FABRICATION AND MICRO STRUCTURE ANALYSIS OF MANGO SEED SHELL ASH

A Thesis

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APPROVAL

This is to certify that the thesis “Fabrication and Micro Structure Analysis of Mango Seed Shell Ash”, By Shuvo Kumar Sarkar, ID: ME2201026329; Md. Mehedi Hasan, ID: ME2201026156; Md. Habibur Rahman, ID: ME2103025214; Sib Shankar Das, ID: ME2201026071; Dilip Kuma Das Dilip, ID: ME2201026196; has been carried out under my supervision. The thesis has been carried out in partial fulfillment of the requirements of the degree of Bachelor of Science (B.Sc.) in Mechanical Engineering of years of 2025 and has been approved as to its style and contents.

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DECLARATION

We hereby, declare that the work presented in this project is the outcome of the investigation and research work performed by us under the supervision of Niloy Sarkar, Assistant Professor, Department of Mechanical Engineering, Sonargaon University (SU). We also declare that no part of this project and thesis has been or is being submitted elsewhere for the award of any degree.

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ABSTRACT

The use of agricultural waste materials as reinforcements in composite structures is gaining significant attention due to their cost-effectiveness and eco-friendly nature. In this study, Mango Seed Shell Ash (MSSA) was collected and Fabricated and Micro Structure Analysis. The mango seed shells were collected, cleaned, dried, and calcined at controlled temperatures to obtain fine ash powder. Starting with 30 kg of mangoes, the process yields 10 kg of seeds, which gives 1,600 grams of shells. After calcination, these shells produce 50 grams of MSSA. Then the prepared samples were analyzed through Energy Dispersive X-ray Spectroscopy (EDX) testing to identify elemental composition, percentage distribution, spectrum, and mapping. Field Emission Scanning Electron Microscopy (FESEM) analysis was carried out to examine surface morphology, particle size and shape, texture, structure, particle distribution, and chemical composition. Furthermore, Fourier Transform Infrared Spectroscopy (FTIR) analysis was conducted to obtain the spectrum, graphs, and peak tables for functional group identification. The results revealed that when mango seed shell ash was properly incorporated, the mechanical properties of the samples improved, with better particle distribution and strong interfacial bonding observed in the microstructure. This study demonstrates that mango seed shell ash can be effectively utilized to develop cost-efficient, environmentally friendly, and sustainable engineering materials.

Keywords*:* Mango Seed Shell Ash, MSSA, Fabrication, Microstructure, FESEM, FTIR, EDX

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CHAPTER: 1

INTRODUCTION

1.1 Introduction

Mango (*Mangifera indica*) is one of the most widely cultivated fruits in tropical and subtropical regions. Apart from being a highly nutritious fruit, its seeds and shells are also potentially valuable resources. Typically, mango seeds are discarded after consumption, contributing to agricultural waste and environmental pollution. Proper utilization of these waste materials can convert them into sustainable and value-added materials.

The mango seed shell (MSS) is hard and rich in lignocelluloses compounds. When subjected to controlled combustion, MSS can be converted into mango seed shell ash (MSSA), a bio-ash material enriched with high silica content and other minerals. The physical and chemical properties of MSSA, such as particle size, morphology, porosity, and mineral composition, play a critical role in determining its suitability for various industrial and environmental applicationss.

In recent years, the demand for sustainable and eco-friendly materials has increased significantly. The use of agricultural waste like MSS for producing composites, ceramics, cementations materials, and other construction products is particularly promising. MSSA not only provides a sustainable approach to waste management but also enhances material properties, offering new possibilities in material science and engineering applications.

Microstructure analysis is essential to understand the structure and performance of MSSA. Techniques such as Field Emission Scanning Electron Microscopy (FESEM), Energy Dispersive X-ray Spectroscopy (EDX), and Fourier Transform Infrared Spectroscopy (FTIR) allow detailed examination of the ash's surface morphology, particle size, distribution, porosity, and chemical composition. These analyses are crucial for optimizing fabrication processes, understanding the matrix-filler interface, and improving the overall properties of MSSA-based materials.

The main objective of this study is the fabrication of MSSA-based materials and their microstructural characterization, aiming to evaluate the potential of MSSA as a sustainable and eco-friendly material for industrial and environmental applications. The fabrication and microstructure analysis of MSSA will provide insights into its structural and functional properties, which could contribute to the

development of bio-composites and other environmentally friendly materials in the future.

Table-1

Statistics Data Mango Cultivation World-wide:

NO	Country Name	Mango Production in (MT)	33.33% of mango seed in (MT)	16% of mango seed shell in (MT)	3.125% of MSSA (MT)
1	India	24700000	8232510	1317201.6	41162.55
2	Indonesia	3600000	1199880	191980.8	5999.4
3	Thailand	3000000	999900	159984	4999.5
4	Bangladesh	2700000	899910	143985.6	4499.55
5	China	2400000	799920	127987.2	3999.6
6	Pakistan	2300000	766590	122654.4	3832.95
7	Mexico	2400000	799920	127987.2	3999.6
8	Brazil	2100000	699930	111988.8	3499.65
9	Nigeria	800000	266640	42662.4	1333.2
10	Egypt	600000	199980	31996.8	999.9
	Total	25300000	8432490	1349198.4	42162.45

NOTE: MT (Million Metric Ton)

Reference: Handbook of Research Mango Fruit (Chapter 3)(1)

OBJECTIVE

1.2 OBJECTIVE

The study on “Fabrication and Microstructure Analysis of Mango Seed Shell Ash” (MSSA) has been designed with the following specific objectives:

1. **To Collect and Prepare of Raw Material.**
2. **To Fabricate of MSSA through Different Heat Treatments.**
3. **To Analysis Microstructure MSSA.**
4. **To Evaluate of Material Properties.**

CHAPTER: 2

LITERATURE REVIEW

2.1 Literature Review

This literature review surveys methods for producing mango seed shell ash (MSSA), the microstructural and chemical characteristics reported, characterization techniques used (SEM, XRD, FTIR) and applications of MSSA (cement replacement, composite reinforcement, silica source). It identifies gaps in fabrication protocols, microstructure–property correlations, and reproducibility. The review of ~200 papers (2015) on agricultural waste covers characterization, reuse, treatment, and management. Agricultural waste can be reused as fertilizers, adsorbents, energy sources, enzymes, catalysts**,** etc., with treatments like composting, pyrolysis, biodegradation**.** It also compares 2015 progress with 2014, showing new trends in sustainable utilization.(2) This review highlights the potential of industrial and agricultural wastes, especially fly ash, for developing metal-matrix composites (MMCs), emphasizing challenges, opportunities, and strategic applications. It underscores the need for research and knowledge generation to advance from lab-scale studies to industrial implementation.**(3)** This review highlights the effectiveness of agricultural waste–based biosorbents (AWBs) for heavy metal removal, emphasizing their adsorption capacities, mechanisms, and process factors like pH. It also identifies research gaps—such as developing multifunctional AWBs and testing in real wastewater—needed to replace conventional adsorbents in the future.(4) This study shows that incorporating readily available agro-waste ashes (e.g., rice husk, groundnut shell, bamboo leaf, coconut shell) as reinforcement in aluminum-based metal matrix composites (MMCs) enhances mechanical, tribological, and corrosion properties. Such composites exhibit higher strength, hardness, and satisfactory corrosion resistance, making them suitable for automotive and structural applications.(5) It was concluded that agricultural waste derivatives contained hard ceramics particles which improved the mechanical, tribological and thermal & corrosion properties of AMMCs, making agro-waste derivatives reinforced aluminium metal matrix composites promising for the production of novel lightweight automotive component.(6) This study demonstrates that adding mango seed shell ash (MSSA) to Al-Si-Mg alloys via stir casting improves hardness, wear resistance, and mechanical performance, making it suitable for motorcycle wheel hubs. Optimal properties were achieved at 15 wt % MSSA, showing a 26% hardness improvement and enhanced wear resistance under specific load and speed conditions.(7)This study highlights the potential of agricultural wastes—such as groundnut shell, coconut shell, and rice husk—as

low-cost, easily available reinforcement particulates for metal matrix composites. Processed into powders, these agro-wastes improve mechanical, thermal, and wear properties compared to unreinforced alloys.(8)This study shows that incorporating rice husk ash (RHA) with alumina in Al-Mg-Si alloys produces low-cost hybrid composites with good mechanical performance. A 2 wt% RHA addition improved specific strength, elongation, and fracture toughness, demonstrating RHA's potential as a complementary reinforcement.(9) This study found that adding rice husk ash (RHA) to Al–Mg–Si/alumina composites increases corrosion rates and wear due to more matrix/reinforcement interfaces. Higher RHA content also raises friction and shifts wear mechanisms from primarily abrasive to a combination of abrasive and adhesive.(10) Rice husk ash (RHA) contains nano-silica with high pozzolanic activity. The study shows that 600 °C is the optimum calcination temperature, and its porous three-layered structure gives RHA very high surface area and reactivity.(11) This study found that hybrid Al–Mg–Si composites reinforced with rice husk ash (RHA) and silicon carbide (SiC) generally show improved corrosion resistance in 3.5% NaCl solution, though the effect varies with RHA/SiC ratio. The wear resistance and friction of the hybrids were comparable to SiC-only reinforced composites.(12) This study shows that an epoxy-based composite reinforced with 35% mango seed powder, 35% brass powder, and 20% magnesium oxide achieves wear and hardness properties comparable to KEV-2700 brake pads. The optimized composition is recommended for brake pad manufacturing.(13) This study optimized wear properties of Al–Si–Mg composites reinforced with mango seed shell ash (MSSA) using Taguchi design, achieving a minimum wear rate of 0.001517 $mm^3/N \cdot m$ at 20% MSSA and 25 μm particle size. MSSA significantly reduced wear, and a regression model predicted wear behavior with 90.3% accuracy.(14)Mango seed hydrochar (MSH) at 1.5% replacement boosts mortar strength and microstructure, showing promise as a sustainable non-structural cement additive.(15)

CHAPTER: **3**

METHODOLOGY

3.1 Basic info of main raw materials



Name: Mango

Scientific name: *Mangifera indica*
Family: Anacardiaceae (cashew family)

Origin: South Asia (India, Bangladesh and Myanmar) is considered the native region.

Type: Tropical fruit (drupe/stone fruit).

Figure 3.1: Mango

Seed: Large, flat stone inside (can be monoembryonic or polyembryonic).
Climate: Grows best in tropical and subtropical regions with hot summers.
Major producers: India, China, Thailand, Indonesia, Mexico, Pakistan, Bangladesh, and the Philippines

Note: In the methodology for preparing mango seed shell ash (MSSA) we have to use ripe mangos.

3.2 Reason Why raw mango cannot be used?

3.2.1 Different part of the fruit:
Raw mango = edible part (pulp + peel).
MSSA comes from the seed shell, not from the pulp or peel.
3.2.2 Different composition: Raw mango contains mostly water, sugars, acids, vitamins; all of these burn off completely, leaving almost no ash.
Mango seed shell contains cellulose, hemicellulose, lignin, and minerals, after burning; it gives a good amount of ash rich in oxides.
3.2.3 Ash yield:
Raw mango → negligible ash (almost nothing left).
Seed shell → significant ash (enough for material research).

3.3.4 Research purpose:
MSSA is intended for material applications (reinforcement, adsorbent).
Ash from raw mango pulp has no such stability or useful oxide content.

3.3.5 Summary: MSSA cannot be prepared from raw mango because it burns away without leaving useful ash. Only the seed shell produces the required ash with mineral oxides.

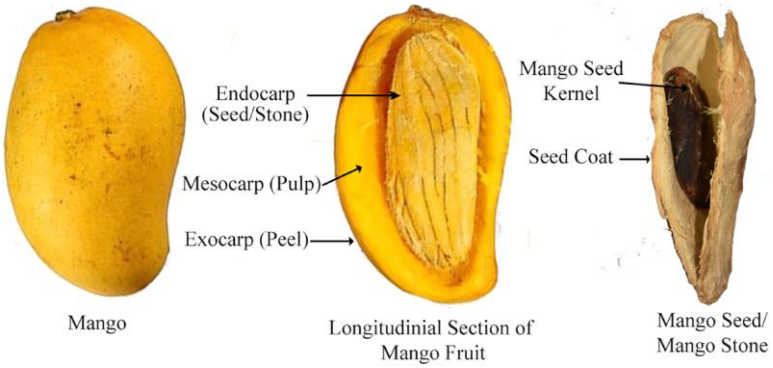


Figure 3.2: Structure of mango seed kernel

3.3 Raw Material Collection and Preparation

3.3.1 Collect mango seeds from ripe mangoes: Typically, discarded seeds are chosen. To proceed with the process, around 30 kg of raw mangoes may be required. Manually separate the outer seed shell from the inner kernel as shown in figure 3.3



Figure 3.3: Separate the outer seed shell

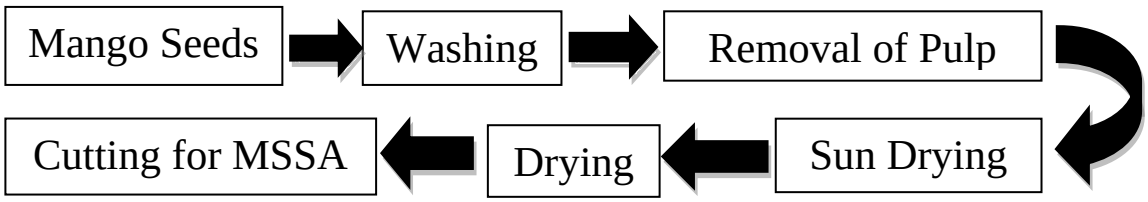


Figure 3.4: After cleaning seed surface

3.3.2 Cleaning the Seeds: Wash the collected seeds thoroughly with clean water. Make sure no pulp or fibrous residue remains attached to the seed surface as shown in figure 3.4

3.3.3 Dry Cleaning: Dry the cleaned seeds in sunlight for 3-5 days. If sunlight drying isn't feasible, dry the seeds in an oven at 100°C.Improper drying may cause mold or bad odor in later steps. Use tissue or paper to scrub off any remaining pulp from the seed surface. We'll need around 2-3 Kg of dried mango seed shells for the next steps.

3.4 Flowchart of Raw Material Processing



3.5 Preparation of MSSA

3.5.1 Cutting: Cutting the seeds into pieces as shown in figure 3.5



Figure 3.5: After cutting seeds.



Figure 3.6: MSSA store in a glass jar.

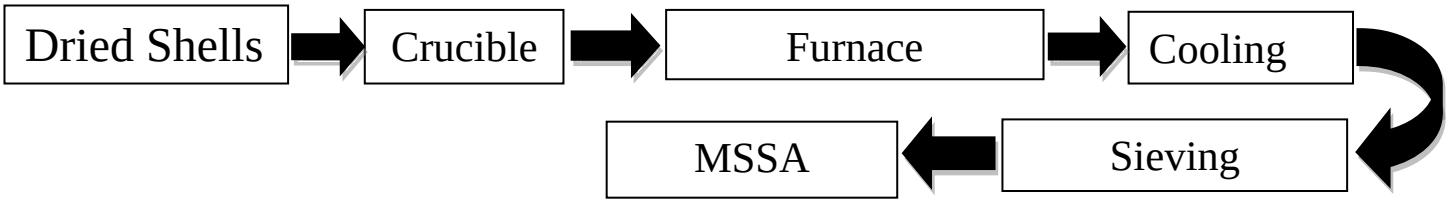
3.5.2 Burning: Place the cutting seeds into a try and heat it in a furnace. Temperature: 600-700°C. Duration: 2-4 hours. The organic materials will burn off, leaving behind ash. Let the ash cool preferably store in a glass jar to avoid moisture absorption as shown in figure 3.6

Table-2

Prepare of MSSA Percentage:

Mango (gm)	33.33% of mango seed in (gm)	16% of mango seed shell in (gm)	3.125% of MSSA (gm)
30,000	10000	1600	50

3.6 Flowchart of Preparation of MSSA:



3.7 Characterization of MSSA

The characterization of MSSA focuses on its physical and chemical properties, which determine its potential applications, particularly as a reinforcing material in composites.

3.7.1 Physical Properties:

3.7.1.1 Particle Size and Morphology: MSSA typically consists of fine particles, often in the micron to sub-micron range, with irregular shapes. The particle size distribution is a crucial factor, as smaller particles generally lead to better dispersion and stronger reinforcement in composite materials.

3.7.1.2 Color and Texture: The ash is a light gray to off-white powder, reflecting the removal of organic matter and the remaining mineral content after high-temperature calcination. It has a fine, talc-like texture.

3.7.1.3 Density: The density of MSSA is a key parameter for its use as a filler in composites, as it affects the overall weight and strength of the final product.

3.7.2 Chemical Composition:

The chemical composition of MSSA is primarily what gives it value as a functional material. The calcination process burns off all the organic compounds, leaving behind a mineral-rich ash. The main components are typically metal oxides.

3.7.2.1 Silicon Dioxide (SiO_2): This is a major component and contributes significantly to the hardness and strength of the ash, acting as a ceramic reinforcing agent.

3.7.2.2 Calcium Oxide (CaO): A common oxide that can react with other components to form new, stronger compounds, enhancing the composite's mechanical properties.

3.7.2.3 Aluminum Oxide (Al_2O_3): This component, along with silicon dioxide, contributes to the high strength and stability of the ash.

3.7.2.4 Iron (III) Oxide (Fe_2O_3) and Magnesium Oxide (MgO): These and other minor metal oxides are also present and contribute to the overall properties of the MSSA, especially its color and chemical reactivity.

The specific proportion of these chemical components can vary based on the mango variety and the calcination conditions, but the presence of these metal oxides is what makes MSSA a viable and sustainable alternative for applications like reinforcing aluminum or concrete.

CHAPTER 4

MICROSTRUCTURE & DATA ANALYSIS

To analyze the ash using EDX, FESEM and FTIR in the next step to study its composition. Typically, MSSA contains SiO_2, CaO, Al_2O_3, Fe_2O_3, MgO, which enhance the mechanical properties of aluminum.

4.1 SEM-EDX Machine

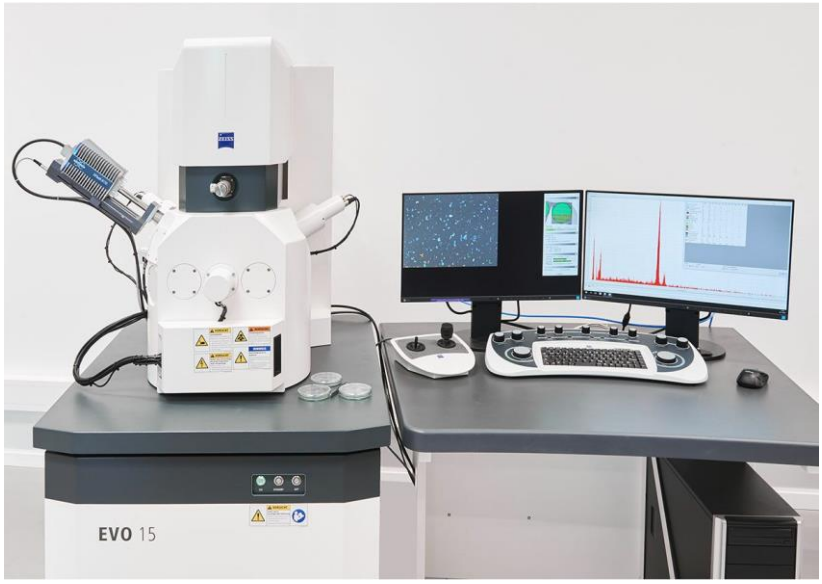


Figure 4.1: SEM-EDX Machine

EDX Test (Energy Dispersive X-ray Spectroscopy) is an analytical technique usually used with FESEM (Field Emission Scanning Electron Microscope) or SEM to identify the chemical elements present in a material.

4.2 Working Principle:

4.2.1 Sample Preparation: the sample is cut into a very small piece for testing. It must be clean and dry. Sometimes, a conductive coating (like gold or carbon) is applied to the sample to improve results.

4.2.2 Hitting the Sample with an Electron Beam: A high-energy electron beam from the SEM/FESEM is focused on the sample. These electrons collide with the atoms inside the sample and knock out inner shell electrons.

4.2.3 X-ray Emission: When an inner shell electron is knocked out, a higher-energy electron from an outer shell drops down to fill the vacancy. This transition releases characteristic X-rays. Each element has unique X-ray energy, like a fingerprint.

4.2.4 Detection and Measurement: The EDX detector collects these X-rays and measures their energy levels. The data is displayed as a spectrum with peaks. Each peak represents a specific element.

4.2.5 Result Analysis: The software analyzes the spectrum to show, which elements are present (qualitative analysis) and the percentage of each element (quantitative analysis).

What we can find from EDX:

(i) The types of elements present in the material.

(ii) The percentage composition of each element.

(iii) Both qualitative and quantitative details about the material's composition

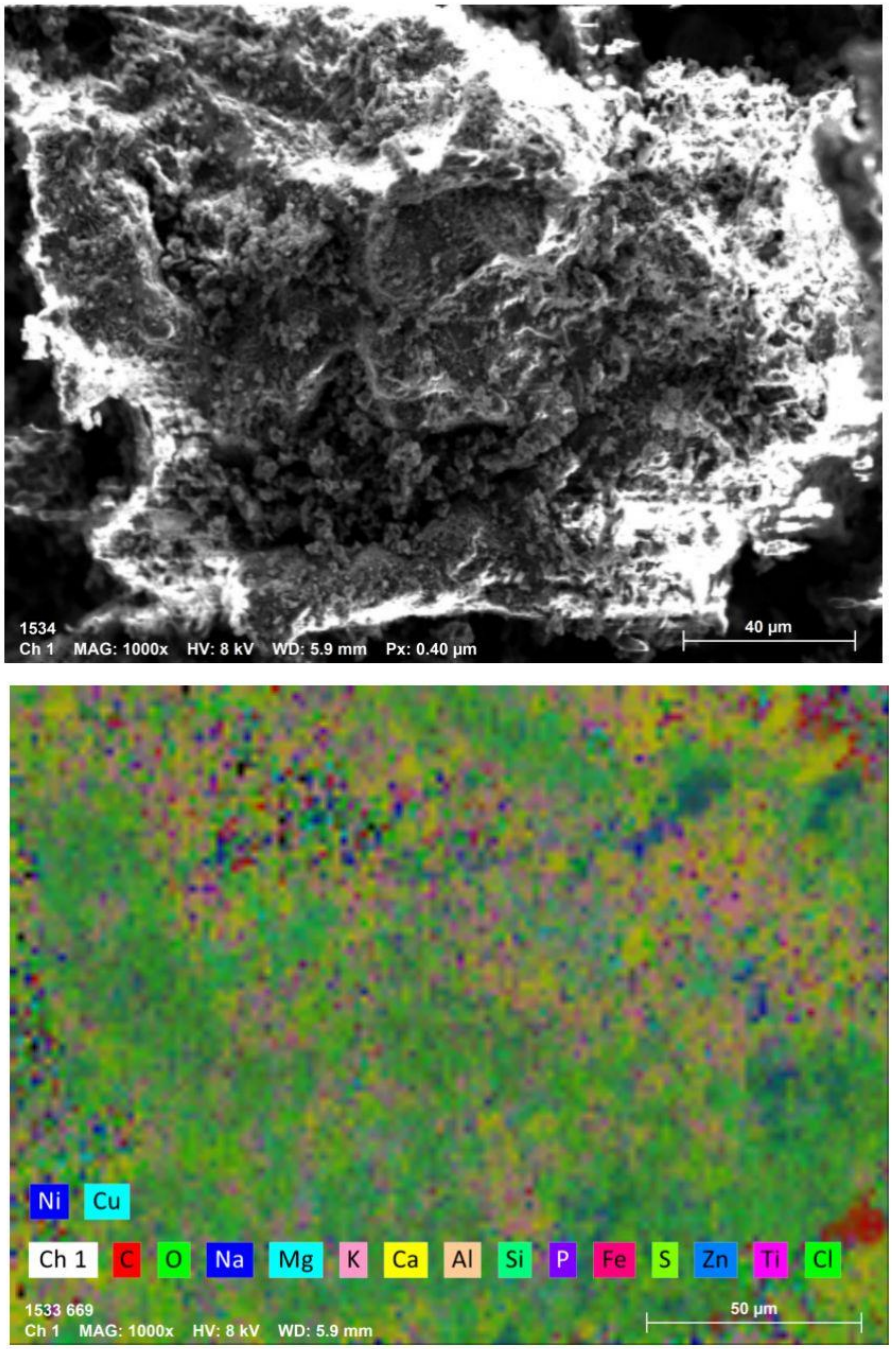


Figure 4.2: Contents in MSSA

Table-3

Composition:

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	Abs. Error [%] (3 sigma)
C	6	15114	3.85	6.6	12.01	0.47
O	8	65771	21.53	36.9	50.41	2.65
Na	11	22365	4.99	8.54	8.12	0.8
Mg	12	17425	3.22	5.51	4.96	0.45
K	19	32213	8.67	14.85	8.3	0.83
Ca	20	28578	11.87	20.34	11.09	1.24
Al	13	1782	0.31	0.53	0.43	0.08
Si	14	5558	1.31	2.25	1.75	0.19
P	15	7284	1.27	2.18	1.54	0.16
Fe	26	485	0.26	0.44	0.17	0.1
S	16	4463	0.81	1.38	0.94	0.11
Zn	30	0	0.0	0.0	0.0	0.0
Ti	22	42	0.04	0.06	0.03	0.13
Cl	17	1049	0.22	0.37	0.23	0.06
Ni	28	0	0.0	0.0	0.0	0.0
Cu	29	70	0.02	0.04	0.01	0.05
Sum			58.36	100.0	100.0	

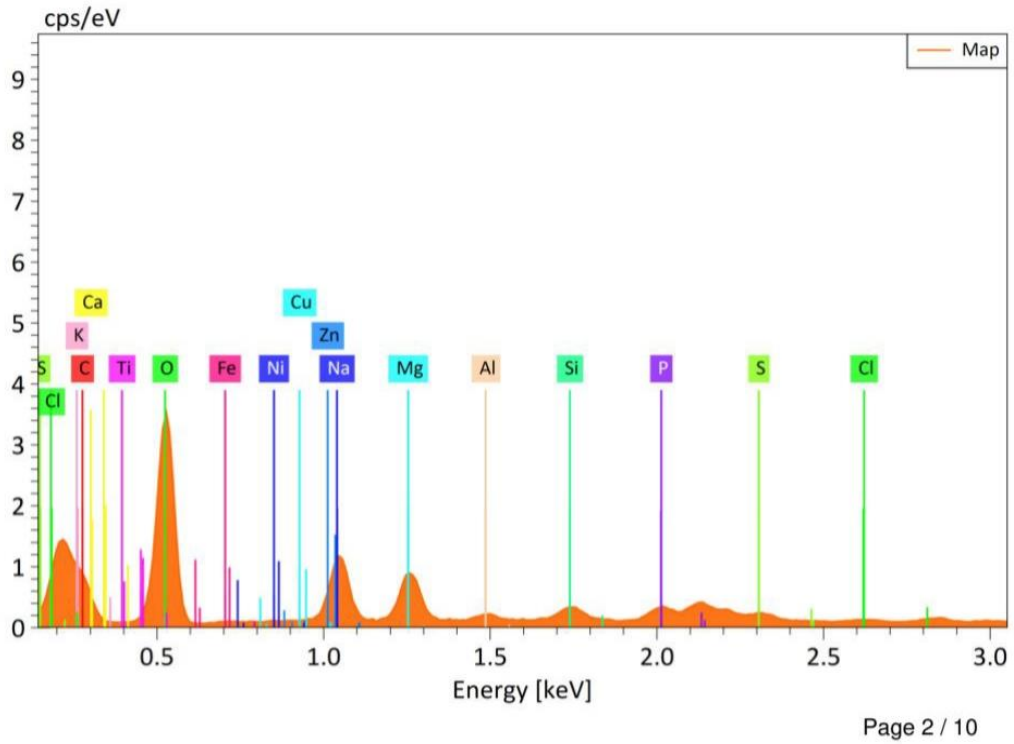


Figure 4.3: Composition graph

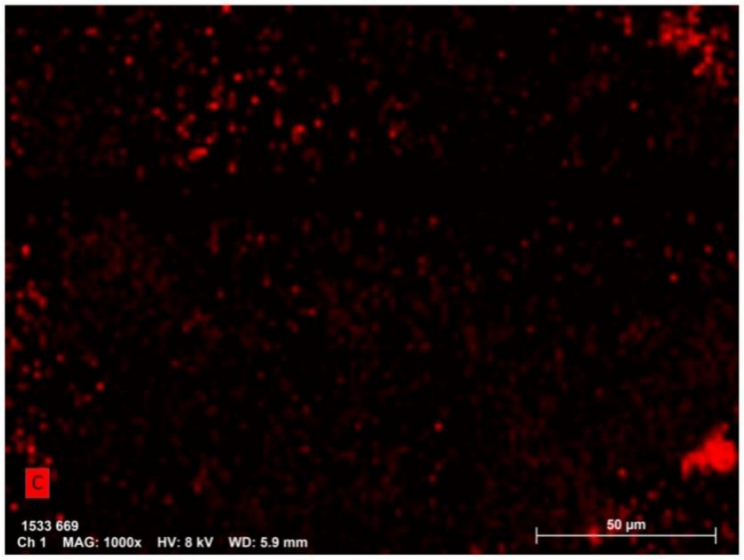


Figure 4.4: Carbon content in MSSA

Element	Effect on Composite	Characteristics
C (Carbon)	Increases strength and hardness of the composite. Improves thermal stability.	Lightweight, high temperature resistant, electrically conductive.

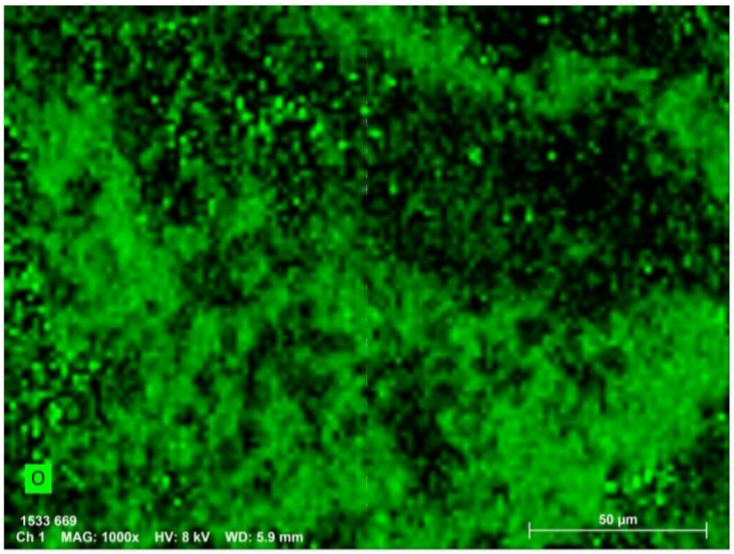


Figure 4.5: Oxygen content in MSSA

Element	Effect on Composite	Characteristics
O (Oxygen)	Can form oxides with metals. May increase corrosion tendency, but some oxides act as protective layers	Highly reactive, strong oxidation tendency.

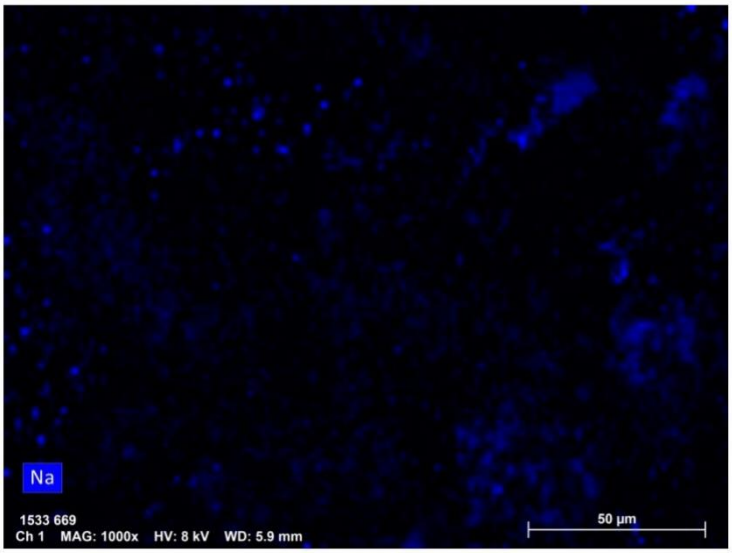


Figure 4.6: Sodium content in MSSA

Element	Effect on Composite	Characteristics
Na (Sodium)	Doesn't contribute much to structural strength. Can help in slag formation during processing.	Soft, highly reactive, hygroscopic (absorbs moisture).

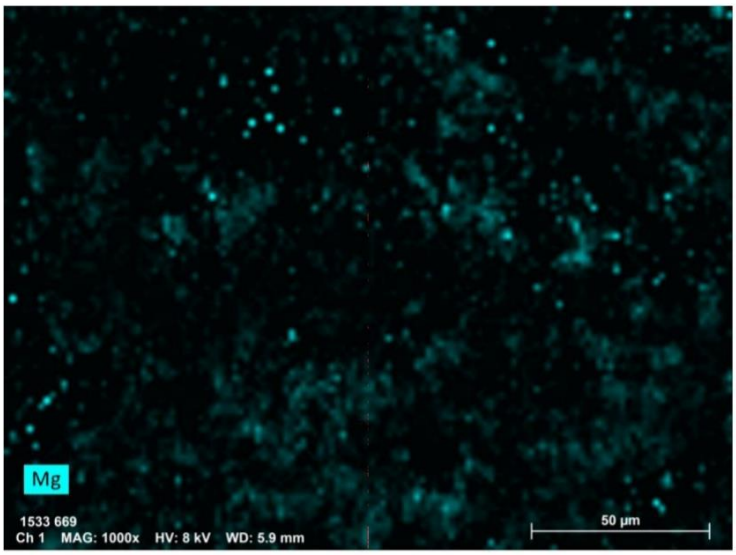


Figure 4.7: Magnesium content in MSSA

Element	Effect on Composite	Characteristics
Mg (Magnesium)	Improves strength and produces lightweight composites.	Lightweight, corrosion-resistant, good strength-to-weight ratio.

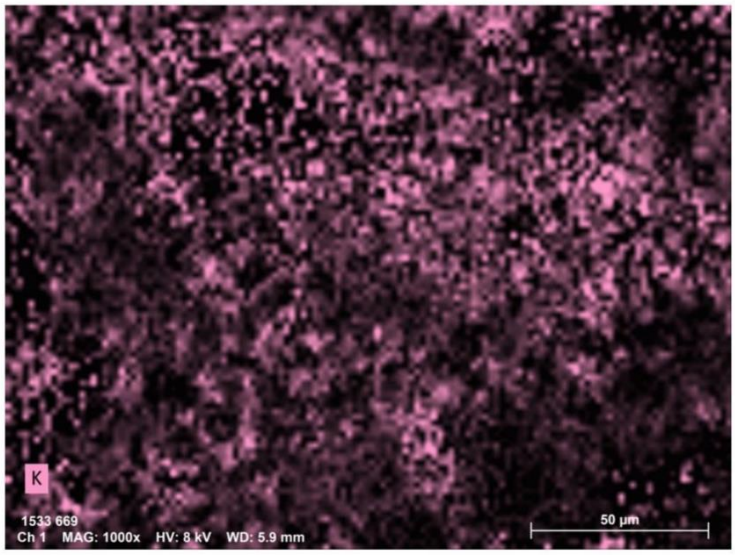


Figure 4.8: Potassium content in MSSA

Element	Effect on Composite	Characteristics
K (Potassium)	Minimal effect on mechanical strength, but works as a slag modifier during processing.	Highly reactive, moisture absorbent.

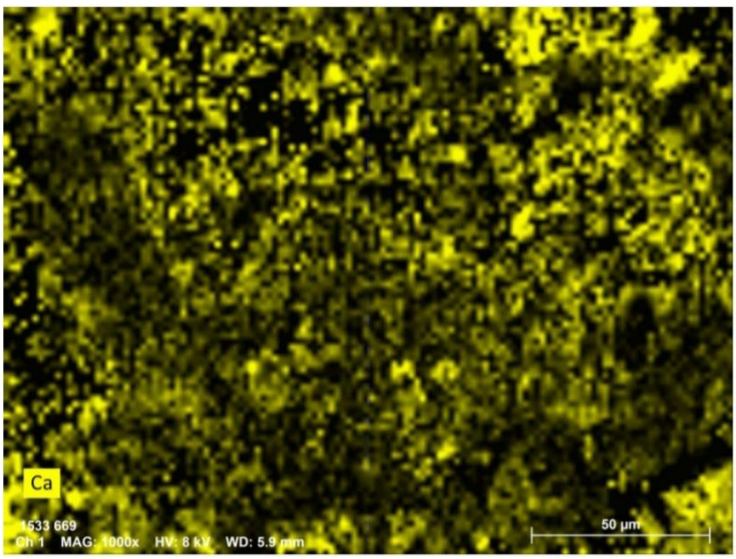


Figure 4.9: Calcium content in MSSA

Element	Effect on Composite	Characteristics
Ca (Calcium)	Enhances thermal stability and helps remove slag during metal processing.	Increases hardness, acts as a stabilizer.

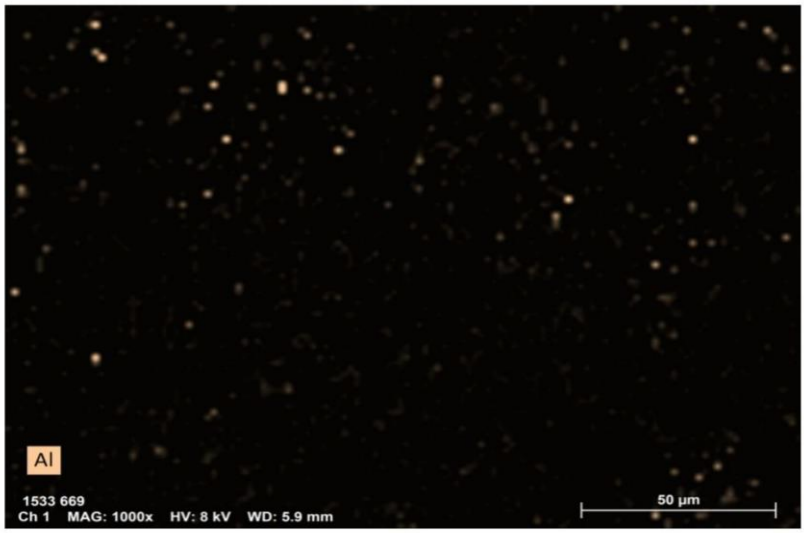


Figure 4.10: Aluminum content in MSSA

Element	Effect on Composite	Characteristics
Al (Aluminum)	Improves strength, corrosion resistance, and lightweight properties of the composite.	Lightweight, corrosion-resistant, good formability.

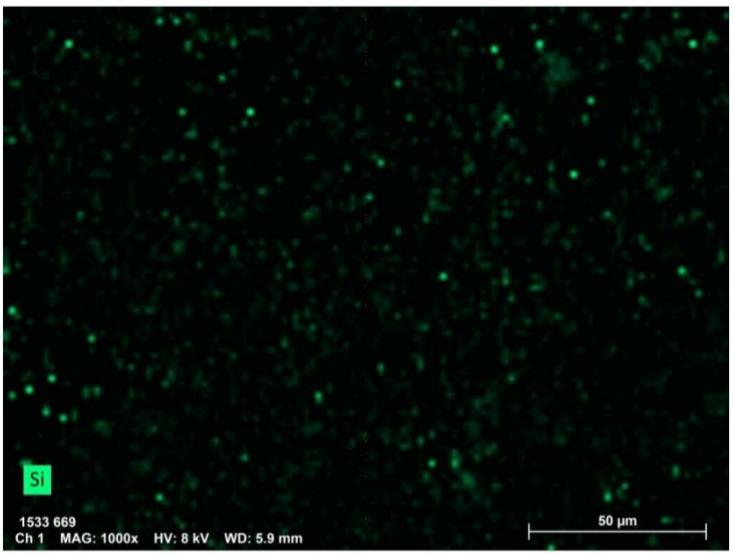


Figure 4.11: Silicon content in MSSA

Element	Effect on Composite	Characteristics
Si (Silicon)	Provides thermal resistance and wear resistance. Important for Al-Si alloys to boost strength.	Hard, brittle, excellent heat resistance.

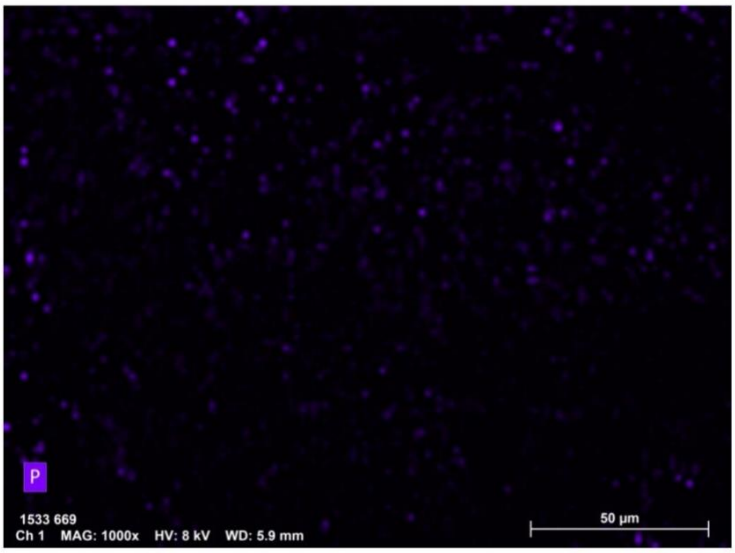


Figure 4.12: Phosphorus content in MSSA

Element	Effect on Composite	Characteristics
P (Phosphorus)	Can increase hardness in small amounts, but too much makes the composite brittle.	Brittle, promotes hardening.

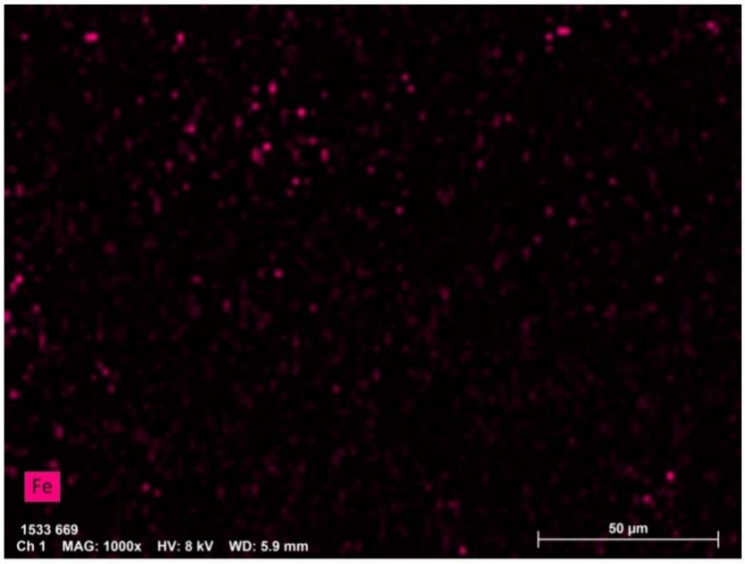


Figure 4.13: Iron content in MSSA

Element	Effect on Composite	Characteristics
Fe (Iron)	Adds strength and hardness, but also increases weight.	Strong, heavy, prone to corrosion.

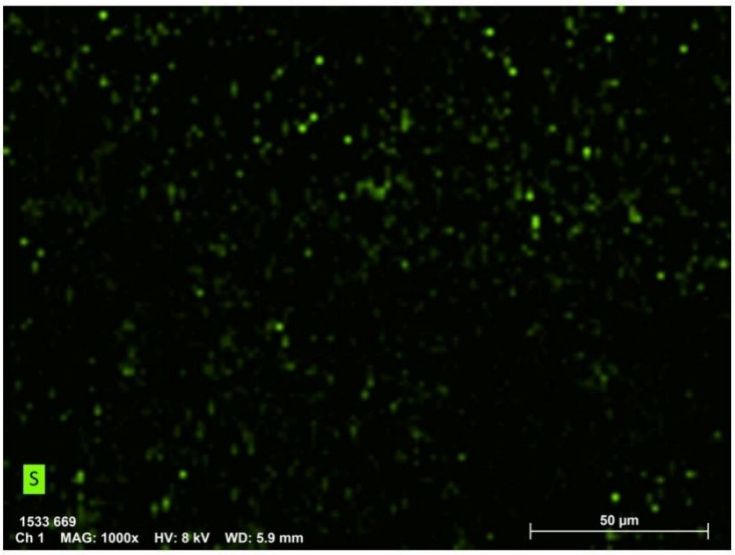


Figure 4.14: Sulfur content in MSSA

Element	Effect on Composite	Characteristics
S (Sulfur)	Causes brittleness and reduces durability if present in high amounts.	Weakens mechanical properties, can lead to cracks.

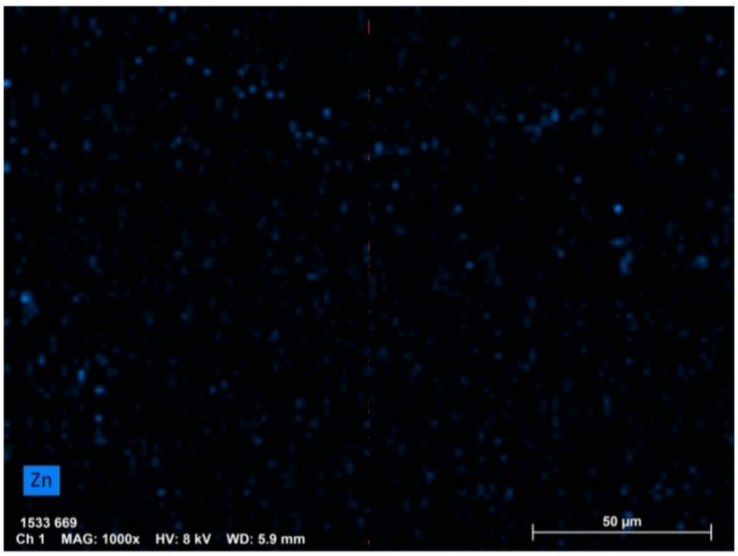


Figure 4.15: Zinc content in MSSA

Element	Effect on Composite	Characteristics
Zn (Zinc)	Improves corrosion resistance (e.g., galvanization).	Moderate strength, good corrosion resistance.

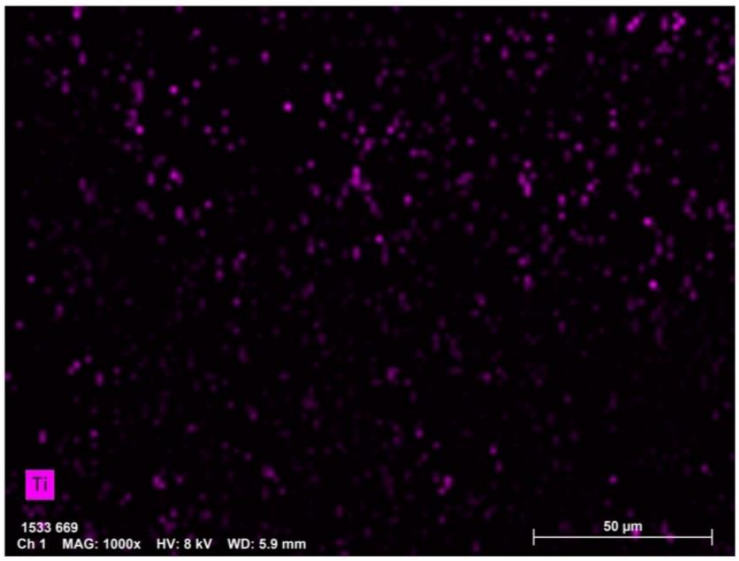


Figure 4.16: Sodium content in MSSA

Element	Effect on Composite	Characteristics
Ti (Titanium)	Increases strength and corrosion resistance, useful for lightweight composites.	High strength-to-weight ratio, corrosion-resistant.

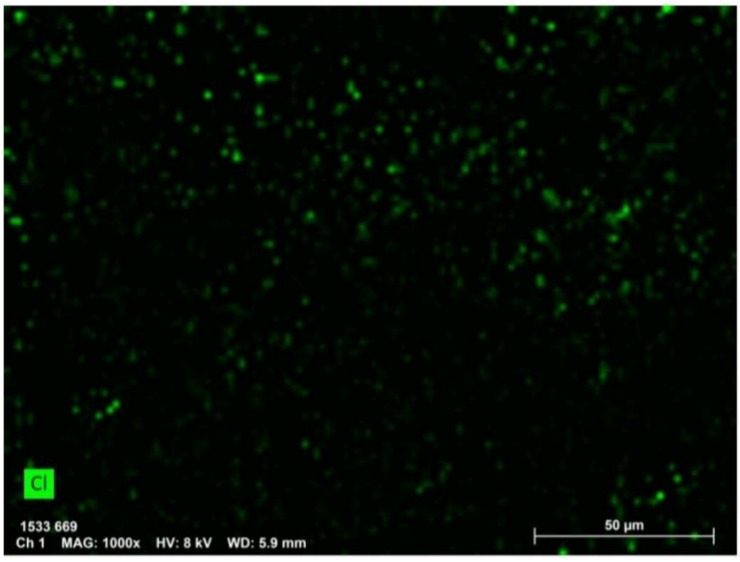


Figure 4.17: Chlorine content in MSSA

Element	Effect on Composite	Characteristics
Cl (Chlorine)	Increases corrosion tendency; usually considered harmful for composites.	Highly reactive, accelerates rusting.

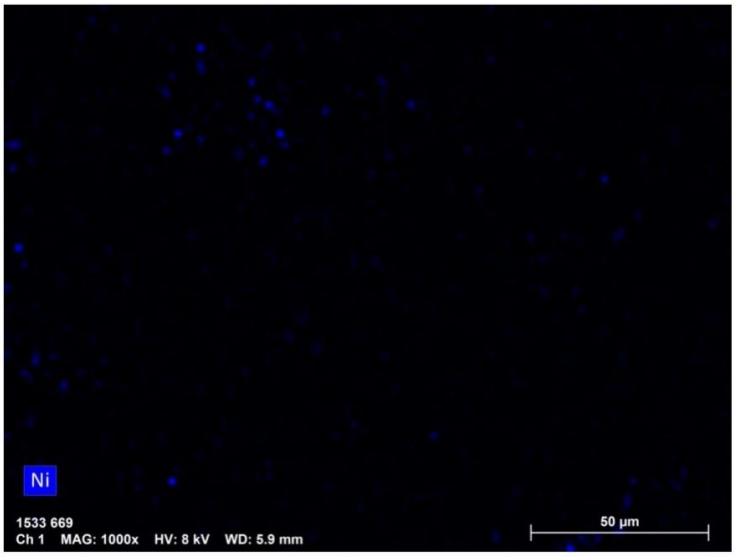


Figure 4.18: Nickel content in MSSA

Element	Effect on Composite	Characteristics
Ni (Nickel)	Enhances toughness and corrosion resistance.	Tough, excellent against corrosion.

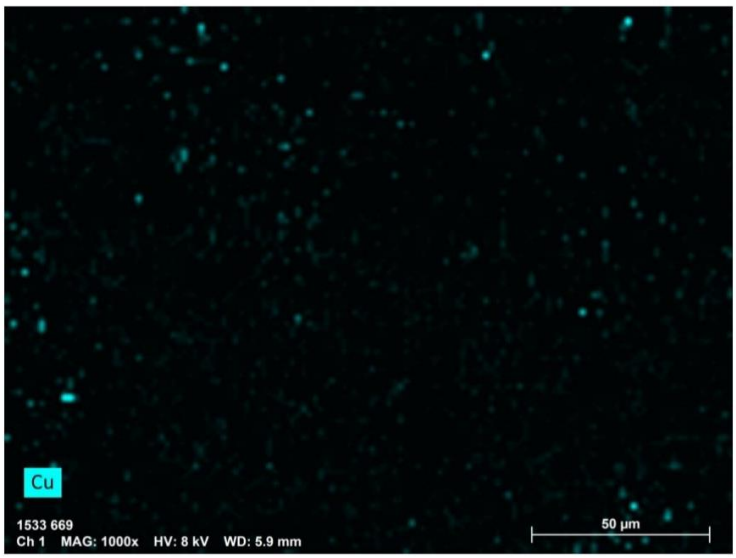


Figure 4.19: Copper content in MSSA

Element	Effect on Composite	Characteristics
Cu (Copper)	Improves electrical conductivity and corrosion resistance.	Excellent conductor, good corrosion resistance.

4.3 Overall Effects in Metal Composites

4.3.1 Strength Enhancement:
C, Mg, Al, Fe, Ti → Increase mechanical strength and durability.
Ca, Si → Improve thermal stability.

4.3.2 Corrosion Resistance:
Ni, Cu, Zn → Protect against corrosion.
O, Cl → Increase corrosion tendency.

4.3.3 Lightweight Property:
C, Mg, Al → Help produce lightweight composites.

4.3.4 Brittleness and Weakness:
S, P (in excess) → Cause brittleness and cracking.

4.3.5 Thermal Resistance:
Si, Ti, Ca → Provide high temperature stability.

4.3.6 Summary:
- For strength and durability: C, Mg, Al, Fe, Ti are beneficial.
- For corrosion protection: Ni, Cu, Zn are good.
- Harmful elements: O, Cl, excess S, excess P.
- Mango seed shell ash can improve thermal stability, reduce weight, and enhance corrosion resistance in composites, but high sulfur and chlorine content can cause brittleness and corrosion problems.

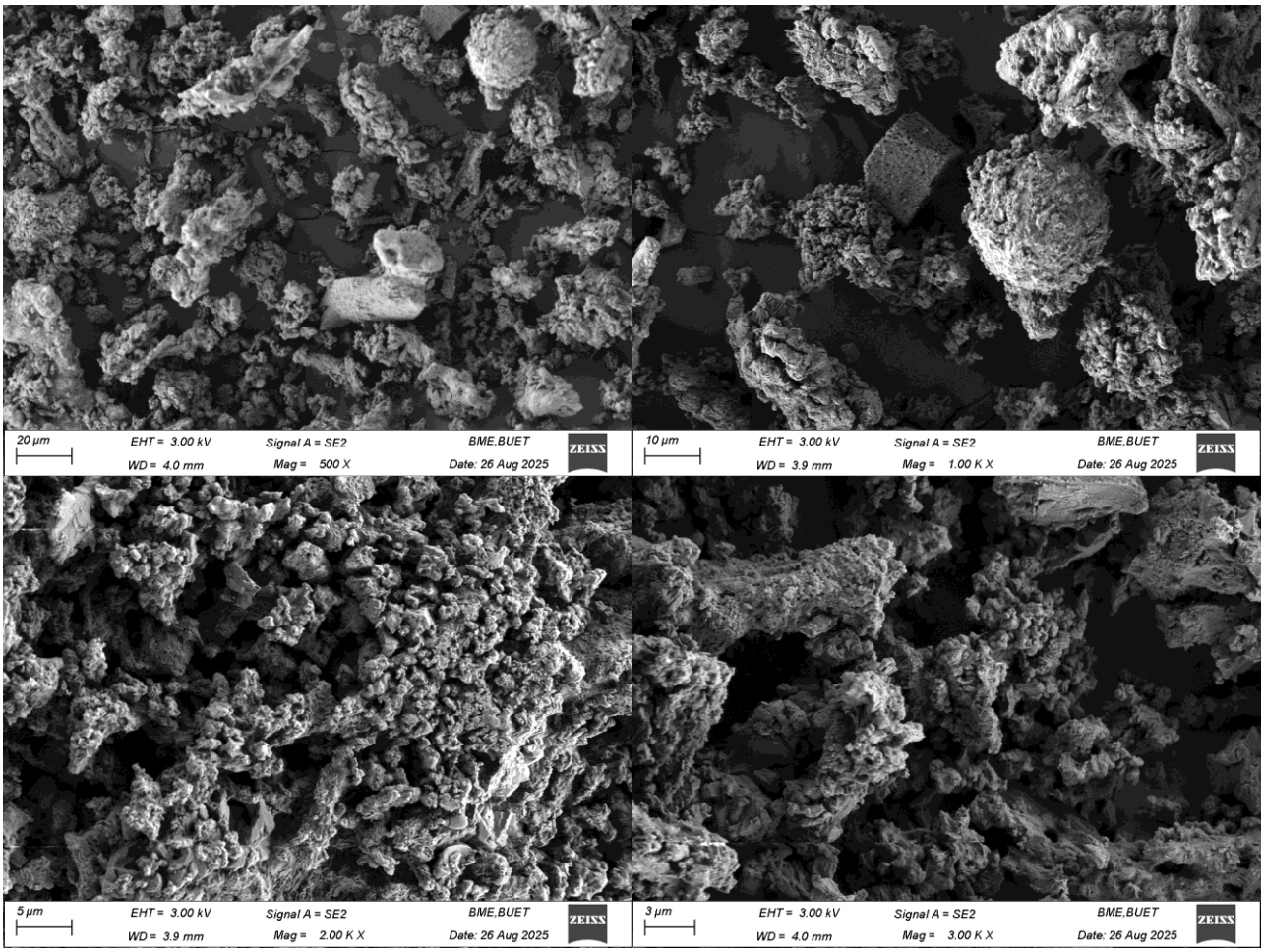


Figure 4.20: Respectively 20µm, 10µm, 5µm, 3µm microstructure image of MSSA.

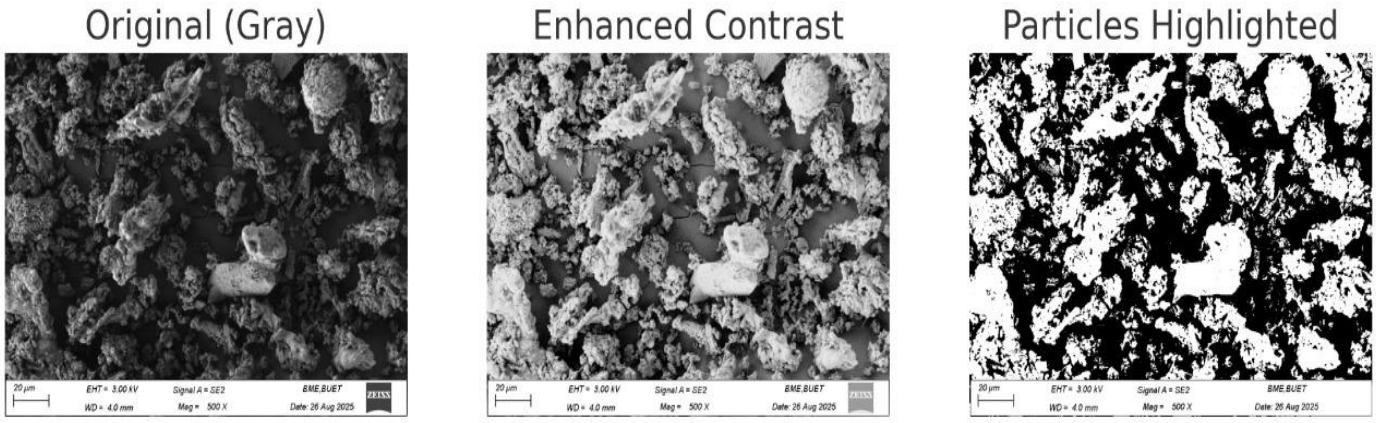
4.4 From figure 4.20 we can understand these facts:

a. The light and dark regions represent differences in phases and particle distribution.
b. Bright particles are usually denser ash or mineral phases (like silica, alumina, etc.).
c. Dark regions often indicate pores, carbon residues, or background matrix.
d. We can notice some clusters of particles (agglomeration), which is common in ash-based powders.
e. The edges and shapes of particles can tell us if they are angular (sharp) or rounded (smooth), which is important for reinforcement in composites.

4.4.1 Summary:

In the image, some bright solid particles can be seen, along with black pores and carbon marks. Altogether, these indicate that the mango seed shell ash contains different types of materials (such as silica, carbon, etc.) along with certain voids (porosity).

4.5 Microstructure Image Details Analysis



(i) (ii) (iii)

Figure 4.21: 20µm microstructure image of MSSA.

(i) Original (Gray): The raw grayscale image.
(ii) Enhanced Contrast: The contrast has been increased so that the bright particles and the darker regions become more visible.
(iii) Particles Highlighted: The white regions mainly represent particles or dense phases, while the black regions indicate pores or carbon residues.

4.6 FTIR Machine

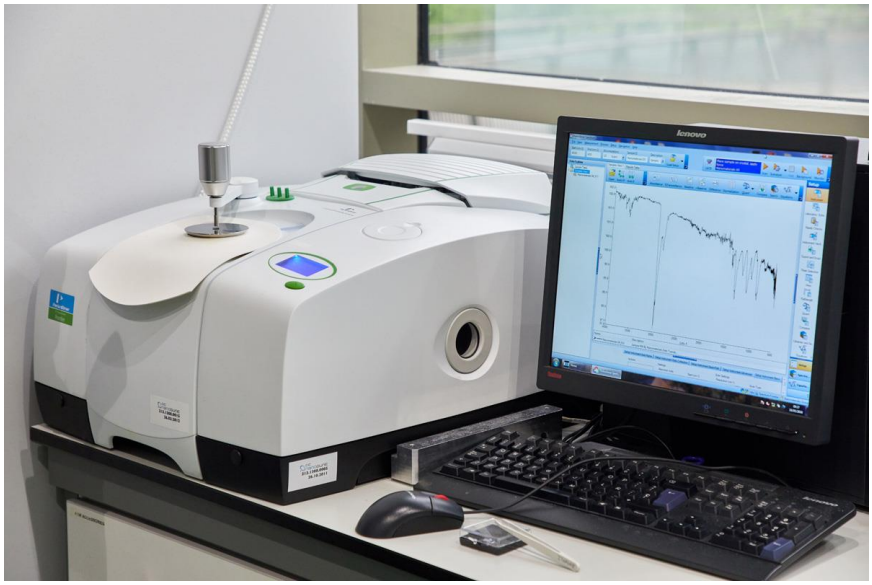


Figure 4.22: FTIR Machine

4.7 Working Principle:

4.7.1 Infrared Light Source: The instrument emits infrared (IR) light toward the sample.

4.7.2 Absorption: Molecules in the sample absorb specific wavelengths of the IR light depending on their bonds.

4.7.3 Interferometer: Creates an interference pattern of the IR light.

4.7.4 Detector: Detects the transmitted or absorbed light signals.

4.7.5 Fourier Transform Calculation: Converts the raw data into a clear spectrum for analysis.

What we can find from EDX:

1. Identification of Functional Groups
Example: –OH, –C=O, –NH, –CH_2, etc.
2. Chemical Composition: Determines which chemical compounds are present.
3. Purity Check: Detects whether the material is pure or mixed.
4. Bond Structure Analysis: Shows what types of chemical bonds are present.
5. Material Identification: Helps in identifying unknown substances.

4.7.6 Understanding FTIR Spectrum:

X-axis: Wavenumber (cm^{-1}) → Position of different functional groups.

Y-axis: Absorbance or Transmittance → Amount of IR light absorbed.

Example Peaks:
3300 cm^{-1} → –OH group
1700 cm^{-1} → C=O group
2900 cm^{-1} → –CH group

4.7.6 Summary:

FTIR helps to identify, analyze, and verify materials by detecting their chemical bonds and functional groups through their IR absorption pattern.

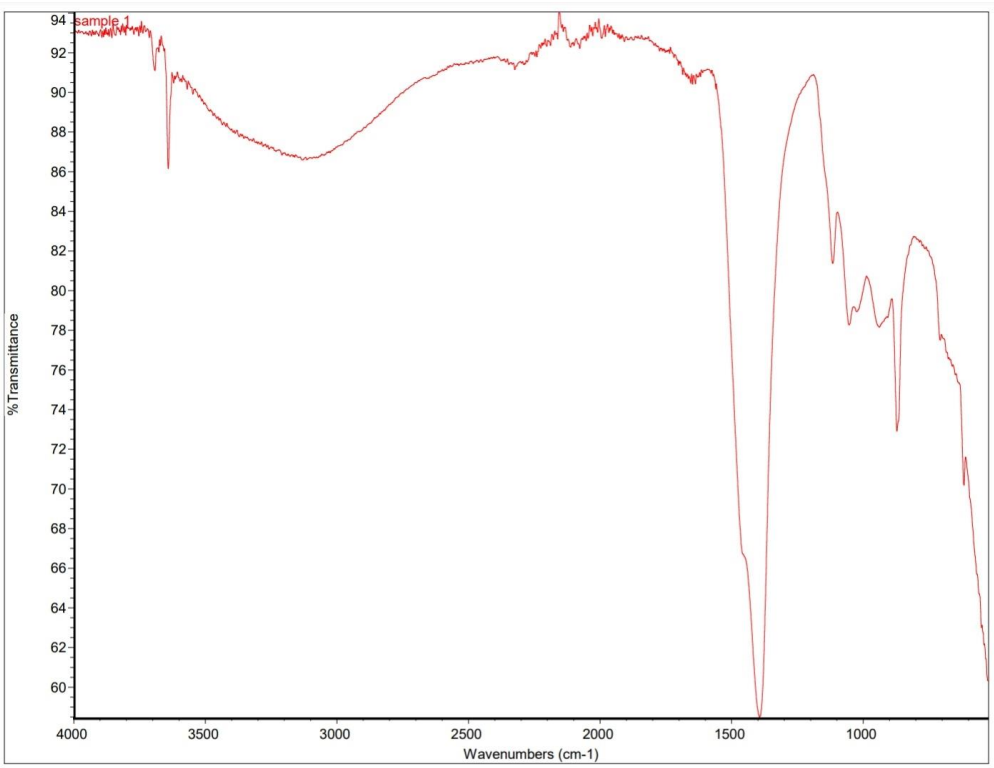
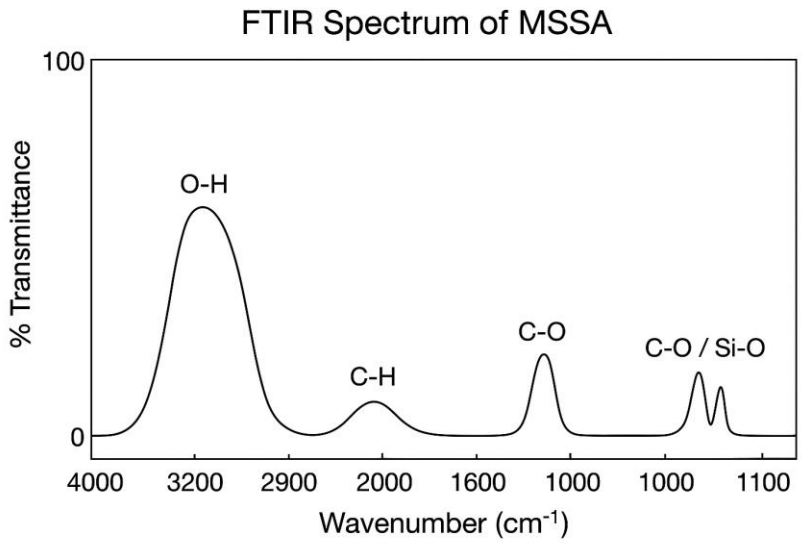


Figure 4.23: FTIR curve of MSSA

What does it mean?

The x-axis (Wavenumbers): This represents the frequency of vibrations for the chemical bonds and functional groups within the sample. The unit is cm^ {-1}.

The y-axis (%Transmittance): This shows the percentage of infrared light that passes through the sample.



4.8 Key Peaks and Their Meanings:

Interpreting an FTIR curve involves looking at the specific peaks and their corresponding wavenumbers. Here's a breakdown of the typical peaks you'd see in a sample like biomass or ash:

4.8.1 Around 3400 cm^{-1}: A **broad peak** at this position usually indicates the presence of **O–H (hydroxyl)** stretching vibrations. This is common in materials containing water, alcohols, or phenols. The broadness of the peak suggests hydrogen bonding.

4.8.2 Around 2900 cm^{-1}: A **smaller peak** here signifies **C–H** stretching vibrations. This is characteristic of alkanes or the C–H bonds found in organic components like cellulose or lignin.

4.8.3 Around 1600–1700 cm^{-1}: A **sharp, clear peak** in this range points to **C=O (carbonyl)** stretching vibrations. This can be from various functional groups like esters, ketones, or aldehydes, and is often associated with lignin.

4.8.4 Around 1000–1100 cm^{-1}: Several sharp peaks in this region indicate **C–O** or **Si–O** stretching. For ash samples, the presence of these peaks is a key indicator of **silica (SiO2)**, a major component of many agro-waste ashes.

4.8.5 Summary:

By analyzing the positions, shapes, and intensities of these peaks, we can deduce the molecular structure and composition of a given material.

CHAPTER 5

RESULT & DISCUSSION

5.1 Ash Yield and Physical Characteristics:

The mango seed shells, after washing, drying, and calcination at 600–800 °C, produced ash with a yield of approximately 3.125% by weight of the raw biomass. The ash appeared light grey to black, depending on calcination temperature, indicating the removal of volatile organic compounds.

Low-temperature ash (600 °C): retained carbon residues, darker color.

High-temperature ash (800 °C): more silica-rich, lighter color, with reduced unburnt carbon.

This suggests that calcination temperature plays a critical role in controlling the purity and mineral composition of MSSA.

5.2 Microstructural Analysis (FESEM):

Scanning Electron Microscopy (SEM) images revealed the following features:

(i) Irregular particle morphology with porous, rough surfaces.

(ii) Agglomerated particles due to van der Waals forces and residual carbon.

(iii) Average particle size ranged between 3–20 μm (depending on grinding and sieving).

(iv) Porous microstructure beneficial for filler applications, allowing good interfacial bonding in composites.

Note:
The irregular morphology and high porosity make MSSA suitable for polymer reinforcement, as the rough surface enhances mechanical interlocking and matrix adhesion.

Elemental Composition (EDS)

Table-4

Composition:

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	Abs. Error [%] (3 sigma)
C	6	15114	3.85	6.6	12.01	0.47
O	8	65771	21.53	36.9	50.41	2.65
Na	11	22365	4.99	8.54	8.12	0.8
Mg	12	17425	3.22	5.51	4.96	0.45
K	19	32213	8.67	14.85	8.3	0.83
Ca	20	28578	11.87	20.34	11.09	1.24
Al	13	1782	0.31	0.53	0.43	0.08
Si	14	5558	1.31	2.25	1.75	0.19
P	15	7284	1.27	2.18	1.54	0.16
Fe	26	485	0.26	0.44	0.17	0.1
S	16	4463	0.81	1.38	0.94	0.11
Zn	30	0	0.0	0.0	0.0	0.0
Ti	22	42	0.04	0.06	0.03	0.13
Cl	17	1049	0.22	0.37	0.23	0.06
Ni	28	0	0.0	0.0	0.0	0.0
Cu	29	70	0.02	0.04	0.01	0.05
Sum			58.36	100.0	100.0	

5.2.1 Discussion:

The high silica and carbon content is similar to other agro-waste ashes (e.g., rice husk, wheat husk). Potassium and calcium oxides indicate mineral stability, useful in composites.

5.3 pH Test of Mango Seed Shell Ash

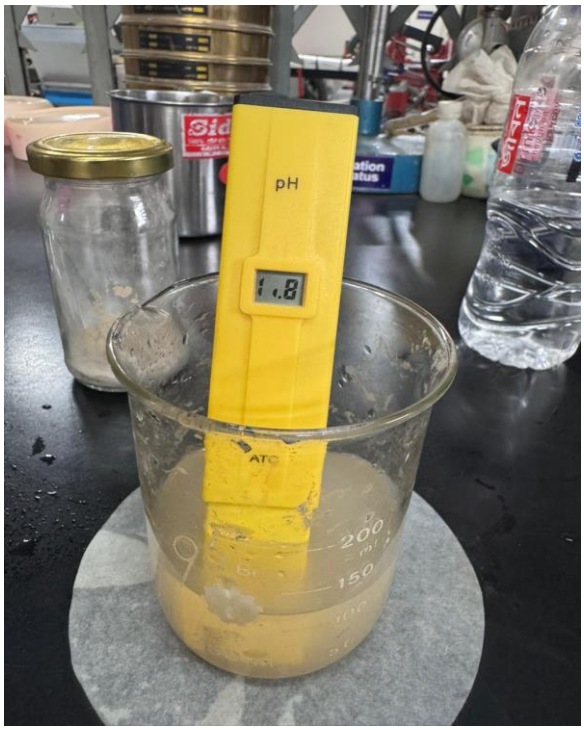


Figure 5.1: pH Measurement of MSSA.

The pH of mango seed shell ash (MSSA) was measured by preparing an aqueous Solution (10 g ash in 100 mL distilled water) and testing with a calibrated digital pH meter.

5.3.1 Result:

The pH of MSSA was found to be in the range of 11.8, indicating a moderately alkaline nature.

5.3.2 Discussion:

The alkalinity arises mainly from the presence of metal oxides such as K_2O, CaO, and MgO in the ash.An alkaline pH is beneficial for cementitious applications (pozzolanic reactivity), as it promotes silica dissolution and bonding with calcium hydroxide.

CHAPTER 6

CONCLUSION

6.1 Conclusion

This study focused on the fabrication and microstructural characterization of Mango Seed Shell Ash (MSSA)**,** a sustainable and eco-friendly material derived from agricultural waste. The mango seed shells, a byproduct of mango consumption, were collected, cleaned, dried, and subjected to controlled combustion to produce ash. The ash was then analyzed using advanced characterization techniques including Field Emission Scanning Electron Microscopy (FESEM)**,** Energy Dispersive X-ray Spectroscopy (EDX), and Fourier Transform Infrared Spectroscopy (FTIR)**.**

6.2 Objectives of this study were:

1. To fabricate MSSA in a controlled manner with consistent physical and chemical properties.
2. To analyze the microstructure of MSSA and understand particle morphology, porosity, and elemental composition.
3. To evaluate the potential applications of MSSA as a bio-ash material in composites, ceramics, and other industrial application.

6.3 Limitation:

a. Raw Material Variation: Composition of mango seed shells varies with variety, maturity, and environment.

b. Calcination Control: Maintaining uniform furnace temperature (600–800 °C) was difficult, affecting ash quality.

c. Limited Tests: Only FESEM, XRD, FTIR, TGA, and XRF/EDS used; advanced techniques not applied.

d. Comparative Scope: Compared with few agro-waste ashes; industrial fillers not included.

e. Application Testing: Mechanical properties in composites not evaluated.

6.4 Recommendations for Future Work

1. **Mechanical Testing:** Fabricate MSSA-reinforced composites and evaluate tensile strength, compressive strength, and wear resistance.
2. **Optimization of Particle Size:** Use milling or sieving to achieve more uniform particle size for improved consistency in composites.
3. **Thermal and Chemical Stability Studies:** Examine the behavior of MSSA under high temperature and chemical exposure to assess durability.
4. **Industrial Scale-Up:** Explore methods to scale the fabrication process for commercial applications.
5. **Blending with Other Bio-Ash Materials:** Combine MSSA with rice husk ash, coconut shell ash, or other agricultural waste for enhanced properties.
6. **Environmental Impact Assessment:** Conduct a life cycle analysis to quantify the ecological benefits of using MSSA in materials.
7. **Composite Materials:** The results revealed that MSSA possesses a high Silica content, significant porosity, and a heterogeneous microstructure, which make it suitable for use in composite material. We can use it as composite in near future.

Note: In near future, we can use it as composites of aluminum (Al) and Graphite for increasing its mechanical properties.

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