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Development of Hybrid Electrode for Welding Using Nano Additives from Agro-wastes

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ABSTRACT

The recycle of agricultural wastes for various other needs have recently continued to attract interest of researchers. In this study, hybrid welding electrodes were developed from agricultural waste using nano additives. The nano additives were created from typical agricultural waste materials (rice husk, coconut shell, and palm kernel shell). The generated nanoparticles were incorporated into the core of a conventional Grade 8 electrode using a suitable glue. The physical and chemical properties (particle size, shape, and elemental content) of the hybrid electrodes formed were thereafter studied. Results show that the hardness of the welded junction improved as the amount of agrowastes in the electrode increased. The SEM and XRD results also displayed an improved thermal stability during welding using electrodes with introduced agrowastes. Hence the adoption of the technology of the hybrid electrodes is recommended for welding applications. Production of nano additives from easily accessible agricultural waste may result in affordable and ecologically friendly welding solutions. The discoveries are expected to aid in the development of more environmentally friendly and potentially cost-effective welding technology.

1. INTRODUCTION

Welding technology has been the driving force behind joining procedures since ancient times. Humphry Davy discovered an electric arc in 1800 by connecting two carbon electrodes in a battery. The fundamentals of gas metal arc welding were developed in the middle of the nineteenth century, following the introduction of the electric generator [1]. Today, specialized welding techniques such as wire arc additive manufacturing cotinues to gain attention ad is used for specialized parts manufacture [2].

Conventional welding electrodes composed of non-renewable materials, present environmental problems due to their production (extraction and manufacturing) methods. These electrodes may not always provide the best performance which results in reduced efficiency in welding. This therefore increases the need for eco-friendly, efficient and high-performance electrode materials to address both environmental concerns and to improve welding technology.

Iron, nickel, and alloys are examples of inorganic materials commonly used in conventional welding electrodes [3]. Recent developments have resulted in the creation of organic electrodes made from agro-industrial waste. These environmentally friendly replacements show encouraging performance qualities in addition to lessening their negative effects on the environment. The electrode core's composition is often the same as that of the base material, if not the same. Despite the fact that there are many workable alternatives, the qualities of the final weld can be significantly impacted by even a little variation in the alloy's composition [4]. Welding electrodes made of organic agro-waste mark a historical change in favor of environmentally friendly production methods. We can make electrodes that strike a balance between environmental responsibility, safety, and performance by utilizing nature's abundance. This green revolution will be propelled forward by cooperation between material scientists, biochemists, and welding specialists [5]. Welding electrode is extremely important in welding technology as it influences the quality of weldment and by extension, the durability of the structure [6].

To create a high-quality coated electrode for welding structural steel, it would be necessary to determine the required qualitative welding features, such as reduced porosity, reduced smoke, improved arc stability, and slag detachability. In order to evaluate the quality of the weld produced with these coated electrodes, weld bead properties would also be determined [7]. While retaining the typical excellent operational characteristics of rutile electrodes, this modification resulted in an increase in the basicity of the slag, which in turn caused a notable increase in all-weld-metal toughness and modifications in operational behavior with a decrease in penetration and width of the weld bead [4].

Because of the several drawbacks of using non-renewable energy sources, the world is turning more and more to using renewable sources. Among many others, the biomass of agricultural crops has demonstrated to be a viable non-renewable energy source, which makes it a better option to extract or synthesise value added products [8].

It is anticipated that using these materials for this purpose would promote opportunities for waste to wealth as well as stronger cutting tool manufacture, which will guarantee increased productivity and higher surface polish for machined materials [9].

The use of agrowastes increased the strength and resistance to corrosion of reinforced or welded metal. Agro-waste can be employed in a variety of ways to boost strength, as demonstrated by its low ductility, elasticity, malleability, high brittleness, resilience, stiffness, and higher specific and yield strengths [10]. Farmers and other agricultural workers may be able to generate additional revenue by selling their waste products to businesses that make welding electrodes. It may contribute to the decrease in welding electrode costs, making welding more accessible and inexpensive for individuals in underdeveloped nations. Additionally, it can lessen reliance on fossil fuels and other non-renewable resources, and promote the use of renewable resources.

SDG 12, which aims to develop sustainable consumption and production patterns by 2030, it is important to ensure the effective and sustainable management of natural resources. The process of turning these waste materials into welding electrodes reduces waste and lessens its impact on the environment. Also, supporting farmers in providing these agricultural waste products and creating a means of income in accordance with SDG 8 (Encouraging sustained, equitable, and sustainable economic growth). Sustainable Cities and Communities, or SDG 11 Localizing the manufacture of agro-waste electrodes can result in the emergence of small-scale companies in local communities [11]. This study therefore aims to model and develop a hybrid electrode with nano additives from selected agro-waste.

2. LITERATURE REVIEW

The contemporary kind of welding was not developed until the nineteenth century. Victorian Englishman Edmund Davy is credited with discovering acetylene. Around 1800, Sir Humphry Davy is credited with using a battery to create the first arc between two carbon electrodes. Arc lighting became well-known after the electric generator was developed in the middle of the 1800s [9]. Late in the 1800s, gas welding and cutting were invented. When arc welding—which uses a metal and carbon arc to join materials—was discovered, resistance welding became feasible [12]. Technology for welding has existed from ancient times. The Bronze Age saw the earliest evidence of pressure welding. Iron fragments were joined through welding during the Iron Age by the Egyptians [13].

Sir Humphry Davy developed an electric arc in 1800, and from there, the concepts of MIG welding began to emerge. At that time, carbon electrodes were utilized. Then, in 1888, a Russian inventor employed arc welding to combine metal. It was the first time in the world, but it was utilized for metal casting by electricity [1].

In 1900 Strohmenger introduced a coated metal electrode to Great Britain. Though it was only a thin coating of lime or clay, it strengthened the arc. Concurrently developed between 1907 and 1914 were resistance welding techniques including spot, seam, projection, and flash butt welding. First to use resistance welding was Elihu Thompson. The dates of his patents were 1885–1900 [14]. Sweden's Oscar Kjellberg developed a covered or coated electrode between 1907 and 1914. Short lengths of bare iron wire were dipped in thick carbonate and silicate solutions, then allowed to cure [1]. Welding is a precise and dependable joining method that results in the local coalescence of materials. This is frequently performed by locally melting the work parts and adding a filler material to create a pool of molten material that cools to form a strong bond. Pressure is occasionally utilized alone or in combination with heat to form the weld. The surfaces of two different components are essentially fused together to form a single unit during the welding process [15]. The impact of agrowaste's materials on various steel material when used as reinforcements cannot be overemphasised. Uchegbulam et al. [16] submitted that the use of various agricultural wastes materials as reinforcement is recently becoming extremely desireable and essential especially in the manufacturing sector. Figure 1 shows various agricultural wastes that have been established as viable alternatives for several purposes.

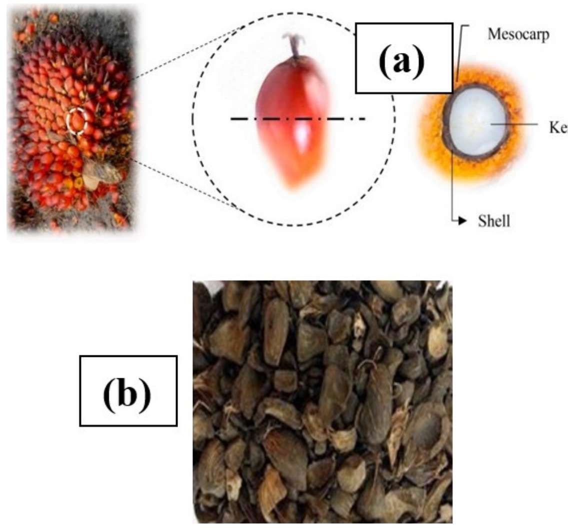

Figure 1. (a) Oil palm fruits, individual fruits, and a cross section of fruit; (b) Coconut
Source [16]

This scope of this project is to explore various ways by which bio waste can be used in the production of electrode for welding, this project is going to be restricted to the use of bio materials only as the parent raw materials. Lower tensile strength: Agricultural welding electrodes are generally weaker than standard welding electrodes. As a result, they may not be suited for applications requiring high strength welds [17].

Agricultural welding electrodes are often less ductile than standard welding electrodes. As a result, they may not be appropriate for situations where the weld must be able to deform without breaking [18]. They are not, for example, appropriate for welding pipes and tubes that must be bent or twisted. Corrosion resistance is often lower in agricultural welding electrodes than in standard welding electrodes [19-21]. This implies they may not be acceptable for situations where the weld must be resistant to corrosion caused by the environment. They are not, for example, ideal for welding stainless steel that will be exposed to seawater. Despite these limitations, agricultural welding electrodes have the potential to be a viable alternative to standard welding electrodes in several situations.

3. METHODOLOGY

To produce the Nanoparticle powder from selected agro-waste, the processes followed include: Acquisition of required materials, Grinding, Milling, Burning, Synthesis of the Iron particles by chemical means, Centrifugation and Calcination. Figure 2 shows the flowchart of the methods employed for the experimentation. The process entails the pulverization of agrowaste materials, synthesis and preparation of binder to the production of electrodes using the synthesised nanoparticles from the agrowastes.

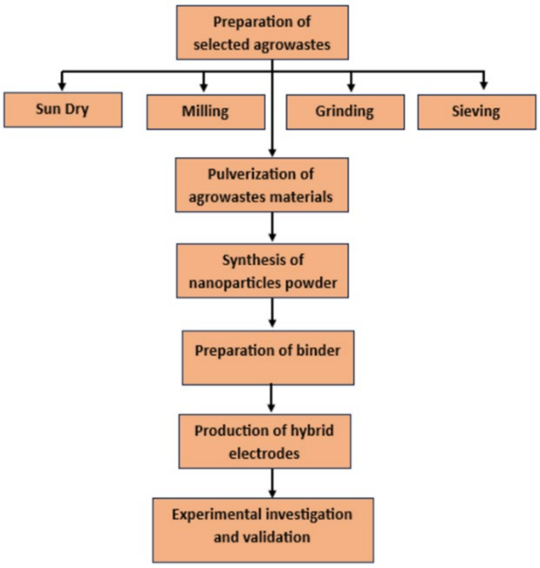

Figure 2. Flow chart of methods

3.1 Materials

The materials used for this experimental process includes welding rods, rice husk ash, coconut shell, palm kernel shell ash, egg shell ash, galvanized and mild steel plates, welding elctrode mould and potassium silicate powder.

3.2 Equipment

The equipment employed for the experimental procedure includes a muffle furnace (2000°C max capacity), centrifuge (120 cc), tensile hardness tester, disk grinder, desktop industrial oven (5000°C), magnetic stirrer hot plate (2000mL). magnetic stirrer bar (1500mL), SEM (JSM-7600F/ Schotky Field Emission Scanning Electron Microscope), a pilotech extraction machine and a welding machine (415V ± 10%). Figure 3 shows some of the various equipment employed for the study. Most of the equipment was sourced from the central engineering laboratory/workshop of Afe Babalola University, Ado-Ekiti, Nigeria.

3.3 Mould design

The design of the mould requires knowledge on software to be used for the design of this model and the simulation. The software to be used for this would be solid works and for the simulation process. The electrode mold was design and fabricated in the woodwork section of the workshop (Figure 4a). The paste was coated on an electrode core, manually by means of a permanent mold casting with the wire forming the core. It is allowed to cure and the mold removed. An electrode has been formed. Figures 4(a), 4(b) and 4(c) show the modeled mould, developed mould and the designed electrode respectively. All of these figures depict the mould and electrode development process.

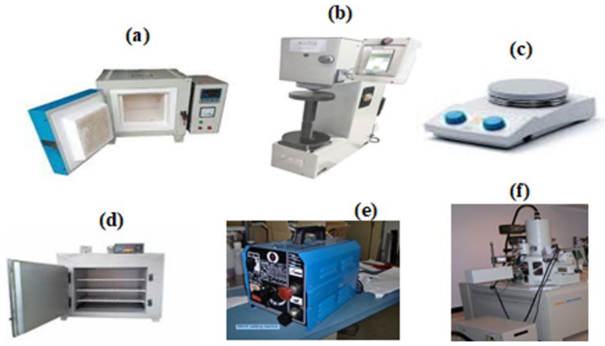

Figure 3. Some equipment used for study (a) Muffle furnace (b) Hardness tester (c) Magnetic stirrer hot plate (d) Desktop industrial oven (e) Welding machine (f) Scanning Electron Microscope

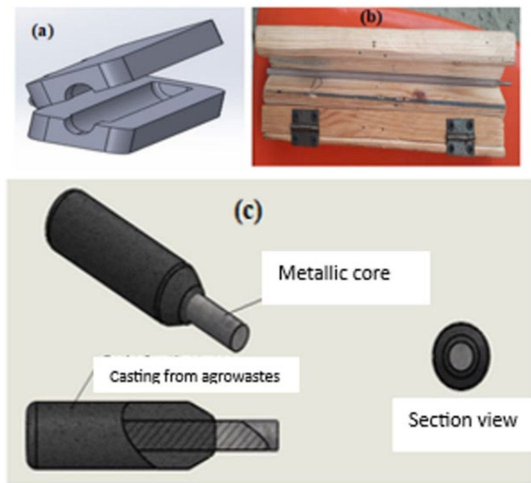

Figure 4. Mould & electrode development (a) 3D view (b) Developed mould (c) Model of welding electrode

3.4 Material preparation

The agro-waste materials selected for the experimentation process for the study were, egg shells, rice husk ash, coconut shell and palm kernel shell. These agro-waste materials were selected because of their availability around the study area and preliminary studies which included a review of literature on the various materials that could possibly serve the intended purpose of the study.

3.4.1 Preparation of pulverized agro-waste materials

(a) Eggshells (ES)

The shells were sourced from cafeterias around the school. The shells were then sorted and the useful dried under the sun for 3 days at 40°C. Then it was grounded into rough coarse powder using a hardened steel crusher and a disc grinder. The powder was then open burnt to char.

(b) Rice Husk (RH)

Rice husk were gathered from agricultural waste disposed. The husk was properly sorted and washed before they were Sun dried at 50°C. It is then placed into the ball mill where it is grinded to its powder form. The powder was then open burnt to char.

(c) Coconut Shell (CS)

The shells are gathered and sorted to remove debris or dirt. Then washed, sun-dried completely. Then process to crushing with hammer mill, the large particles become smaller before they are sent to the grinder to be made into powder form. The powder was the open burnt to char.

(d) Palm kernel Shell (PKS)

Similar to coconut shells, after the materials have been sourced and sorted for debris and dirt, it is then dried completely. The now already dried shells are crushed with hammer mill it is then grinded to powder form. The powder is later open burnt to char. Figure 5 shows the various processes involved in the preparation of the materials.

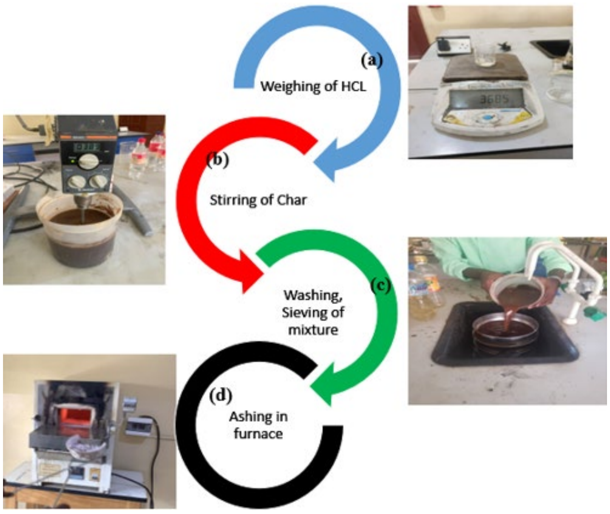

Figure 5. Processes in material preparation

3.4.2 Synthesis of nanoparticles powder from agro-waste

500g of the burnt char of egg shell, coconut shell, palm kernel shell and rice husk is prepared in 1 mole (36.46g) of HCL in 1000ml of water and stirred for 2 hours at 2000rpm. After the mix time is completed, then left to rest for 24 hours.

The mixture is rinsed out with water and sieved, left to drain before transferring to a heat resistant pan and placed in the oven to dry off. The dried powder is placed into the muffle furnace. The furnace is pre-heated to about 700°C, the samples are then placed into the furnace and left to for 2-3 hours to allow for complete combustion. The progress of the sample was regularly observed and temperature monitored. After the heating process is complete, the sample is taken out and allowed to cool down before collecting.

3.4.3 Characterization of nanoparticle welding electrode

The nanoparticle powder from the various agro-waste materials was then characterized using the JSM-7600F Schottky Field Emission Scanning Electron Microscope / EDS. Finding the various phases of the powder and identifying its constituents were the goals of this investigation. The nanoparticle powder was characterised in order to do this by X-ray diffraction (XRD) and Energy Dispersive Spectroscopy (EDS). Pasting the needed powder coating onto the wire surface of the welding electrode is the primary responsibility of the binder. This group of materials is mainly from sodium and potassium silicate compounds.

The developed ash from the agro materials is measured into its mix ratio as shown in Table 1 with the binder (sodium silicate). The mixture is applied into the mold with the electrode core in the middle, the mixture is compressed and left to settle for 24 hours. The mold is later placed in the oven for 3 hours to dry the electrode.

3.5 Experimental application of developed powder

The designed electrode was used in SMAW (shielded metal arc welding) and the resulting weld was examined to see which mechanical characteristics the electrode had enhanced. Using 240 Amp (current) the developed electrode is used in welding 2mm thick mild steel plates together. Figure 6 shows the various welded joints on test samples after the completion of the welding procedure.

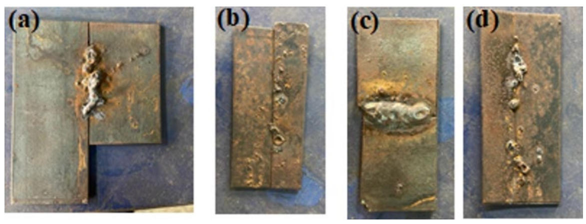

Figure 6. Welded joints using various samples (a) Sample 4 (b) Sample 6 (c) Control sample (d) Sample 1

Table 1. Ratio of agro-waste mixture

Sample No.	Eggshell (g)	Rice Husk (g)	PKS (g)	Coconut Shell (g)	Sodium Silicate (g)	Total (g)
		70% per sample			sample	
1	15.00	27.50	27.50	22.50	27.75	120.3
2	42.50	25.00	40.00	22.50	39.00	169.0
3	17.50	25.00	30.00	40.00	33.75	146.3
4	20.00	20.00	20.00	20.00	24.00	104.0
5	25.00	22.50	22.50	25.00	28.50	123.5
6	30.00	22.50	22.50	30.00	31.50	136.5
7	17.50	30.00	30.00	32.50	28.50	123.5
8	30.00	32.50	32.50	17.50	31.50	136.5
9	27.50	25.00	20.00	22.50	28.50	123.5
10	25.00	20.00	27.50	17.50	27.50	117.0
Total	250.0	250.0	250.0	250.0	300.0	
		Total Agro		Total Mix		
			1000.0		1300.0	

4. RESULTS AND DISCUSSION

4.1 Egg shell analysis

Figure 7(a) shows SEM morphology of Egg shell extracted Nano-Fibers. The extract demonstrates the rough surface of the shell which provides mechanical strength, protecting the delicate contents of the egg. The uneven surface also helps with gas exchange during embryonic development. The SEM results revealed that eggshell considerably decreases mild steel corrosion. The SEM picture is amplified by 500x.The scale bar represents a length of 150 micrometers. The properties of the egg shell's EDS spectrum analysis are displayed in Figure 7(b). The presence of calcium is indicated by the high peak at a certain energy level. The main component of eggshells that gives them their strength and stiffness is calcium carbonate ($CaCO_3$). The y-axis of the spectrum displays the intensity of X-rays released by the sample, while the x-axis depicts energy levels (measured in kiloelectron volts, or KeV). A notable high concentration of calcium carbonate ($CaCO_3$), or limestone, is present in welding electrodes. About half of the composition. It serves as a barrier against pollutants in the atmosphere. The electrodes can function smoothly at large currents thanks to it as well. The crystalline structure of a material can be inferred from the XRD pattern in Figure 7(c). The calcite crystal lattice inside the eggshell is represented by the peak in the XRD pattern, which is seen as the green point at about 2Theta = 26 degrees. It signifies that calcium carbonate ($CaCO_3$) is stable and abundant. The crystalline structure of eggshell components, which affects their electrical conductivity, is depicted in the chart. It is pertinent to state that both Afolalu et al. [8] and Ogedengbe et al. [5] both reported separate enhancements for weldment using eggshell waste as reinforcement material. The opined as well that this was made possible due to the presence of calcium carbonate abundant in the material. This gives credence to the result of the study.

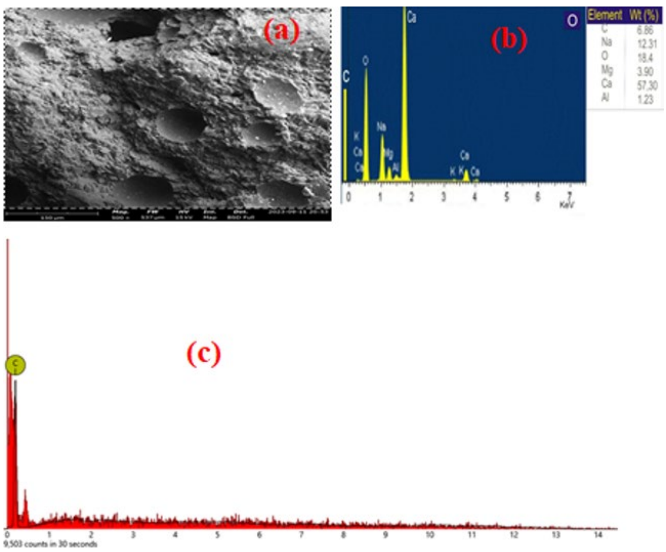

Figure 7. Graphs of analyzed egg shell (a) SEM at 1000x magnification (b) EDS (c) XRD

4.2 Coconut shell analysis

Figure 8(a) shows SEM morphology of the analyzed coconut shell at a magnification of x1000. The mophological results shows the presence again of uneven surfaces with demonstrates the strength contributions offered by the coconut shell. The EDS spectrum analysis properties of the coconut shell are depicted in the schematic in Figure 8(b). It displays peaks that correlate to the various components found in the coconut shell. Calcium and potassium are at 3.69 keV and 3.31 keV, respectively, carbon is at 0.28 keV, oxygen is at 0.54 keV, and so on. with 44.36% of the sample having carbon as its most prominent component. These components support its thermal behavior, combustibility, and strength. A suitable carbon content guarantees stable and easy welding procedures as well as optimum weldability. Between 0.10% and 0.40% of the electrode is present in electrodes.

The crystalline structure of a material can be inferred from the XRD pattern. The calcite crystal lattice inside the eggshell is represented by the peak in the XRD pattern (Figure 8c), which is seen as the green point at about 2Theta = 26 degrees. It signifies that calcium carbonate (CaCO3) is stable and abundant. The crystalline structure of eggshell components, which affects their electrical conductivity, is depicted in the chart.

When added to electrode coats, coconut shells help to maintain thermal stability when welding. Under high-temperature welding circumstances, reliable performance is guaranteed by stable coatings. Their porosity and rough surface help to improve the electrodes' adherence and stability.

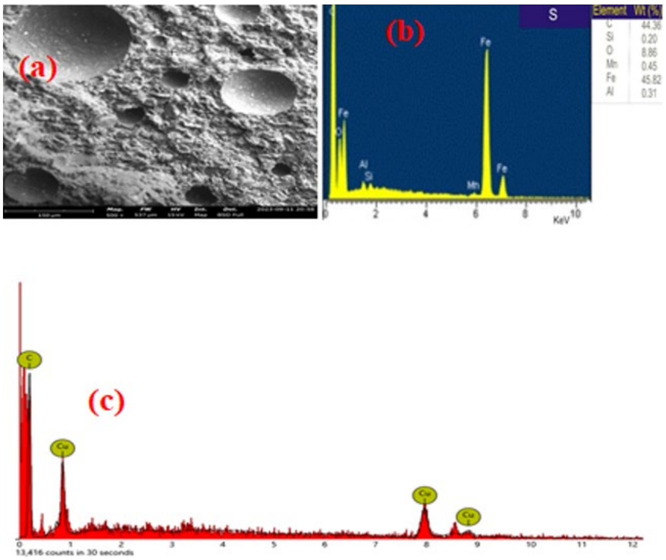

Figure 8. Graphs of analyzed coconut shell (a) SEM at 1000x magnification (b) EDS (c) XRD

4.3 Palm kernel husk

The palm kernel shell surface may be seen in extremely enlarged detail in Figure 9 SEM image, which also highlights the shell's bumpy, uneven, and rough surface. Additionally, the shell's fibrous components are present. Figure 9(a) shows the SEM analysis of the PKS at a magnification of x1000. They are suited for burning because of their porous structure, which also increases the mechanical strength of the shell. The EDS of PKS in Figure 9(b) displays the elements of carbon, oxygen, calcium, phosphorus, magnesium, sodium, and nitrogen that are found in the shells of palm kernels. For welding electrodes, the high carbon and calcium concentration that the EDS indicates is important. Electrodes are made more electrically conductible by the addition of carbonaceous elements. The XRD pattern of PKS, which sheds light on the crystalline structure, is displayed in Figure 9(c). The pattern's peaks line up with particular crystallographic planes in the substance. The strongest peak denotes a high concentration of a particular crystalline phase or a high degree of crystallinity. The peaks indicate the presence of graphitic carbon, which improves thermal stability and electrical conductivity—two factors that are critical to electrode performance—in palm kernel shells. Under welding conditions, the strong crystalline structure guarantees mechanical durability.

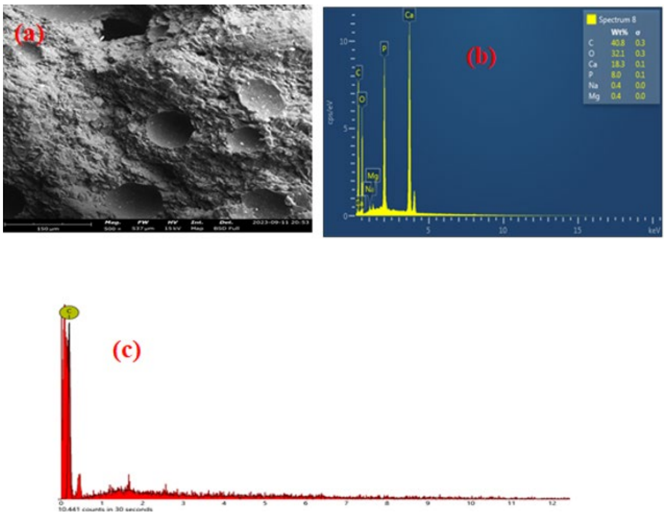

Figure 9. Graphs of analyzed palm kernel shell (a) SEM at 1000x magnification (b) EDS (c) XRD

4.5 Rice husk analysis

A greatly magnified view (SEM image) of the rice husk surface is shown in Figure 10(a), which also reveals the existence of fibrous structures and a rough, uneven, and textured surface within the husk material. RH can be used as coating materials or fillers for welding electrodes. RH's graphitic carbon enhances electrode electrical conductivity.

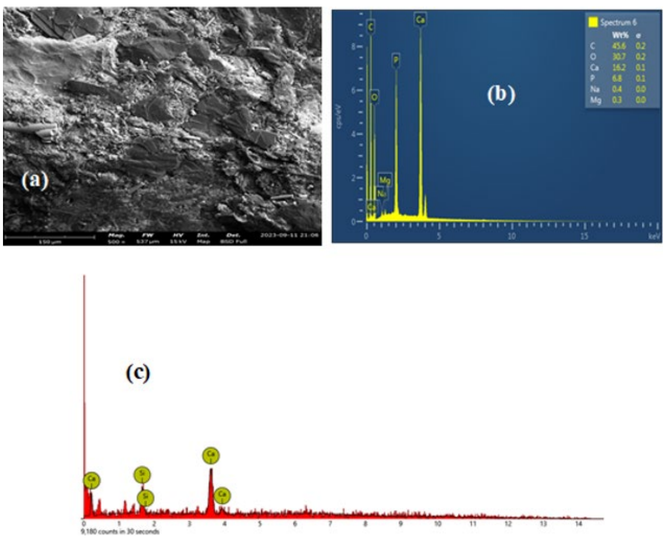

Figure 10. Graphs of analyzed rice husk (a) SEM at 1000x magnification (b) EDS (c) XRD

The chemical components found in rice husk are shown in the EDS spectrum in Figure 10(b). Certain elements, including carbon, oxygen, phosphorus, magnesium, calcium, sodium, and nickel, are represented by prominent peaks. Carbon, which is necessary for electrical conductivity in welding electrodes, is found in rice husk. Figure 10(c) shows the cystalline structure of the material as seen from the XRD results. Ca and silicon peaked from the results of the XRD. There was also some presence of carbon as well in the results representing some level of ther thermal stability again.

4.6 Hardness testing

The welds were evaluated for hardness using a Rockwell testing machine, and the results are presented in Tables 2 and 3. The sections of the generated weld, namely the base Metal and welded joint were tested. Figure 11 shows a view of the hardness testing procedure using a Rockwell hardness tester.

Figure 11. Hardness testing of welded joint

Table 2. Rockwell hardness results using control electrode

S/N	Welding Current (I)	Applied Load (kgf)	Hardness of Welding Joint	Hardness of Sample
1	250	100	63	52

Table 3. Rockwell hardness results using control electrode

S/N	Welding Current (I)	Applied Load (Kgf)	Hardness of Welded Joint	Hardness Value of Sample
2	240	100	52.5	52
5	240	100	53.25	52
7	240	100	53.75	52
9	240	100	54.25	52

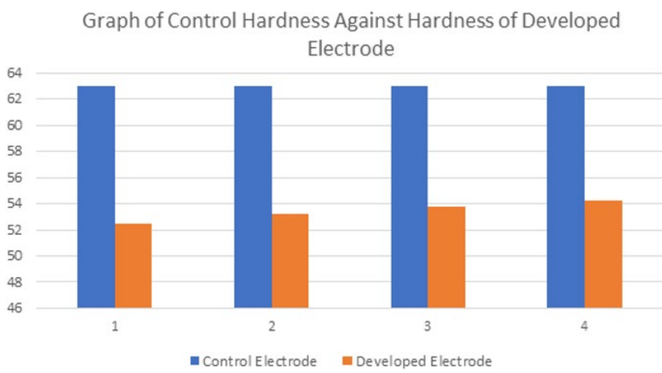

Figure 12. Graph comparing the hardness of control weld with the developed electrode

Figure 12 demonstrates that the hardness of the welded junction improves as the amount of agro-waste in the generated electrode increases in comparison to the base metal (2mm mild steel plate) welded with a control electrode (Grade 8). This result agrees with Afolalu et al. [8] who reported a hardness improvement after yhe use of agro-waste based flux powder for welding process.

5. CONCLUSION

In order to enhance the quality of the weld joint, this study used egg shell, rice husk, palm kernel shell, and coconut shell to produce nanoparticle electrode for use as welding electrode in SMAW welding procedures. The findings are summarized below.

i. When employed in SMAW welding procedures on mild steel rods, the generated electrode increased weld hardness compared to welds made with the control electrode.
ii. When compared to conventional electrodes, Carbon and Nitrogen Oxide is significantly reduced rendering it safer to weld with.
iii. The material used for the developed electrode reduce the moisture absorption of the electrode as compared to control electrodes.
iv. The SEM and EDX examination clearly demonstrate the atomic and weight structure of these wastes after treating them to chemicals to break down the cellulose, and the resulting values in variation show that it consists more of carbon and oxygen.

Basically, the adoption of the agro-based electrode for improved weld quality such as hardness of the welded joint would ensure a more durable joint that would ensure a more dependable structure or part joining void of rapid failure. The acceptability of the agricultural waste components was evaluated using a detailed physicochemical examination, taking into account their composition, mechanical qualities, and thermal stability. Egg shell, coconut shell, rice husk, and shell from palm kernel were found as appropriate materials for the electrode model, based on their availability and acceptable features.

In the future areas such as the investigation of the economic feasibility of large-scale production using agro-waste materials, comparative study with other eco-friendly materials and the long-term durability and performance of these hybrid electrodes in industrial settings could all be explored to further deepen the possibility and wide acceptance of the use of these hybrid electrodes for welding purposes and their acceptability as all these were not highlighted or fully discussed in this present study.

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