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DEVELOPMENT OF HYBRID NANO CUTTING FLUID FROM TRI-AGRO WASTE SYNTHESIZED NANOPARTICLES

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ABSTRACT

Despite the vast opportunities that nanotechnology presents due to its application in various sectors, these opportunities are still yet to be maximized in many other areas. Agricultural wastes which ordinarily are a menace to the environment could be synthesized into nanoparticles and used to develop cutting fluids. This study highlights the possibility of the development of such nanofluids from tri-agro wastes. Banana peels, Coconut shells, and Egg shells were synthesized into nanoparticles using the centrifugal process and were characterized using a scanning electron microscope. Nanoparticles were sonicated to ensure homogeneity and mixed with the base fluid to develop the nanofluids. Performance evaluation on grinding of stainless steel plates showed that the developed nanofluids produced a better surface finish of 1.00µm than the conventional cutting fluid which produced a surface finish of 1.73 µm during the grinding of galvanized steel. Also, results for mild steel showed a better surface finish (0.617 µm) when nanofluids were used as against when the conventional cutting fluid was used (1.857 µm). Hence, the use of nanofluids developed from tri-agro wastes has not only solved the problem of environmental pollution but has also proved to be a better metal working fluid providing improved surface finish during metal working activities.

Keywords: agro wastes, nanoparticles, nanofluids, steel, surface roughness, synthesis.

1. INTRODUCTION

One of the most machined materials in the manufacturing industries in the 21st century is the carbon steel family. This results from the wide area of application offered by these materials which cut across many engineering sectors examples of which include the building construction, automotive and manufacturing industries [1]–[3]. Selecting cutting fluids during machining involves assessing the cost, quality, and environmental effects. Along with lubrication, cooling, and cleaning capacity are also important characteristics. Cutting fluid viscosity and its influence on machining are other important variables to take into consideration [4]–[5]. The amount of heat produced between the workpiece and tool decreases as the cutting fluid viscosity increases, resulting in less wear [6] and influencing the surface finish and amount of energy conserved during machining [3]. Generally, research has proven that the choice of cutting fluid influences surface finish and tool wear rate during the machining of steels [4], [7]. Recently, research has been directed toward developing alternative cutting fluids using agricultural wastes. Livestock wastes and crop residues in particular have proven useful as nanofluids because they are friendly environmentally and economically [8]. The innovative idea of Nanofluid makes use of Nano-sized particles in the base fluid to serve both cooling and lubricating purposes in machining. In addition to their varied physical characteristics, nano-based cutting fluids have also created a new path in terms of thermo physical properties. There has been a lot of concern raised about Nanofluids in lubricants. Nanofluids are utilized as coolants because of their viscosity and thermal conductivity characteristics [9]. To drive home the importance of cutting fluids during machining operations, Alabi *et al.*, [10] investigated the effect of using vegetable oils as a replacement for soluble oil during the machining of steels. Their interest was majorly focused on machinability, power consumption, and tool wear rate. They reported that the use of vegetable oils-based cutting fluids resulted in an increase in the ease of machining, reduced power consumption, and improved tool life during the machining of steel samples. They, therefore, concluded that ecology-friendly oils (vegetable oils) could be considered suitable as a replacement for conventional cutting fluids (soluble oils). Similarly, Ogedengbe *et al.* [11] experimented with the effects of heat generation on cutting tools and machined workpieces during the machining of steels. They simulated various approaches to heat removal during machining using Ansys version 19.1 software. They discovered two major wear types (Flank and Crater) were dominant on the tool and resulted in the shortened tool life. They proposed the use of cutting fluids and various means of application to alleviate this problem. Particularly on the use of nanofluids during machining, Afolalu *et al.* [8], developed silica Nano cutting fluids from rice husk for machining operations using the chemical synthesis method. Nanoparticles developed were mixed with base fluid, bonified concentration mix of 0.1 - 2.5 g/L, and applied during the machining operation of steel plates. Surface roughness and SEM micrographs were used to evaluate the performance of the nanofluids compared with conventional cutting fluids during the machining operation. Results show that when nanofluids were applied surface finish was improved and the machining time was reduced. Sarhan *et al.* [12], developed nanofluids from SiO2 Nanoparticles and carried out a comparative analysis of their effect and that of mineral oils during the milling operation. They reported a large reduction in the power consumed during the machining operation when the nanofluids were used as against power consumption during the use of mineral oils. Hence they concluded that the use of nanofluids resulted in power conservation during machining activities. Using the MQL technique, Nam *et al.* [13] examined the impact of nanofluids in a micro-drilling procedure with aluminum as the workpiece material. Vegetable and paraffin oils were combined with nano diamond (ND) to produce nanofluids. During the machining operation, a variety of cooling conditions had been used, including compressed air (CA) lubrication, base oil with the MQL technique, and MQL based on nanofluids. The minimal number of holes through micro-drilling before tool failure was 87 when CA lubrication was utilized. However, it was able to drill 150 holes successfully while employing the nanofluid-based MQL approach and standard base oil lubrication. The impact of ND particles was investigated through inspections and evaluations based on thrust force and drilling torques up to 86 holes. SEM images were taken in order to evaluate the caliber of the drilled holes. The outcomes demonstrated that the use of nanofluids enhanced the number of holes drilled and decreased thrust force and torque, improving the quality of the holes drilled. Results obtained showed that the use of nanofluids increased the number of drilled holes and reduced thrust force and torque thereby enhancing the quality of the holes drilled. In order to compare the outcomes of dry and wet lubrication, Shen *et al*. [14] carried out a study using Al_2O_3 nanoparticles and a cutting fluid based on nanodiamonds in an MQL context. They discovered that the outcomes were comparable. For the investigation to provide the desired data, a cast-iron grinding process was used. It was shown that nanofluid settings worked more effectively in terms of lowering grinding forces and enhancing quality characteristics than dry and standard cooling machining conditions. Likewise, the effective cooling action of nanofluid environments prevents the workpiece's combustion problem.

2. METHODOLOGY

2.1 Nanopowder Synthesis from Tri-Agro Waste

2.1.1 Synthesis process from banana peel

The moisture content in the banana peels was eliminated by sun drying and thereafter burnt into fine powder in the furnace to produce ash at a very high temperature. The synthesization process involved the reactivation of the manganese in the ash produced from the banana peels. The moisture content in the peels was removed by sun drying and the peels were afterward burnt in a furnace to produce fine powdery ash at a very high temperature. To produce the nanopowder, a quantity of the ash produced was mixed with salt and distilled water, stirred with a stirring rod, and thereafter mixed on a magnetic stirrer at a medium speed for about 1 hour. The resulting mixture is allowed to react for two days.

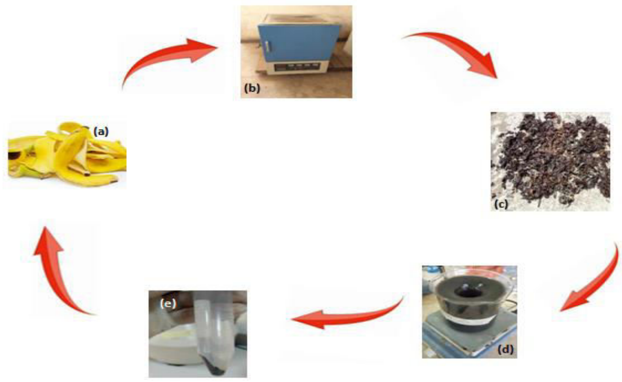

Figure-1. Steps in nanoparticle production from the banana peel (a) Agro waste (Banana peels) (b) Ash making process using the Muffle Furnace (c) Banana Peels for Ash production (d) Magnetic Stirring Process (e) Nanoparticle production by centrifugal process.

After two days, the Nano mixes were transferred to centrifuge tubes and the centrifuge machine was set to 4000rpm for 30 minutes for each batch. As shown in Figure-1(d), the nanoparticles sank to the bottom of the tube. 11 liters of the Nano mixture was centrifuged for two days. The procedure yielded a total of 209.75g of nanopowder after further calcination.

2.1.2 Synthesis process from coconut shell

The shells were acquired, washed, and dried for 3 days. It was then crushed to a fine powder in a planetary ball mill utilizing a metal crusher and a disc grinder. The powder was thereafter burnt for 2 hours at 900^{o}C in a Muffle furnace to generate coconut shell ashes, a precursor for the synthesis process. The hot ash was left to cool for about 12 hours. The next step was synthesis. The method involves using metal chemistry expertise to obtain iron Nanoparticle powder from coconut shell ash. This chemical equation governs the process.

$$CoconutShell + FeSO_4.H_2O \rightarrow FeO + C$$

5 grams of coconut shell ashes were then combined with 153.4 grams of Iron salt and 1 liter distilled water to make a 0.5 molar solution. On a heated plate with a magnetic stirrer, the solution was agitated for 1 hour. The stirred solution was allowed to stand for a day to allow reactions to occur. After 24 hours, the reaction was complete and the solution included iron nanoparticles. The iron nanoparticle powder was centrifuged from the solution to remove it from the mixture. The solution was put into 10 ml centrifuge tubes and spun for 15 minutes, resulting in a combination of nanoparticles and nanofluids at the bottom of the tubes. All the solution was then

centrifuged. The procedure yielded a total of 94.5g of nano-powder after further calcination.

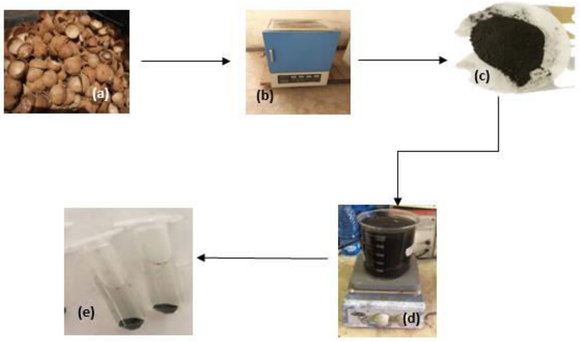

Figure-2. Steps in nanoparticle production from Coconut Shell (a) Agro wastes (Coconut Shell) (b) Ash making process using the Muffle Furnace (c) Ash production from Coconut Shell (d) Iron Solution onhot plate (e) Nano particle production by centrifugal process.

2.1.3 Synthesis process from egg shell

With the aid of a mortar and pestle, the collected egg shells were broken up into little pieces and put in a crucible blast furnace with a thermal heat capacity of up to 2300°C. However, for this research, the furnace was set to fire for 3 hours at a temperature of 2000 °C. Before filtering with a sieve shaker to remove oversized particulates from the necessary particle size, the ashes were allowed to cool for about 10 hours. The calcium carbonate salt and eggshell ashes were weighed in grams using a mass meter. A beaker containing the ashes, 100g of salt, and 1000 ml of distilled water was filled after the ashes were weighed on a mass scale. A Stuart hot plate and a magnetic stirrer were used to thoroughly stir this mixture. The mixture was allowed to spin clockwise for an hour. This beaker was stirred for an hour using a magnetic stirrer. The identical sample was collected twelve times in clear plastic kegs. In a centrifuge tube, the particles are suspended in a liquid medium. The tube is then spun in a rotor at a specific speed. The solution was allowed to settle in the keg for 24 hours before centrifugation. The solution was put in 12 tubes and spun for 15 minutes in a laboratory centrifuge made by Surgifield Medical England in Devon, UK. This cycle continued until the solution was exhausted. The procedure yielded 68 grams of nano-powder after further calcination.

2.2 Assessment of Nanoparticle Particles

To ascertain the powder's microstructure, phases, and constituent elements, the nanoparticles underwent SEM and EDS analysis. SEM micrographs have a deep field of view, which gives them a three-dimensional appearance that is useful for examining surface morphology. Magnification ranges from ten times (about equal to a strong hand lens) to over 500,000 times (roughly equivalent to the finest light microscopes). To prepare for SEM testing, a large amount of each sample was placed in the specimen chamber and fixed to the specimen holder (specimen stub). Then a low-vacuum sputter coating of platinum was applied to the sample. This coating happened in a high-pressure chamber with a short working distance, with the electron optical column differentially pumped to keep the electron gun vacuum low. Both biological and material specimens may be embedded in resins and polished to a mirror-like sheen for backscattered electron imaging or quantitative X-ray microanalysis.

2.3 Preparation of Nanofluids Samples

The nanoparticles were weighed to generate 9 distinct mass concentrations, shown in Table-1. 300ml of distilled water was mixed with iron oxide nanoparticles ranging in mass from 2.268g to 11.43g, manganese oxide nanoparticles ranging in mass from 5.03g to 25.17g, and calcium oxide nanoparticles ranging in mass from 2.72g to 8.16g. They were all sonicated to produce 9 different Nano cutting fluid concentrations. Control was water soluble oil to guarantee the homogeneity of the fluid and that the nanoparticles were uniformly distributed in the base fluid, each sample was sonicated in an Ultrasonic bath for 1 hour at a time.

Table-1. Weight percentage of nanoparticles showing varying concentrations in 300ml of distilled water.

SAMPLE	CaO		FeO		Mn_3O_4	
	MASS	WT%	MASS	WT%	MASS	WT%
A	8.16g	0.0272	0	0	0	0
B (PURE DISTILLED WATER)	0	0	0	0	0	0
C	0	0	11.34g	0.0378	0	0
D	0	0	0	0	25.17	0.0839
E	4.08g	0.0136	5.67g	0.0189	0	0
F	0	0	5.67g	0.0189	12.59g	0.042
G	2.72g	0.00907	3.78g	0.0126	8.39g	0.028
H	4.08g	0.0136	0	0	12.59g	0.042
I	4.9g	0.0163	2.268g	0.00756	5.03g	0.0168
J (CONTROL)	0	0	0	0	0	0

2.4 Experimentation for Performance Evaluation

The performance of the developed Nanofluid was evaluated during a grinding operation. For this experiment, two (2) steel plate types (galvanized steel of dimension 45x30 mm and stainless steel of dimension 50x40mm) were acquired and their surfaces were ground using a disc grinding machine. Each sample of cutting fluid was applied during the machining operation, in equal amounts for a duration of 15 seconds. Surface roughness analysis of the ground steel plates was conducted to evaluate the performance of the nanofluids through a comparative study of the surface finish produced during the use of the conventional cutting tool (control) and the Nanofluid. This assessment was conducted using a Mitutoyo Surftest SJ-210 SRT. A spectroscopical examination was also carried out using a JOEL-JSM 7600F Scanning Electron Microscope to assess the performance of the Nanofluid viz-a-viz the conventional cutting fluid.

3. RESULTS AND DISCUSSIONS

3.1 Spectroscopical Analysis of Nano Particles

a) Banana peel (Manganese oxide)

The EDX graph of the produced Nanoparticle powder, displayed in Figure-3, verified the chemical composition of Manganese oxide. The main components of the Nanoparticle, with concentrations of 29.45% and 38.7 % are Mn and O, respectively. The existence of additional elements in a coconut shell, such as C, Si, Al, Fe, Ca, and K is due to the banana peel not being leached prior to thermal decomposition; nevertheless, the heating was efficient enough to eliminate certain other earth metals and metal contaminants.

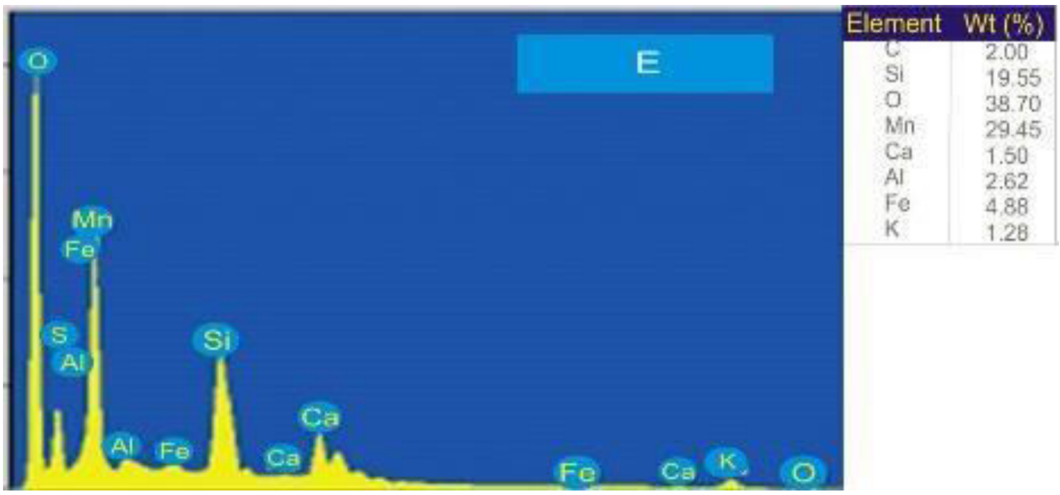

Figure-3. EDX micrography of developed manganese oxide nanoparticles.

b) Egg shell (Calcium oxide)

The EDX graph of the produced Nanoparticle powder, displayed in Figure-4, verified the chemical composition of Calcium oxide. The main components of the Nanoparticle, with concentrations of 32%, 21.1% and 21% are Ca, Si, and O respectively. The existence of additional elements in the coconut shell, such as C, Al, Fe, Mg, Na, and K is due to the egg shell not being leached before to thermal decomposition; nevertheless, the heating was efficient enough to eliminate certain other earth metals and metal contaminants.

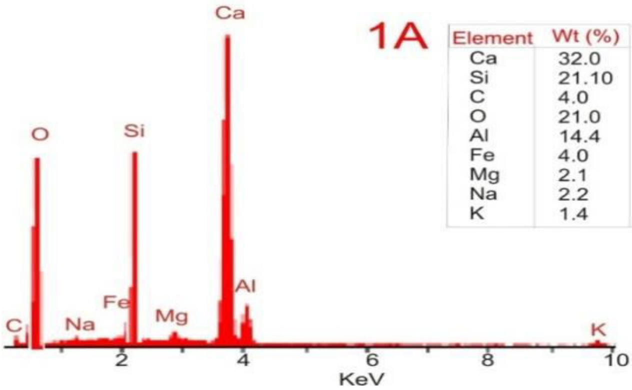

Figure-4. EDX micrography of developed calcium oxide nanoparticles.

c) Coconut shell (Iron oxide)

The EDX graph of the produced Nanoparticle powder, displayed in Figure-5, verified the chemical composition of Iron oxide. The main components of the Nanoparticle, with concentrations of 57.1 % and 23.3 % are Fe and O, respectively. The existence of additional elements in the coconut shell, such as C, Si, Al, and Mn, is due to the coconut shell not being leached prior to thermal decomposition; nevertheless, the heating was efficient enough to eliminate certain other earth metals and metal contaminants.

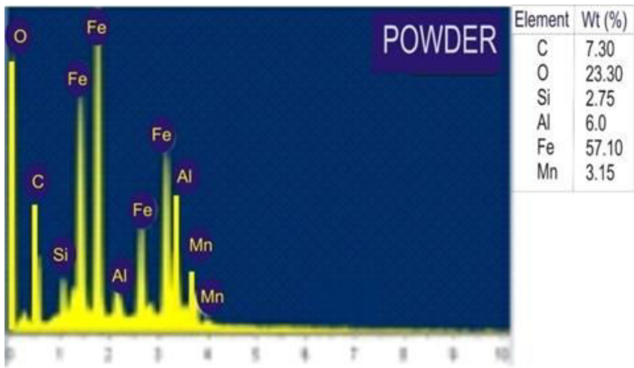

Figure-5. EDX micrography of developed iron oxide nanoparticles.

3.2 Surface Roughness Analysis

a) Galvanized steel

Surface roughness results show that the highest arithmetical mean roughness value of 1.73µm was recorded using cutting fluid sample J while the lowest arithmetical mean roughness value of 1.00 µm was recorded using cutting fluid sample E. From Table-1, Cutting Fluid sample E had the highest combinational values of Nanoparticles from Calcium and Iron oxides (4.08g and 0.0136wt / 5.67g and 0.0189wt), but without Manganese oxide nanoparticles. This compositional mix of Nanofluids with the base fluid produced the best surface finish during the grinding operation. Although cutting fluid sample I, had the overall highest values of nanoparticles mix of the 3 oxides, it ranked 6th in performance after cutting fluid samples E, C, D, H, and F. It is pertinent to note that all Nanofluids samples performed better than distilled water (sample B) ranked 9th and soluble oil (sample J) ranked 10th. This shows that the developed Nanofluids performed excellently well as a suitable alternative to the conventional cutting fluid and distilled water.

Table-2. Surface roughness results for galvanized steel.

GALVANIZED STEEL										
Sample	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Mean Ra (µm)	1.49	1.59	1.02	1.03	1.00	1.13	1.39	1.07	1.30	1.73
Rank	8th	9th	2nd	3rd	1st	5th	7th	4th	6th	10th

b) Stainless steel

Surface roughness results show that the highest arithmetical mean roughness value of 1.73µm was recorded using cutting fluid sample J while the lowest arithmetical mean roughness value of 0.68 µm was recorded using cutting fluid sample E. Generally, the same trend was noticed as cutting fluid sample E produced the best surface finish during the grinding operation. The poorest surface finish was recorded with the use of samples I and J as expected. Hence, nanofluid samples performed better than the conventional cutting fluids during the grinding operation.

Table-3. Surface roughness results for stainless steel.

STAINLESS STEEL										
Sample	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Mean Ra (μm)	1.35	1.33	0.85	0.88	0.68	1.10	1.36	1.13	1.37	1.73
Rank	7th	6th	2nd	3rd	1st	4th	8th	5th	9th	10th

4. CONCLUSIONS

This research involved the development of a hybrid tri-agro waste nano cutting fluid and the performance evaluation of the fluid viz-a-viz the conventional cutting fluid. The study informed the following conclusions below;

a) Nanoparticles of oxides of Calcium, Manganese, and Iron can be successfully synthesized from eggshells, banana peels, and coconut shells respectively using the chemical synthesis method.
b) The dominant elements of the synthesized oxides were 32% Ca, 21.1% Si & 21% O for Calcium Oxide; 29.45% Mn, and 38.7% O for Manganese Oxide, and 57.1% Fe and 23.3% for Iron Oxide.
c) The surface roughness of sample E with compositional values 4.08 g and 0.0136 wt / 5.67g and 0.0189wt returned as the lowest and hence was the most preferred and recommended composition for effective surface finish improvement.
d) Generally, the surface roughness of developed nanofluids was lower than that of the conventional cutting fluid and distilled water, hence the developed Nanofluid is preferable as cutting fluid during metal working activities.

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