and biological methods by self-assembling of atoms to new nuclei that grow into a nanoscale particle [13].

There are some techniques available for the characterization of nanoparticles [14]. For instance, J. G. Whiting et. al. stated that a variety of common particle size measurement methods exist such as sieve analysis, laser light scattering, static image analysis, and dynamic image analysis (DIA) [15]. Non-bio nanoparticles usually increase the thermal conductivity of base fluids. However, they also increase the viscosity of the nanofluid which is not preferable as it will increase the operation cost of the system due to higher pressure drop [16]. The cost to produce non-bio nanoparticles is very high because it requires advanced and sophisticated equipments [17]. This may hinder the application of nanoparticles in industry [18]. Therefore, the objective is to investigate the method for synthesis of bio nanoparticles as its nature fibre that might lower viscosity of base fluids which is preferable to lower pressure drop. On the other hand, the particle size and density of bio nanoparticles were characterised to provide useful information and literature review for other researches that investigate the application of bio nanoparticles in future.

2. Methodology

2.1. Collection of raw materials

The method used to prepare mango tree bark nanoparticles and mango tree leaf nanoparticles was top-down method. Top-down method is the method that the raw material crushed into tiny nano-sized particles [19]. Mango tree barks and leaves were obtained from the mango trees found in Pekan, Pahang, Malaysia. The mango tree branches were chopped down from a mango tree and the mango tree barks were separated from the tree branch by using parang machete. Simultaneously, the mango leaves were removed from the tree branches by using hands. All the raw materials collected were processed to remove the dirty and unwanted parts as shown in figure 1.

![Figure 1. Removal of unwanted parts from raw materials.](image-url)
2.2. Moisture removal
The processed raw materials were put into a plastic bag and weighted using weighing scale as shown in figure 2(a) and 2(b). The actual weight of mango tree barks collected was 800g. Meanwhile the actual weight of mango tree leaves collected was 780g. After that, the tree barks and leaves were dried under hot sun for 8 days as shown in figure 2(c). Completely moisture removal can be determined when the constant weights of raw materials achieved.

Figure 2. Weighting and drying processes (a) weighing mango barks (b) weighing mango leaves (c) drying the raw materials under hot sun.

2.3. Material preparation
The completely dried raw materials were crushed using blender with dry mill (Panasonic Mill PSN-MXGM1011) as shown in figure 3(a). The motor speed of the blender was 12,000 rpm (with rated water load). After that, the powder size raw materials were sieved to get the finest powder shown in Figure 3(b) and 3(c). The bigger size powder were crushed and sieved until fine powder was obtained. Then, the fine powder were be sieved again using piece of cloth to get semi nano-size powder. After that, the powder were further ground in wet method using FRTSCH Planetary Micro Mill PULVERISETTE 7 premium line. The powder were weighted for 5g added into the container filled with 5mm zirconium oxide balls together with 20ml of distilled water. To avoid overpressure, the powders were ground in steps of 3 minutes, followed by a programmed pausing time of 8 minutes at speed of 800rpm for 60 minutes of grinding. The powders after wet grinding are shown in figure 4.

Figure 3. Crushing and sieving processes (a) crushed mango barks (b) sieving mango bark powder (c) sieving mango leaf powder.
2.4. Bulk density measurement
First, the nanoparticles were sieved into a beaker until volume of 50ml. Then, the weight of the beaker was as shown in figure 5. The density of mango tree bark nanoparticles and mango tree leaf nanoparticles were determined by using equation (1) [20]. These steps were repeated with volume of 60ml, 70ml, 80ml, 90ml and 100ml to make sure that the obtained density results are consistent and average bulk density can be calculated. The same method was used to measure the density of TiO2 nanoparticles and the results were compared with the bulk density information provided by the manufacturer (NovaScientific) in order to verify the accuracy of the density measurement method.

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\text{Bulk density} = \frac{\text{Mass of particles}}{\text{Volume of particles}} \tag{1}
\]

Figure 5. Density measurement of mango bark nanoparticles.

2.5. Particle size characterization
The particles of dry mango tree barks nanoparticles and dry mango tree leaves nanoparticles were characterised using JSM-7800F Schottky Field Emission Scanning Electron Microscope as shown in figure 6. The particle size of wet mango tree barks nanoparticles and wet mango tree leaves nanoparticles were characterised using Malvern Zetasizer Nano ZS90 particle analyzer machine as shown in figure 7.
3. Results and discussions

3.1. Moisture removal
Moisture removal of the mango tree barks and trees were determined using weight measurements. Shown in figure 6 are variations of weight with time for mango bark and leave samples. As can be clearly seen for the figure, as expected, the weight decreased from day 1 to day 8 for both samples. However, the moisture removal rate for mango tree leaf was higher than that of mango tree bark at all days. From Day 1 to Day 8, mango tree barks have lost total weight of 504g (63%). Meanwhile, mango tree leaves have lost total weight of 606g (78%). This shows that mango tree leaves have higher moisture contents than mango tree barks. Therefore, the time required to remove all the moisture in mango tree leaves is longer than mango tree barks. After Day 6, the weights for both samples became constant indicating that there was no moisture content remaining in both samples.
Figure 8. Moisture removal of mango tree barks and mango tree leaves.

The results of the measured bulk densities of mango tree bark and leaf nanoparticles are presented in table 1 and table 2 respectively. The tables show that the average density of mango tree bark nanoparticles is 0.2505 g/ml and that of mango tree leaf nanoparticles is 0.2108 g/ml. From the results, it can also be observed that mango tree barks nanoparticles have higher bulk density than mango tree leaves nanoparticles.

Table 1. Bulk density of mango bark nanoparticles.

| Trial | Volume, ml | Mass, g | Density, g/ml |
|-------|------------|---------|---------------|
| 1     | 50         | 12      | 0.240         |
| 2     | 60         | 15      | 0.250         |
| 3     | 70         | 18      | 0.257         |
| 4     | 80         | 20      | 0.250         |
| 5     | 90         | 23      | 0.256         |
| 6     | 100        | 25      | 0.250         |
| Average |          |         | 0.2505       |

Table 2. Bulk density of mango leaf nanoparticles.

| Trial | Volume, ml | Mass, g | Density, g/ml |
|-------|------------|---------|---------------|
| 1     | 50         | 10      | 0.200         |
| 2     | 60         | 13      | 0.217         |
| 3     | 70         | 15      | 0.214         |
| 4     | 80         | 17      | 0.213         |
| 5     | 90         | 19      | 0.211         |
| 6     | 100        | 21      | 0.210         |
| Average |          |         | 0.2108       |

3.2. Moisture removal

The FESEM images results indicated that the average size of mango tree barks nanoparticles is around 102 nm. The result of mango tree bark nanoparticles size are shown in figure 9. The average size of mango tree leaves nanoparticles is around 132 nm as shown in figure 10. From the results, it shows that both types of nanoparticles do not have regular sizes and shapes of particles.
The average fineness of mango tree bark particles measured by intensity is 125.5nm as shown in figure 11. The average fineness of mango tree leaf particles measured by intensity is 206.1nm as shown in figure 12.
4. Conclusion
The mango tree barks and mango tree leaves nanoparticles can be synthesised with wet grinding method. From image analysis using FESEM, the average size of mango tree barks nanoparticles is around 102nm and the average size of mango tree leaves nanoparticles is around 132nm. From particle sizer analysis, the average fineness of mango tree bark particles measured by intensity is 125.5nm and the average fineness of mango tree leaf particles measured by intensity is 206.1nm.

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