**Moringa oleifera** Leaf Powder Madura Variety:
Characterization and Biomaterials Property for Biomedical and Nanotechnology Application

H Susanto\(^1\), A Taufiq\(^2\), S Sunaryono\(^3\), S Soontaranon\(^3\), Y A Hariyanto\(^2\), A I Mawardi\(^4\), N G Adreyanto\(^1\), D T Yunisa\(^1\), F Rufiandita\(^1\), F Nizarghazi\(^1\), G Alifi\(^1\), L N Putri\(^1\), S M Kurnia\(^1\), Sumardi\(^1\)

\(^1\)Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5 Malang 65145, Indonesia
\(^2\)Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5 Malang 65145, Indonesia
\(^3\)Synchrotron Light Research Institute, 111 University Venue, Nakhon Ratchasima 30000, Thailand
\(^4\)Department of Post Graduates Studies, Universitas Islam Negeri Sunan Ampel, Surabaya 60237, Indonesia

*Corresponding author’s email: hendrabio@um.ac.id

**Abstract.** Biomaterials have a potential property and become the future target in the advanced bioengineering and its application. One of the local biodiversities is *Moringa oleifera* widely spread in the East region of Indonesian archipelago especially Madura islands. *Moringa oleifera* leaf ingredients are a promising local source for a future target in biomaterials development, biomedical science, bionanotechnology, and engineering. Importantly, *Moringa oleifera* leaf powder consists of a higher concentration of organics materials and some essential minerals. However, it is still lack of information of the specific organic compounds and minerals within the Madura variety samples and how the structural characteristics of this biomaterials. The goal of this study was to characterize the essential ingredients and its structural properties within the *Moringa oleifera* leaf powder from Madura variety. The samples of *Moringa oleifera* leaf powder were characterized by X-ray fluorescence spectroscopy (XRF), small angle X-ray scattering (SAXS), and organic compound analysis by the proximate test. Interestingly, the significant content of protein, carbohydrate, Vitamin A, and vitamin C was observed in these samples while the lower level of lipid was confirmed. The higher level of Calcium, Phosphor, Ferrum, Potassium, Sodium, Sulfur, Molybdenum, Barium, and Manganese was found in the samples. The primary and secondary particle size and fractal dimension were obtained from SAXS data analysis proving that the synthesized green nanoparticles from *Moringa oleifera* leaf powder Madura variety have a significant feature as a potential candidate for nanomaterials in biomedical administration. Thus, the underlying data of organic ingredients, minerals concentration, and structural feature provide a hallmark for the *Moringa oleifera* leaf powder Madura variety as the potential future candidate in biomaterials and biomedical application linked to bioengineering development.

**Keywords:** *Moringa oleifera*, leaf powder, biomaterial, biomedical, nanotechnology.
1. Introduction
Nowadays, the advanced development of materials based on biocompatibility is a long-term target for bioengineering, medical application, and biomaterials-based study. The characterization of materials property and chemical activity of this biomaterials has been attracting more attention to exploring as the potential future candidate for natural and harmless materials. Natural materials sources have been widely used in the several fields including the miracle flora from Asia, Moringa oleifera. This plant has been established as the novel biomaterials resources and was explored to be a potential natural material for environmental safety and bioengineering [1–4], bioenergy [5–7], biomedical sciences [8–11], poultry science [12], and others. The greener synthesis of nanoparticles from natural resources suggested the harmless waste materials and environmental friendly [13].

Importantly, the recent report showed that malnutrition and metabolic syndrome played a valuable contribution to the global health problem [14]. Increasing the mortality incidence in younger age or infant is significantly associated with short-term breastfeeding period, metabolic perturbation, and caloric imbalance [15]. The lack of access to nutritional food in the lower income community especially from developing countries results in severe undernutrition status in the long-term period [14,16]. As a consequence, the susceptibility of this population to several metabolic and infectious diseases gradually increased in the last decade [17,18]. According to the local wisdom and previous data, Moringa oleifera is the promising material combating nutritional deficiency and metabolic imbalance in the population [19]. The Moringa is well established as the traditional medicinal plant with higher nutrition due to the presence of some essential nutrients in their leaf [20,21].

Despite serving as the future candidate for undernutrition therapy in the clinical or biomedical application, in advanced bioengineering development, Moringa oleifera is essential to produce biomaterials or green materials [22,23]. Several previous works reported that Moringa oleifera has been applied as a novel nano-hydroxyapatite for bone repair [24], electrochemical application [25], ZnO green nanomaterials [26], NiO nanoparticles and cancer cell proliferation inhibition [27,28], TiO nanoparticles synthesis for wound healing model [29], and antibacterial agent [30]. Importantly, the moringa leaf easily found abundantly around the Indonesian archipelago, especially in Madura islands opens new opportunity to be used for producing the bionanomaterials. Therefore, due to the simplicity, stability, and biocompatibility of this biomaterials, in this work, the leaf powder from the local bioresources was selected to analyze the chemical property and its potential application. Even though some studies have been done with their preliminary laboratory work related to green synthesis of moringa nanoparticles, however, there is limited information on how the fundamental molecular and structural characteristics of moringa leaf powder originated from Madura variety. Moreover, there is no report on biomaterials synthesis by using moringa leaf powder of Madura variety.

Here, in this study, the preparation of moringa leaf powder using a simple method provided an opportunity to produce the organic leaf powder with higher nutrients concentration and potential rough biomaterials for applied nanotechnology. The employment of organic and an organics protocol in this work is related to its advantages in producing high-quality bionanomaterials. The characterization of green nanomaterials from local biodiversity in particular moringa leaf powder Madura variety by employing co-precipitation technique will be explored in the preliminary laboratory work. Furthermore, the selected properties such as organic compounds, minerals, structure, and particles size of the samples are also discussed.

2. Materials and Methods
The samples preparation were conducted by collecting Moringa leaf from a local variety of Madura islands. The Moringa leaf powder was processed from the fresh leaf harvested in the local farming area. The leaf of Moringa oleifera was washed by clean water and dried at room temperature (25–27 °C) for 4-5 days. The room humidity was maintained to avoid ingredient degradation during the drying step. Next, the dried leaf was collected and drilled followed by filtering step with specific mesh. The Moringa leaf powder samples were then stored at sterilized aluminum foil bag for the green nanomaterials characterization.
Green nanomaterials synthesis of *Moringa oleifera* Madura variety was fabricated using the co-precipitation method. *Moringa oleifera* leaf powder was dissolved in 45 mL HCl at room temperature, and the solution then was filtered. In the following step, about 15 mL solution was titrated by using 28 mL NH\textsubscript{4}OH and stirred for 30 min. Furthermore, the resulted solution was washed in the serial process and filtered immediately. The measurement of nutritional ingredient (proximate analysis) and bio-nanomaterials characterization (X-ray fluorescence/XRF spectroscopy) were conducted at *Sentral Ilmu Hayati* Laboratory, Brawijaya University, and Sentral Laboratory, Universitas Negeri Malang, Indonesia. In the final laboratory work, to investigate the particle size and structural properties, the samples were also characterized by using synchrotron-based small-angle angle X-ray scattering (SAXS) owing by SLRI, Thailand.

3. Results and Discussion

The primary step in our preliminary study was to access the essential macro and micronutrient ingredients within Moringa leaf powder Madura variety. Organic analysis showed that Moringa leaf powder Madura sample has a higher concentration of protein (> 32% /100 g dried leaf powder), lower lipid level (<6% /100 g dried leaf powder), and significantly higher for carbohydrate (> 37% /100 g dried leaf powder) (Figure 1A). Furthermore, very importantly, the significance of vitamin A and vitamin C concentration was also observed in this sample while no significant difference for Vitamin B1, B2, and B3 in the same sample (Figure 1B). Next, the primary characteristics of the basic compound within moringa leaf powder are shown in Table 1.

![Figure 1](image)

**Figure 1.** The basic bioproperties of Moringa leaf powder Madura variety. (A). Macronutrients concentration within the dried leaf of *Moringa oleifera*, (B). Vitamins concentration within the dried leaf of *Moringa oleifera*

The raw and synthesized *Moringa oleifera* was characterized using synchrotron SAXS. The scattering profiles of the samples and their fitting analysis results are shown in Figure 2 and Table 2, respectively. The particles distribution equation of the primary particles was employed to the log-normal model [31]. In this case, we combined bilog normal spherical and mass fractal models to investigate the size distribution, structural and form factors as well as primary and secondary particles size distributions of the samples [31, 32].
Table 1. Elemental content of *Moringa oleifera* leaf powder Madura variety

| No | Elemental content | Concentration (%) |
|----|-------------------|-------------------|
| 1. | Ca                | 68.5              |
| 2. | Mg                | 0.5               |
| 3. | P                 | 1.6               |
| 4. | Na                | 3.8               |
| 5. | K                 | 14.7              |
| 6. | Fe                | 2.1               |
| 7. | S                 | 3.0               |
| 8. | Cu                | 0.3               |
| 9. | Mn                | 10                |
| 10. | Ni               | 0.1              |
| 11. | Mo               | 8.3               |
| 12. | Ba               | 3.4               |
| 13. | Ti               | 0.2               |
| 14. | Si               | 0.5               |
| 15. | Cr               | 1.1               |
| 16. | Yb               | 0.5               |

Figure 2. Synchrotron SAXS profiles of the (A) raw and (B) synthesized *Moringa oleifera*

Based on Figure 2, the experimental data (represented by circles) were fitted by the mathematical model (represented by red line) through SASfit program [33]. Based on Table 2, it is shown that the primary particle size of the Moringa leaf powder decreased significantly after the synthesizing process. This data implied that the co-precipitation method at room temperature can be applied to produce the smaller particle size of green nanomaterials from Moringa leaf powder. This result is in line with the previous work presenting that the natural nano-sized magnetite could be prepared effectively by employing such a method [31]. The decrease in the particle size confirmed that the green nanoparticles are able to be economically and easily synthesized by this method. Therefore, the prepared samples in this work are potentially able to be used in reducing the toxicity effect and increasing biocompatibility in biomedical applications.
Table 2. SAXS analysis of *Moringa oleifera* leaf powder Madura Variety

|                          | A      | B      |
|--------------------------|--------|--------|
| **Primary particle size (nm)** | 3.45   | 1.75   |
| **Secondary particle size (nm)** | 8.90   | 5.10   |
| **Fractal Dimension**     | 2.90   | 2.88   |

The major problem of biomaterial application in medical administration is strongly associated with toxicity and how the biomaterial absorption related to the particle size. Thus, the primary concern for advanced green nanomaterial application should be focused on size and harmless activity in the living materials, particularly in human physiology. According to our previous work, it has been proven that the co-precipitation method at an average temperature increased particles solubility and decreased toxicity effect [34]. Also, this study showed that the green nanoparticles have a compact and smooth surface property even synthesized by a simple method. In line with another laboratory data, the material synthesis by using co-precipitation method results in the homogeneity nanoparticles related to the surface property and its basic structure [35]. This data was confirmed by the fractal dimension value within a range from 2.88 to 2.90. The fractal dimension illustrated that green nanomaterials from *Moringa oleifera* leaf powder Madura variety performed a higher solubility within the solution because this value indicated that *Moringa Oleifera* has a roughness surface. Importantly, the solubility level of specific materials linearly correlated to the particles size which decreases the particle size will improve the particle solubility in the solution [36].

In the advanced nanotechnology and materials science, the critical process was addressed on nanoparticles synthesis process. Prominently, the synthesis method will determine the physicochemical properties and thermodynamics activity within living materials. The solubility of nanomaterials related to particle size in the living organism fluid is essential for bio-nanomaterials. It will implicate the biological feature of these nanoparticles results in the different activity among those nanoparticles. The fast expansion of biotechnology mixed nanotechnology in the biomedical field provides a central hallmark to explore the activity of specific nanoparticles in biological processes. Also, the higher biocompatibility of nanoparticles was synthesized from green materials promising candidates as a safety agent in the living organism. Importantly, there is limited information of the essential chemical and structural characteristics of moringa leaf powder Madura islands variety. Based on the above explanation, *Moringa oleifera* leaf powder produced by co-precipitation method can be proposed as the novel green materials candidate in medical application. Hence, bionanomaterials from *Moringa oleifera* leaf powder Madura variety can be proposed as an additional and potential biomaterials in medical treatment and others application.

Nowadays, the essential role of *Moringa oleifera* as green biomaterials has been proposed in the biomedical area. *Moringa oleifera* leaf has a potent activity to reduce obesity and diabetes. Isothiocyanate within moringa leaf significantly reduced body weight, gluconeogenesis, alleviate insulin resistance, and post-prandial plasma glucose in T2DM patients [37–39]. Moringa leaf extract was also potential agent against hyperlipidemia [40], reduced hyperglycemia through enhancing mitochondrial respiratory chain [41], children with undernutrition [42,43], propagated neural differentiation [44], and became vital source of vitamin A for younger age [45]. Moreover, the anti-cancer performance of green nanomaterials has received global attention since they showed a significant activity to inhibit the cell proliferation rate and proposed as nanomedicine. Pre-treatment with *Moringa oleifera* showed anti-proliferation effect that tended to reduce the cancer cell growth and induced the cell death as entirely [28]. Based on our preliminary investigation, it was suggested that the *Moringa oleifera* leaf powder Madura variety might have a similar potential role in combating hyperglycemia, hyperlipidemia, protein undernutrition, vitamin A deficiency in a child, and anti-proliferation natural agent against cancer. Also, we hypothesized that the co-interaction between green nanoparticles and cancer cell membrane corroborates the disruption of the cancer cell membrane.
4. Conclusion
Based on the data analysis, we conclude that the green nanomaterials of Moringa leaf powder show better characteristics as a potential candidate for biomedical and nanotechnology than that of other similar materials. Therefore, the Moringa leaf powder Madura variety becomes a novel and essential new alternative biomaterial to be applied in medical treatment and nano-engineering.

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