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# Stability and density analysis of mango bark and mango leaf nanofluids

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**Abstract.** Thermal conductivity is one of the primary properties for nanofluids application investigated by many researchers. However, there are other factors such as stability and density that need to be considered to reduce sedimentation, pressure drop as well as sustain the enhanced thermal physical properties of nanofluid. The purpose of this study is to investigate and analyse the stability and density of mango bark (MB) and mango leaf (ML) nanofluids as well as hybrid nanofluids between mango bark and leaf with SiO<sub>2</sub> and TiO<sub>2</sub>. The stability of nanofluids was measured using sedimentation method. The nanofluids arranged in order of pure ML nanofluid with increasing volume concentration of 0.25%, 0.50% and 1.00% followed by MB nanofluid, ML/SiO<sub>2</sub> nanofluid, MB/SiO<sub>2</sub> nanofluid, ML/TiO<sub>2</sub> nanofluid and MB/TiO<sub>2</sub> nanofluid. The density of nanofluids was measured using KEM DA-640 density meter and calculated using mixture rule equation. The results show that the stability of the nanofluids started to show sedimentation after 1 day of storing. Mango bark nanofluids were more stable than mango leaf nanofluids. At 1% concentration, MB nanofluid has the highest density (0.9981) followed by MB/TiO<sub>2</sub> (0.9970), ML/TiO<sub>2</sub> (0.9964), ML (0.9963), MB/SiO<sub>2</sub> (0.9962) and ML/SiO<sub>2</sub> (0.9962). Density of nanofluids have small increment with volume concentration. Meanwhile, the density of nanofluids have small decrement with volume concentration using analytical calculation. The results also shows small average error of 0.17% between experiment and analytical calculation.

## 1. Introduction

In past, addition of micron-size particles to fluids was found to enhance the heat transfer rate of the fluids. Then, nano-size particles was found to improve the poor stability and sedimentation of the micron-size particles, erosion, and clogging of the channels, also the decreased pressure drop in heat transfer systems hampered the application of these microfluids. This shows that dispersion stability of nanofluid is an important factor to sustain the enhanced thermal physical properties of nanofluids [1]. Besides that, some researches start to investigate the application of bio particles as drag reduction agent. Waskito et al. investigate the effect of coconut fibre suspensions on drag reduction in circular pipe. The result shows that 7.6% of drag reduction under condition of 25000 Reynolds number with circular pipe ID 38 [2]. Yanuar et al. also shows that biopolymer guar gum solution have effect of drag reduction either on a spiral pipe or circular pipe. The result shows the highest drag reduction can up to 30%. However, it will causes rapid mechanical degradation [3]. Kapal et al. shows the drag reduction of 4% to 6% using bamboo and abaca fiber suspensions in circular pipe [4].

Application of nanofluids in industrial field is strongly depends on the stability of nanofluids. Many researchers have defined stability as the ‘validity of nanofluids’ [5]. There are many methods for stability analysis such as zeta potential, sedimentation, centrifugation, spectral analysis, electron microscopy and



light scattering [6]. However, it is very difficult and big challenge in nanofluid technology to the maintain of colloidal stability [7]. Thus, some techniques have been developed by researchers to enhance the stability of nanofluid [8]. Most common methods used are addition of surfactant, surface modification, pH control and ultrasonication [9,10].

Density can be defined as the heaviness of a material. Thus, density is very dependent on the type of nanoparticle material suspended. For instance, denser material used as nanoparticle suspended in base fluids will caused higher density of nanofluid. However, some parameter like nanoparticle shape, size, zeta potential and additives affect the density of nanofluids insignificantly [11, 12]. Density is one of the important physical properties of nanofluid that affect pressure drop and pumping power in heat transfer systems significantly [13]. Although density of a nanofluid is one of the most important physical properties of the nanofluid, it has not been investigated deeply compared with other physical properties [14]. The objective in this study is to investigate and analyse the stability and density of mango bark and mango leaf nanofluids.

## 2. Methodology

The technique used for nanofluids preparation was two step method. Bio nano-materials were first synthesized by physical method. The mango barks and leaves were dry grinded, sieved and wet grinded into nano-size. Then, the bio nanoparticles mixed with non-bio nanoparticles and added into distilled water. After that, the nanofluids were stirred homogeneously and ultrasonic bath with constant amplitude for a period of time for nanofluids stability.

### 2.1. Mango bark and mango leaf nanoparticles preparation

Mango tree barks and leaves have been collected and dried under hot sun. After 8 days of drying process, the mango tree barks and leaves were crushed into smaller pieces using blender with dry mill unit (Panasonic Mill PSN-MXGM1011). Then, sieving process was conducted to filter out the bigger pieces to obtain the smallest pieces. Then, the powder will be used to conduct wet grinding using FRTSCH Planetary Micro Mill PULVERISETTE 7 premium line to gain nano-size nanoparticles. The specification of FRTSCH Planetary Micro Mill PULVERISETTE 7 premium line as shown in table 1.

**Table 1.** Specification of FRTSCH Planetary Micro Mill PULVERISETTE 7 premium line.

Specifications	Planetary Micro Mill machine
Working principle	Impact force
Optimal for material type	Hard, medium-hard, brittle
Number of grinding station	2
Grinding tools	Grinding bowls and grinding balls
Material of grinding tools	Sintered corundum, zirconium oxide
Grinding bowl sizes	45 ml
Grinding ball diameter	5 mm
Max. feed size (depends on material)	5 mm
Final fineness (depending on material)	< 0.1 micro meter
Rotational speed of main disk	100-1100 rpm
Grinding process	Dry/wet
Grinding in inert gas	Yes
Typical grinding time down to analytical fineness	3 minutes
Transmission ratio planetary disk / grinding bowl	$i_{\text{relative}} = 1 : -2$
Effective diameter of main disk	140 mm
Centrifugal acceleration ( $g = 9.81 \text{ m/s}^2$ )	95 g
Electrical details	100-120 V / 200-240 V/1~, 50-60 Hz,
Weight	44 g
Dimension (W x D x H)	Bench top instrument 40 x 58 x 36 cm

### 2.2. Nanofluids preparation

The material type and base fluid used for nanofluids were mango bark, mango leaf, silicon dioxide (SiO<sub>2</sub>), titanium dioxide (TiO<sub>2</sub>) and distilled water. Mango bark and leaves nanoparticles were synthesized using top-down method. SiO<sub>2</sub> and TiO<sub>2</sub> nanoparticles were purchased online from NovaScientific manufacturer. Bio and non-bio nanoparticles were weighed using weighing scale and put into containers mixing with distilled water. After that, all the containers were labelled and proceed with stirring and ultrasonic bath. The proportion of each nanoparticles and base fluid in nanofluid at different concentration were as shown in table 2.

**Table 2.** Proportion of each nanoparticles and base fluid in nanofluid at different concentration.

Nanofluid, %	Bio nanoparticles, %	Non-bio nanoparticles, %	Base fluid, %
0.25	0.125	0.125	99.75
0.50	0.250	0.250	99.50
1.00	0.500	0.500	99.00

### 2.3. Stability measurement

The nanofluids stability measurement technique used is visual inspection of the sedimentation due to the fact that this method is simple and reliable. However, it required long period of visual inspection to determine the stability of nanofluid. The nanofluids were placed inside test tube and left for two weeks. Daily visual inspection of nanofluids was conducted using high quality camera.

### 2.4. Density measurement

Density is very important in identifying unknown materials by analysing the physical, chemical and biological properties. For the nanofluids, volume are determined using graduated containers. With the weight and the volume of the nanofluid, densities can be obtained through equation (1) [15]. Besides, the density of nanofluids were also measured using KEM DA-640 density meter with specification of the density meter is shown in table 3. Both calculation and experiment results will be compared.

$$\rho_{nf} = \phi_w \rho_w + \phi_m \rho_m + \phi_{bio} \rho_{bio} \quad (1)$$

**Table 3.** Specification of KEM DA-640 density meter.

Specifications	Planetary Micro Mill Machine
Measurement method	Resonant frequency oscillation
Measurement range	0 – 3 g/cm <sup>3</sup>
Temperature range	0 – 96 °C
Accuracy (Density)	+/- 1x10 <sup>-4</sup> g/cm <sup>3</sup>
Accuracy (Temperature)	+/- 0.5 °C
Repeatability	SD 5x10 <sup>-5</sup> g/cm <sup>3</sup>
Resolution (Density)	0.0001 g/cm <sup>3</sup>
Resolution (Temperature)	0.01 °C
Viscosity correction	Yes
Sampling	Manual by syringe Auto by sampling pump
Minimum sample required	Approx. 1 ml (Syringe) Approx. 2 ml (Pump)
Method	Saves up to 100 different methods in built-in memory
Measurement time	1 to 4 minutes (Auto) 2 to 10 minutes (Manual)
Dimensions (W x D x H)	320 x 365 x 250 mm
Weight	18 g

### 3. Results and discussion

#### 3.1. Stability of nanofluids

The arrangement of the nanofluids from left to right is pure mango leaf (ML) nanofluid with increasing volume concentration of 0.25%, 0.50% and 1.00% followed by pure mango bark (MB) nanofluid, ML/SiO<sub>2</sub> nanofluid, MB/SiO<sub>2</sub> nanofluid, ML/TiO<sub>2</sub> nanofluid and MB/TiO<sub>2</sub> nanofluid shown in figure 1. From the results, it shows that all nanofluids have similar results of decreasing stability over time. It shows that the mango bark nanofluids have better stability compared with mango leaf nanofluids. For

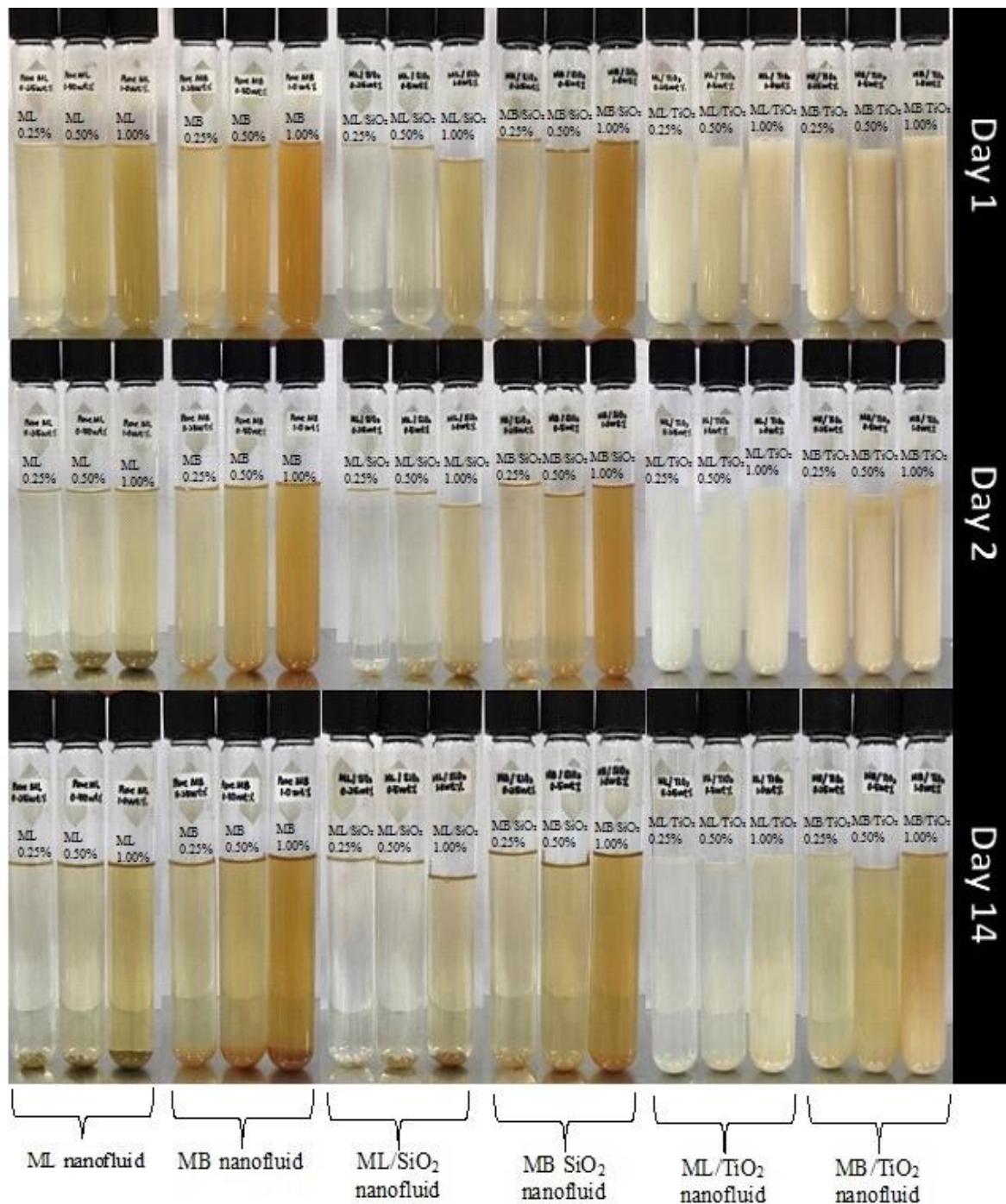


Figure 1. Visual inspection of nanofluids.

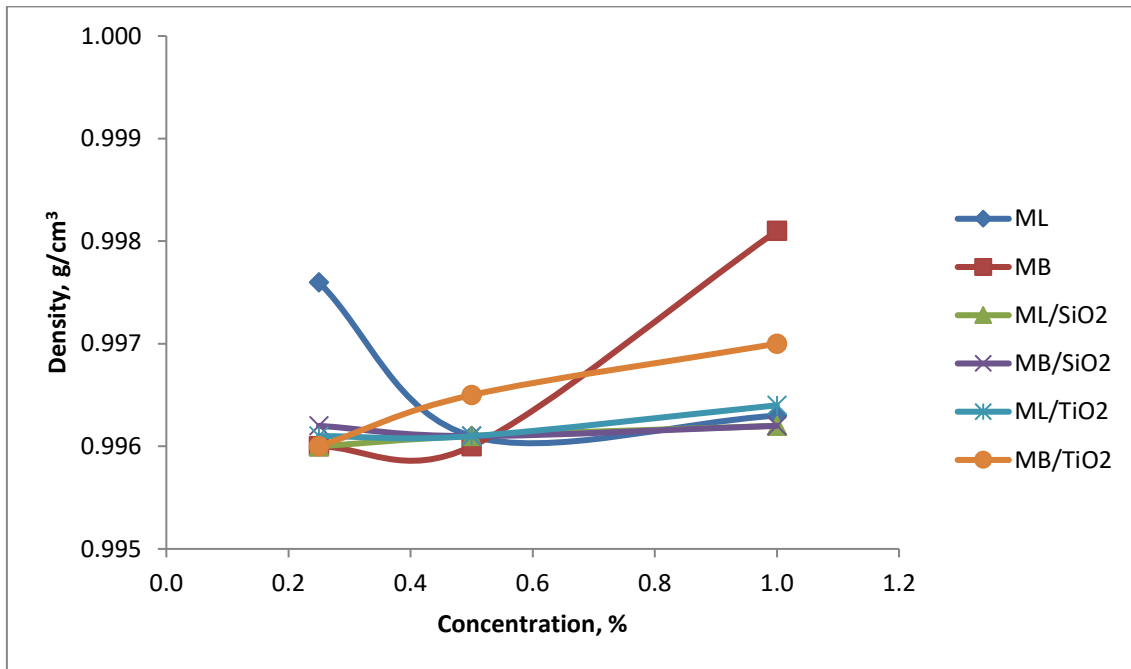
hybrid nanofluids, nanofluids with MB/SiO<sub>2</sub> particle type have better stability compared to ML/SiO<sub>2</sub>, ML/TiO<sub>2</sub> and MB/TiO<sub>2</sub>. Meanwhile, hybrid nanofluids have better stability compared with pure ML and MB nanofluids. For all particle type of nanofluids, the results shows that the higher volume concentration of nanofluids have lower stability than lower volume concentration of nanofluids. However, the longer the time taken for a nanofluid to have sign of sedimentation, the more stable the nanofluid is. For instance, Farbod et al. shown that CNT/water nanofluid have excellent stability with no sign of sedimentation after 80 days [16]. Thus, it proven that the nanofluids in this research have relatively low stability as there have sedimentation after 1 day. After 14 days, it shows small increase of sediment level which means small decrement of stability. Therefore, addition of surfactant needed to further improve the stability of nanofluids.

### 3.2. Density of nanofluids

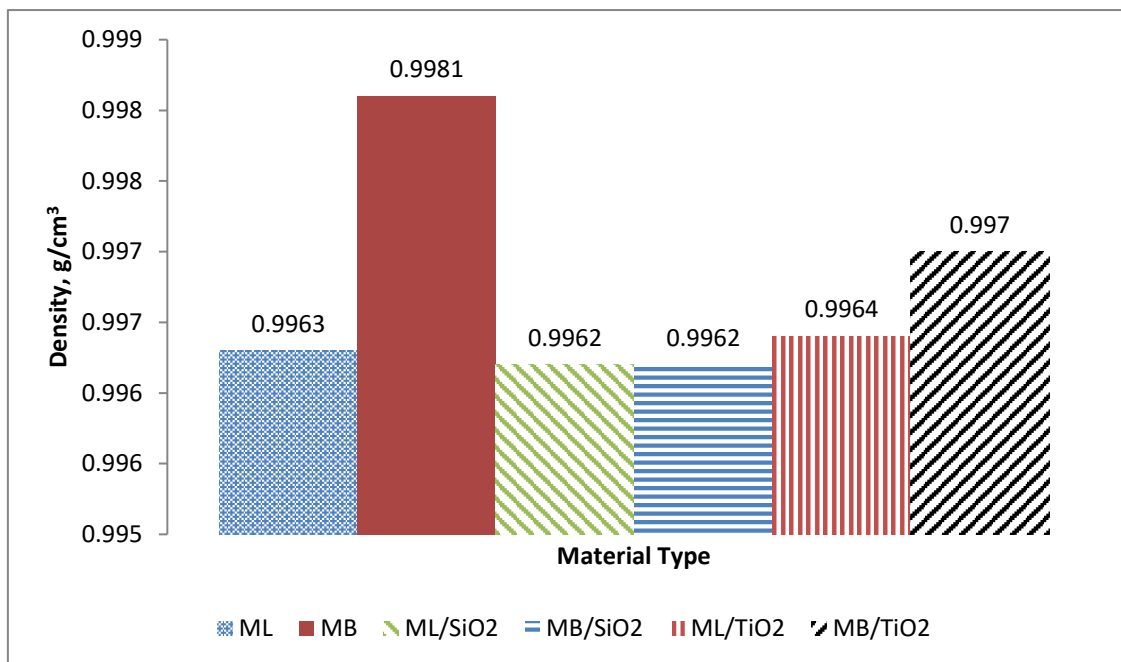
The density results of nanofluids obtained from experiment and analytical calculation method at 30 °C are as shown in table 4. From the results, it shows that the error between experimental and analytical calculation are very small (below 1%). Since the error is very small, equation (1) is valid to calculate the density of nanofluids. The density of nanofluids calculated through equation shows that the density decrease with increasing volume concentration. However, the density of nanofluids obtained from experiment shows different trends. For some nanofluids, the density decrease with concentration for most of the nanofluids density increases with concentration. The density of the nanofluids increased with volume concentration except ML nanofluids as shown in figure 2. At 1% of volume concentration, MB nanofluid has the highest density (0.9981) followed by MB/TiO<sub>2</sub>, ML/TiO<sub>2</sub>, ML, MB/SiO<sub>2</sub> and ML/SiO<sub>2</sub> as shown in figure 3. From the results, nanofluids with mango bark particles tend to have higher density than nanofluids with mango leaf particles.

**Table 4.** Density of nanofluids using experiment and analytical calculation method at 30 °C.

Material type	Volume concentration, %	Density (Experiment), g/cm <sup>3</sup>	Density (Calculation), g/cm <sup>3</sup>	Error, %
ML	0.25	0.9976	0.9980	0.04
ML	0.50	0.9961	0.9961	0.00
ML	1.00	0.9963	0.9921	0.42
MB	0.25	0.9960	0.9981	0.21
MB	0.50	0.9960	0.9963	0.03
MB	1.00	0.9981	0.9925	0.56
ML/SiO <sub>2</sub>	0.25	0.9960	0.9978	0.18
ML/SiO <sub>2</sub>	0.50	0.9961	0.9956	0.05
ML/SiO <sub>2</sub>	1.00	0.9962	0.9925	0.37
MB/SiO <sub>2</sub>	0.25	0.9962	0.9979	0.17
MB/SiO <sub>2</sub>	0.50	0.9961	0.9957	0.04
MB/SiO <sub>2</sub>	1.00	0.9962	0.9929	0.33
ML/TiO <sub>2</sub>	0.25	0.9961	0.9982	0.21
ML/TiO <sub>2</sub>	0.50	0.9961	0.9963	0.02
ML/TiO <sub>2</sub>	1.00	0.9964	0.9952	0.12
MB/TiO <sub>2</sub>	0.25	0.9960	0.9982	0.22
MB/TiO <sub>2</sub>	0.50	0.9965	0.9964	0.01
MB/TiO <sub>2</sub>	1.00	0.9970	0.9956	0.14



**Figure 2.** Effect of volume concentration.



**Figure 3.** Effect of particle type at 1% volume concentration.

#### 4. Conclusion

The stability of the nanofluids are relatively poor. The nanofluids with high volume concentration have lower stability than nanofluids with low volume concentration. The nanofluids with ML particle type have lowest stability followed by MB, MB/TiO<sub>2</sub>, ML/SiO<sub>2</sub>, ML/TiO<sub>2</sub> and MB/SiO<sub>2</sub>. Therefore, addition of surfactant to nanofluids might improve the stability of the nanofluids. The density of the nanofluids increased with volume concentration except ML nanofluids. At 1% of volume concentration, MB nanofluid has the highest density (0.9981) followed by MB/TiO<sub>2</sub>, ML/TiO<sub>2</sub>, ML, MB/SiO<sub>2</sub> and ML/SiO<sub>2</sub>.

The density of nanofluids obtained from analytical calculation have very small error compared with experimental (below 1%). Therefore, equation (1) is valid to calculate the density of nanofluids.

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