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UTILIZATION OF MORINGA LEAVES (*Moringa oleifera* L.) AND SEAWEEDS (*Sargassum sp*.) TO IMPROVE NUTRIENT CONTENTS OF LIQUID ORGANIC FERTILIZER

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ABSTRACT

Liquid organic fertilizer is increasingly applied in crop production to optimize the use of solid organic fertilizer. Green biomass is one of composing material for the production of liquid organic fertilizer, since the nutrient contents in plant tissue determines the quality of liquid organic fertilizer. The first experiment was the identification of the nutritional content of moringa and seaweed leaves, included nitrogen, phosphorus, potassium, magnesium, magnesium calcium, organic carbon, cellulose and lignin. The second experiment was the effect amendment of moringa and seaweed green biomass on nutrient properties of liquid organic fertilizer and was conducted in a completely randomized design. The treatment was consisted of (1) moringa leaves of flowering twigs, (2) moringa leaves of unflowering twigs, and (3) seaweed. The first experiment revealed that the highest nitrogen, phosphorus, and magnesium contents were found in unflowering moringa leaves, while the highest potassium, calcium and cellulose were found in seaweeds. In addition, flowering moringa leaves had the highest lignin content among evaluated plant leaves. The second experiment found that the highest of nitrogen content was found in LOF produced by using seaweeds, followed by those in using unflowering moringa leaves and flowering moringa leaves. The highest of calcium, magnesium and organic carbon were recorded in LOF produced by using unflowering moringa leaves followed by followed by those in using flowering moringa leaves and seaweeds. In addition, the highest pH, phoshorus, and potassium were found in LOF produced by using flowering moringa leaves.

Keywords: Liquid Organic Fertilizer; Moringa leaves; Nutrient Contents; Seaweeds

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1. INTRODUCTION

The advantages of using liquid organic fertilizer are more practical, the manufacturing process is faster, it penetrates the soil faster and absorbed faster by plant (1). Liquid organic fertilizer is a fermented fertilizer from various organic materials in liquid form (2). The manufacture of organic fertilizers requires several basic ingredients including crop residues, sawdust, animal manure, household waste (3). Anggraini *et al.* (2019) (4) reported several basic ingredients for making liquid organic fertilizers such as market waste, dry leaves, tofu pulp and EM4. Fahrurrozi *et al.* (2017) (5) used the basic ingredients of *kamal* leaf forage in making liquid organic fertilizer.

Moringa leaves have potential as a source of forage. Moringa leaves are effective as an ingredient in the production of biological fertilizers that can improve plant growth and soil fertility. This is because moringa leaves have nitrogen levels of 4.02%, phosphorus 1.17%, potassium 1.80%, calcium 12.3%, magnesium 0.10% and sodium 1.16% (6). Moringa leaves are abundant in the environment. However, the nutrient quality of moringa leaves is influenced by many factors including plant age, plant growth environment and plant organs.

In addition to moringa, which is abundant in coastal areas, seaweed is one of the diverse marine biota species in Bengkulu Province. Several studies conducted in Bengkulu Province (7) (8) and Enggano Island showed that seaweed species were easily found along the coast of Bengkulu Province such as brown seaweed with *Sargasum* sp. Basmal (2009) (9) reported that seaweed had enormous potential because it could substitute the need for synthetic fertilizers containing cytokinin, auxin and gibberellin growth regulators that are useful for increasing plant production.

2. MATERIALS AND METHODS

Experiment 1. Identification of Nutrient Content of Moringa Leaves and Seaweed

This research was conducted in April - July 2022 at the Soil Science Laboratory, Faculty of Agriculture, Universitas Bengkulu. The design used in this study was a completely randomized design (CRD) including moringa leaves and seaweed. The treatments were repeated 3 times so there were 9 experimental units consisting of: Moringa leaves flowering twigs, Moringa leaves not yet flowering twigs, seaweed.

The research process was started by the collection of forage sources around municipality of Bengkulu. The samples were part of the moringa leaves, flowering moringa leaf twigs and moringa leaf twigs that have not flowered. Seaweed leaf samples were taken on the coast of Sepang bay, Bengkulu. The observations were Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, C-organic, Cellulose and Lignin levels. Data were analyzed with F-test, differences between treatments were tested with the Least Significant Difference (5%). Plant tissue analysis was conducted at the Soil Science Laboratory, Faculty of Agriculture, Bengkulu University.

Experiment 2. Effect of Moringa Leaf Forage and Seaweed on the Nutrient Quality of Liquid Organic Fertilizer

This research was conducted from April to August 2022 at the Soil Science Laboratory, Faculty of Agriculture, Universitas Bengkulu. The design used in the research was completely randomized design (CRD) and repeated 3 times and the treatment including moringa leaves from flowering twigs, moringa leaves from non-flowering twigs, seaweed. Tools and materials used are buckets, knives, trays, plastic barrels, stirrers, scales, filters, cameras, meters, hoses, stationery, moringa leaves, seaweed, cow urine, EM4.

Potential forage was fermented into liquid organic fertilizer, with a mixture of 10 kg of moringa and seaweed forage, 20 liters of cow urine, 20 liters of EM4 solution (100 ppm), and 50 liters of water. Fermentation was carried out in plastic barrels with a volume of 150 liters. The fermentation barrel is placed under the roof so that it is not directly exposed to sunlight and rain and was conducted for 4 weeks. Observations of pH, nitrogen, phosphorus, potassium, magnesium, calcium, and organic C. Data were analyzed with F-test, differences between treatments were tested with the Least Significant Difference (5%). LOF nutrient analysis was conducted at the Soil Science Laboratory, Faculty of Agriculture, Universitas Bengkulu.

3. RESULTS AND DISCUSSION

3.1 Nutritional Contents of Moringa Leaves and Seaweed

The results of the identification of nutrient levels of moringa leaves and seaweed showed significant differences in the elements of N ($P \leq 0.05 = 0.00001$), P ($P \leq 0.05 = 0.0002$), K ($P \leq 0.05 = 0.0027$), C-organic ($P \leq 0.05 = 0.0140$), Mg ($P \leq 0.05 = 0.0010$), Ca ($P \leq 0.05 = 0.0001$), cellulose ($P \leq 0.05 = 0.0094$), lignin ($P \leq 0.05 = 0.0169$).

Nitrogen

The highest N content (3.12%) was found in moringa leaves from non-flowering twigs (Figure 1A), followed by moringa leaves in the reproductive phase, and seaweed. The high nitrogen content in moringa leaves in the non-flowering phase related to the active photosynthesis of young leaves. According to Laka and Wangge (2018) (10), tissues that were actively photosynthesizing had high nitrogen content. Moringa leaves from non-flowering twigs had high nitrogen levels, because nitrogen levels were needed in large enough quantities, especially when plant growth entered the vegetative phase. N levels in moringa leaves from flowering twigs were lower than those that had not flowered, perhaps because the moringa leaves used come from the reproductive phase. The low level of N in the leaves of moringa flowering twigs from the reproductive phase was related to the active generative growth of plants, especially flowering. According to Purba *et al.* (2021) (11), leaf nutrients in the generative phase were dominated by phosphorus elements to

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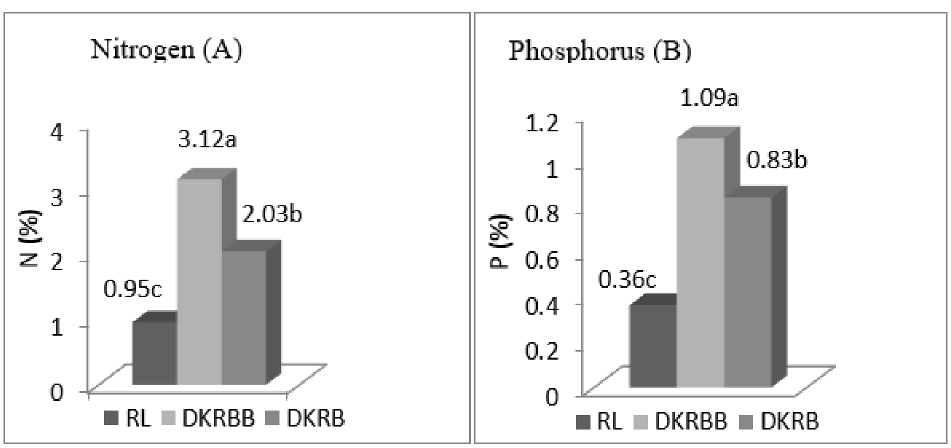
support flowering. The results of this study also showed that seaweed had the lowest nitrogen content compared to the nitrogen content in Moringa leaves (both leaves that have not flowered, and leaves that have flowered). The low nitrogen nutrients in seaweed were caused by the availability of nitrogen elements in the water was less. According to Desrochers *et al.* (2022) (12) the content of nitrogen and phosphorus in seaweed depended on the availability of nutrients in the waters. This was due to the ability of seaweed to utilize nutrients in the waters influenced by physical factors (temperature, light, and water movement), chemical (nutrient concentrations and forms of nutrients) and biological (type of seaweed) (13).

The N content of Moringa leaves from non-flowering twigs in this study was lower than the results of Adiaha's (2017) (6) research, which was 4.02%. Stevents *et al.* (2021) (14)analyzed the nitrogen content of moringa leaves throughout Nigeria and concluded that the nitrogen content of the leaves ranged from 3.71 to 4.04%. This difference was due to differences in leaf color of the moringa plants analyzed. The color of moringa leaves affected the mineral content of moringa leaves (15).

Nitrogen content of seaweed in this study was higher than the results of Sofiana *et al.* (2024) (16) which showed that the nitrogen content of *Sargassum polycystum* seaweed from the waters of Lemukutan Island, Sungai Raya Islands District, Bengkayang, West Kalimantan was 0.14%. Previous research results, Sunarpi *et al.* (2021) (17) reported that the nitrogen content of seaweed waters of Lombok, *S.crassifolium* was 0.51%, *S.polycystum* 0.50%, and *S.cristaefolium* 0.52% and similar to the results of research Yustin *et al.* (2005) (18) which reported that the seaweed contains nitrogen levels ranging from 0.02-0.03%. However, the N content of seaweed in this study was lower than the results of research by Basmal *et al.* (2019) (9) which reported the extraction of nutrients of seaweed *Sargassum* sp. nitrogen content was 1.64%.



Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 1: Nitrogen (A), phosphorus (B), Seaweed (SW)

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Phosphorus

The highest phosphorus content (1.09%) was found in moringa leaves from non-flowering twigs (Figure 1B), followed by reproductive phase moringa leaves, and phosphorus content in seaweed. The high phosphorus content in moringa leaves of unflowered twigs was related to the growth phase of the plant performing generative growth, especially flowering. According to Salisbury (1995) (19) phosphorus was spread easily in most plants, from one organ to another, and disappears from old leaves, accumulating in young leaves and flowers and developing seeds. Therefore, young tissues had higher phosphorus content than old tissues.

The low P content in Moringa leaves from the reproductive phase was related to physiological changes in the plant during this phase. During the reproductive phase, plants tend to allocate more resources to the formation of flowers, fruits, and seeds, which might reduce the availability of phosphorus in the leaves. The results of this study also showed that seaweed had the lowest phosphorus content compared to the phosphorus content in moringa leaves (both leaves that have not yet flowered, and leaves that have flowered). The low phosphorus nutrient in seaweed was caused by the ability of seaweed to utilize nutrients in the water. According to Zainuddin and Nofianti (2022) (20), phosphorus level in seaweed was low and it was influenced by physical factors (temperature, light and water movement). The P content of moringa leaves from unflowered twigs in this study was lower than the results of Adiaha's (2017) (6) research, which was 1.17%. The results of previous studies showed that the P content of moringa leaves ranged from 0.152-0.304 g/100 g (21). Moringa leaves throughout Nigeria range from 169.50 - 182.80 ppm (22), 100 g phosphorus (70/mg) (22). This difference was caused by the differences in cultivars of moringa plants analyzed. According to Oyeyinka (2018) (23), moringa leaf nutrients varied according to cultivar and geographical location where the plant grew.

The P content of seaweed in this study was higher than the results of research by Sofiana *et al.* (2024) (16) that used *Sargassum polycystum* from the waters of Lemukutan Island, Sungai Raya Islands District, Bengkayang, West Kalimantan which is 0.02%. Previous research results Sunarpi *et al.*, (2021)(17) *S.crassifolium* 0.02%, *S.polycystum* 0.07%, and *S.cristaefolium* 0.08%. The results of Basmal *et al.*, (2019) (9) *Sargassum* sp. ranged from 132.8-197.7 ppm. The results of research by Basmal *et al.*, (2014) (9) reported that *Sargassum* sp. was 0.05%. The results of research by Utomo and Asmawit, (2012) (24), *Sargassum polycistum* was 0.09 mg/100g from the coastal waters of Bengkayang Regency. While Anggarito *et al.* (2005) (18) reported in the ranged from 0.003-0.207%.

Potassium

The highest potassium (K) content (1.3%) was found in seaweed (Figure 2A), followed by Moringa leaves. The high potassium content in seaweed was due to the salt derived from living organisms (plants) which was one of the macro elements needed by plants so that seaweed absorbed more potassium. According to Sundari *et al.* (2014) (25), potassium was needed by plants to regulate the mechanism of photosynthesis, protein synthesis, as well as the opening of stomata and carbon dioxide supply.

The results of this study also showed that moringa leaves (both leaves that have not flowered, and leaves that have flowered) have a lower potassium content than seaweed. According to Dwidjoseputro (1989) (26), potassium had an important role as a catalyst, especially in the conversion of proteins and amino acids, as well as in the preparation and burning of carbohydrates. The K content of seaweed in this study was higher than the results of research by Sofiana *et al.* (2024) (16) which showed that *S. polycystum* seaweed from the waters of Lemukutan Island, Sungai Raya Islands District, Bengkayang, West Kalimantan was 0.46%. Previous research results of Basmal *et al.* (2019) (9) reported that *Sargassum* sp. ranged from 201.2-206.9 ppm. As well as the results of research Sagara *et al.* (2023) (27), seaweed K levels ranged from 0.87-2.88%. However, the K content of seaweed in this study was lower than the results of research Sunarpi *et al.*, (2021) (17) which r eported that *S.crassifolium* was 3.14%, *S.polycystum* 6.0%, and *S.cristaefolium* 6.11% from Lombok waters. The results of previous research by Basmal (2010) (8)were 10.00%. As well as the results of Basmal's research (2009) (8) *Sargassum* sp. which is 2.32% from Binuangen Banten.

The K content of moringa leaves in this study is higher than the results of Stevents *et al.* (2021)(14) who analyzed the potassium content of moringa leaves throughout Nigeria and concluded that the potassium content of the leaves ranged from 0.02-0.23%. However, the K content in this study was lower than the results of Manggara and Shofi (2018)(28), which was 264.96 mg/100 g. The results of previous research by Sultana (2020) (21)showed that potassium levels ranged from 1.317-2.025 g/100 g. As well as the results of Adiaha's research (2017) (6) which was 1.80%.

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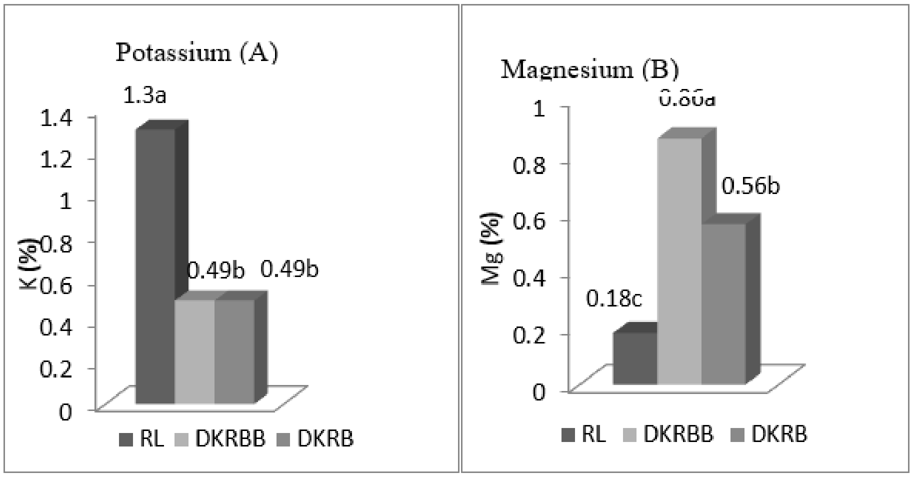

Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 2: Potassium (A), magnesium, (B), content of moringa and seaweed leaves

Magnesium

The highest magnesium (Mg) content (0.86%) was found in moringa leaves of non-flowering twigs (Figure 2B), followed by moringa leaves in the reproductive phase, and seaweed. The high magnesium content in the vegetative phase of moringa leaves was related to the active plant during the process of preparing leaf green substances (chlorophyll). This was because old leaf tissue had more chlorophyll content when compared to young tissue. Therefore, the old tissue had higher magnesium content than the young tissue. The results of this study also showed that seaweed has the lowest magnesium content compared to the magnesium content in moringa leaves (both leaves that have not flowered, and leaves that have flowered). The low magnesium nutrient in seaweed was caused by many factors. According to Lozano-Munoz and Diaz (2020) (29) the character of growing seaweed, in terms of habitat, environmental factors, temperature, season, depth, sampling location, exposure to waves and currents affect the components contained in seaweed.

The Mg content of moringa leaves in this study was higher than the results of Stevents *et al.* (2021) (14) who analyzed the magnesium content of moringa leaves throughout Nigeria and concluded that the magnesium content of the leaves ranged from 0.03-0.04%. However, the Mg content of moringa leaves in this study was lower than the results of Adiaha's (2017) (6) research, which was 1.16%. The nutritional content of fresh moringa leaves per 100 g, magnesium content 42/mg (22). This difference was related to differences in the place of growth of the moringa plants analyzed. According to Laura (2021)(30), the nutritional and mineral composition of moringa leaves was based on geographical location, especially variations in soil nutrient content. Seaweed Mg levels in this study were lower than the results of research by Sunarpi *et al.* (2021) (17) which reported that the magnesium content of seaweed from Lombok waters was *S.crassifolium* 8.7%,

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S.polycystum 8.6%, and *S.cristaefolium* 8.5%. Previous results, Basmal (2009) (8) reported that seaweed magnesium content was 0.80%.

Calcium

The highest calcium (Ca) content (1.03%) was found in seaweed (Figure 3A), followed by vegetative phase moringa leaves, and calcium content in reproductive phase moringa leaves. According to Khairy and El-Sheikh (2015) (31), calcium was the most important element, and calcium had high levels in seaweed. The low level of Ca in moringa leaves (both leaves that have not flowered, and leaves that have flowered) was caused by young leaves still needing a process to get old so that young leaves had low calcium content, while old leaves had higher calcium content. Ca content of seaweed in this study was higer than the results of research by Sunarpi *et al.* (2021) (17) calcium content of seaweed waters of Lombok, namely *S.crassifolium* 0.86%, *S.polycystum* 0.86%, and *S.cristaefolium* 0.85%. Previous research results Basmal (2009) (8), *Sargassum* sp. from Binuangen Banten calcium content was 0.06%. As well as the results of research by Sagara and Suryawan. (2023) (27) 0,87-2,88%.

Calcium content of moringa leaves in the study was lower than the results of research by Prawesti *et al.* (2024) which showed that the calcium content of Moringa leaves ranged from 1.536-2.758%. Stevents *et al.* (2021)(14) analyzed the calcium content of moringa leaves throughout Nigeria and concluded that the calcium content of the leaves ranged from 1.65-2.03%. The results of Sultana's research (2020)(21) calcium content ranged from 1.322-2.645%. As well as the results of Adiaha's research (2017)(6), which was 13.3%.

Organic Carbon

The highest organic carbon (C) content (11.4%) was found in moringa leaves from flowering twigs (Figure 3B), followed by that in unflowering moringa leaves and seaweed. The high organic content in moringa leaves from flowering twigs related to the active growth phase, in which plants experience increased production of organic compounds, including glucose and cellulose. Climate, sunlight and moisture played a role for organic compounds' production. Leaves exposed to more sunlight may produce more organic C through photosynthesis.

The results of this study also showed that seaweed had the lowest C-organic content compared to the C-organic content of moringa leaves (both leaves that have not flowered, and leaves that have flowered). The low C-organic nutrient content in seaweed was caused by light factors. In addition, because inorganic carbon in seawater occurred primarily as bicarbonate (HCO_3^-), the inability of some species to use HCO_3^- as a carbon source could lead to carbon limitation (32). According to Cornwall *et al.* (2015) (33), carbon was limited under certain conditions, such as high light levels that could lead to increased carbon requirements.

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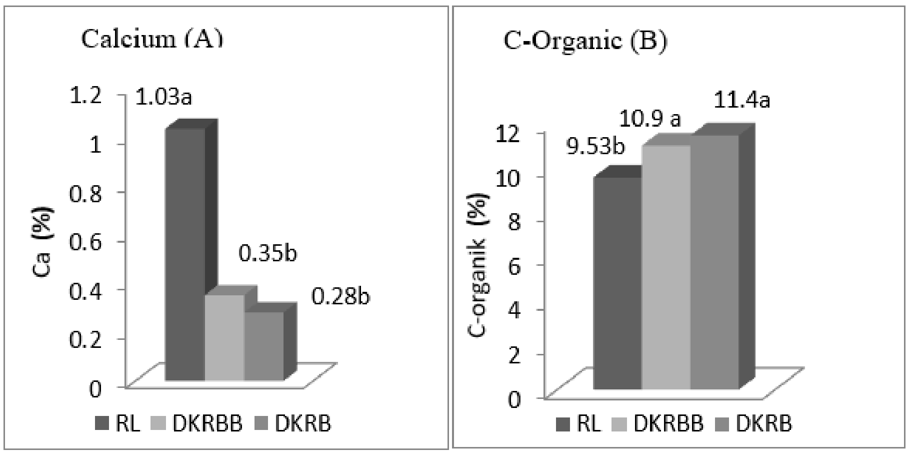
The C-organic content of moringa leaves in this study was higher than the results of Adiaha's (2017) (6) research, which was 11.1%. This difference was caused by genetic differences in the moringa plants analyzed. According to Hernández *et al.* (2022) (15)the nutrient content of moringa leaves was influenced by genetic factors. The C-organic content of seaweed *(Sargassum* sp.) in this study was higher than the results of research by Basmal *et al.* (2019) (9) extraction of seaweed nutrients *Sargassum* sp. C-organic levels ranged from 0.47%-0.55%.



Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 3: Calcium (A), and C-organic (B), content of moringa and sea weed leaves

Cellulose

The highest cellulose content (7.92%) was found in seaweed (Figure 4A), followed by moringa leaves. The results of this study also showed that moringa leaves (both leaves that have not yet flowered, and leaves that have flowered) had no different cellulose. The low cellulose nutrient content in moringa leaves was caused by several factors such as genetic variability between plant species could affect the cellulose content in leaves and environmental factors such as climate, soil, and nutrients play a role in the cellulose content of leaves. Interactions with the growing environment contributed to create the variations in plant cell wall components including cellulose (34).

The cellulose content of seaweed in this study was lower than the results of research by Ansyah *et al.* (2024)(35), *Gracilaria* sp. of seaweed contained 19.7% cellulose. The cellulose content of each marine plant had differences depending on the type, growth and location. Cellulose was an important polysaccharide and is the main component of hard cell walls that surround plant cells and make plant stems, leaves and branches strong. The cellulose content of moringa leaves in this study was lower than the results of research by Islamiati *et al.* (2022) (36), which was 16.43%. Méndez and Murillo (2018)(37), which was 12.11%. Singh *et al.* (2019)(38), which was 16.84%.

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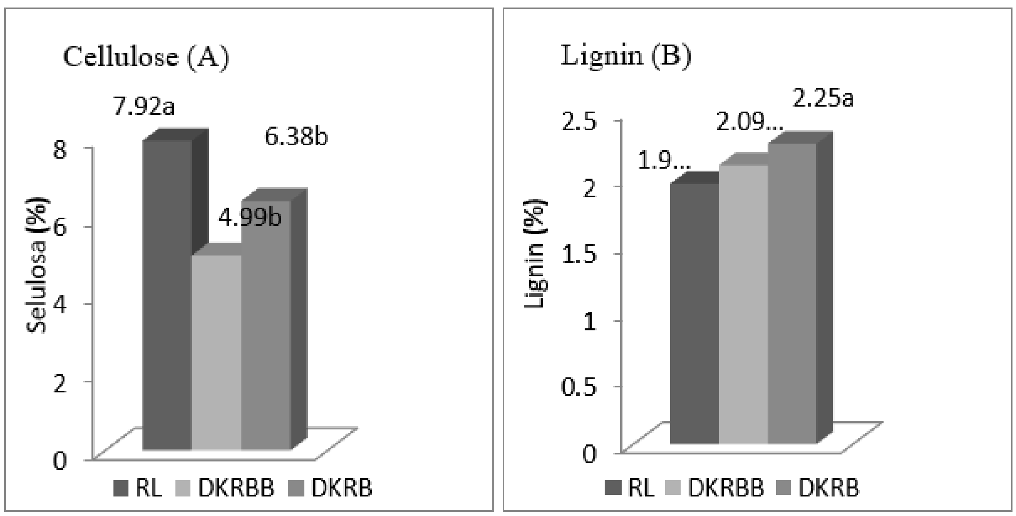
Lignin

The highest lignin content (2.25%) was found in moringa leaves of flowering twigs (Figure 4B), followed by moringa leaves of unflowered twigs, and seaweed. The high lignin content in moringa leaves from flowering twigs related to moringa plants including woody plants. Lignin could be found in the cell walls of plants. According to Anggraito *et al.* (2018) (18), lignin was one of the phenolic compounds. The results of this study also showed that seaweed had the lowest lignin content compared to the lignin content in moringa leaves (both leaves that have not flowered, and leaves that have flowered). The low lignin nutrient in seaweed was suspected that some seaweed species had adapted to certain environmental conditions. For example, if seaweeds had adapted to low nutrient availability, they might have lower lignin content.



Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 4: Cellulose (A) and lignin (B) content of moringa and sea weed leaves

The lignin content of moringa leaves in this study was lower than the results of the research by Islamiati *et al.* (2022) (36), which was 2.49%, Giridhar *et al.* (2018) (39) 4.57% and Singh *et al.* (2019)(38) 3.68%. This difference was due to differences in the growing characteristics of the moringa plants analyzed. According to Yang *et al.* (2023)(40), the nutrient content of moringa leaves depended on geographic region, solar radiation, humidity, soil type, and harvest time. Seaweed lignin levels in this study were lower than the results of research which was 25.4% (41).

3.2 Nutrient Quality of Liquid Organic Fertilizer

The use of various types of forage as a source of nutrients in the manufacture of liquid organic fertilizer (LOF) affected the content of phosphorus ($P \leq 0.05 = 0.0017$), potassium ($P \leq 0.05 =$

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0.0025), C-organic ($P \leq 0.05 = 0.0049$), but did not affect pH ($P \leq 0.05 = 0.1374$), nitrogen ($P \leq 0.05 = 0.1574$), calcium ($P \leq 0.05 = 0.3516$), magnesium ($P \leq 0.05 = 0.5771$).

pH

The results showed that the use of various types of forage as a source of nutrients in making LOF had a pH that were insignificantly different, ranged from 7.31 to 7.89 (Figure 5A). The decomposition of organic matter could cause the pH to approach neutral. This related to the anaerobic fermentation process that was carried out properly could produce liquid organic fertilizer with a more stable pH. The declining pH slightly at the beginning of the composting process due to bacterial activity that produced acid with the emergence of other microbes decomposed material, the pH of the material will rise after a few days and then be at neutral conditions. Adding effective microorganisms, such as EM4 could help in the fermentation process and regulated pH. These microorganisms could reduce acid production during fermentation, thus contributing to a more neutral pH. According to Jalaluddin *et al.* (2016)(42) pH in composting affected the activity of microorganisms.

Fermentation temperatures in the optimal range (around 25-30°C) could increase the activity of beneficial microorganisms and minimized acid production. Storing liquid organic fertilizer in a place that was not exposed to direct sunlight and at a stable temperature could help keep the pH stable (42). According to Anggraito *et al.* (2018) (18), the stability of the pH value of the material during the composting process was one indication of the work of decomposing microorganisms.

Nitrogen

The highest nitrogen content (1.74%) was found in seaweed LOF (Figure 5B), followed by Moringa leaf LOF with unflowered twigs and Moringa leaf LOF with flowering twigs. Seaweed-based LOF materials provided higher nitrogen content than other sources. This related to environmental conditions during fermentation, such as temperature and pH, playing an important role in increasing nitrogen content. Optimal temperature (around 25-30°C) and suitable pH (between 6-8) could accelerate the activity of microorganisms, thereby increasing the decomposition of organic matter and the release of nitrogen.

Moringa leaf-based LOF material flowering twigs provide lower nitrogen content than LOF made from seaweed. This was related to the fermentation method used. Anaerobic fermentation, which was carried out in conditions without oxygen, could reduce the decomposition of nitrogen compounds. Under anaerobic conditions, microorganisms tend to utilize other compounds as energy sources, which could result in decreased nitrogen release into the liquid fertilizer. Environmental conditions such as temperature and pH during fermentation also play an important role. Higher temperatures could increase the activity of microorganisms, which could accelerate

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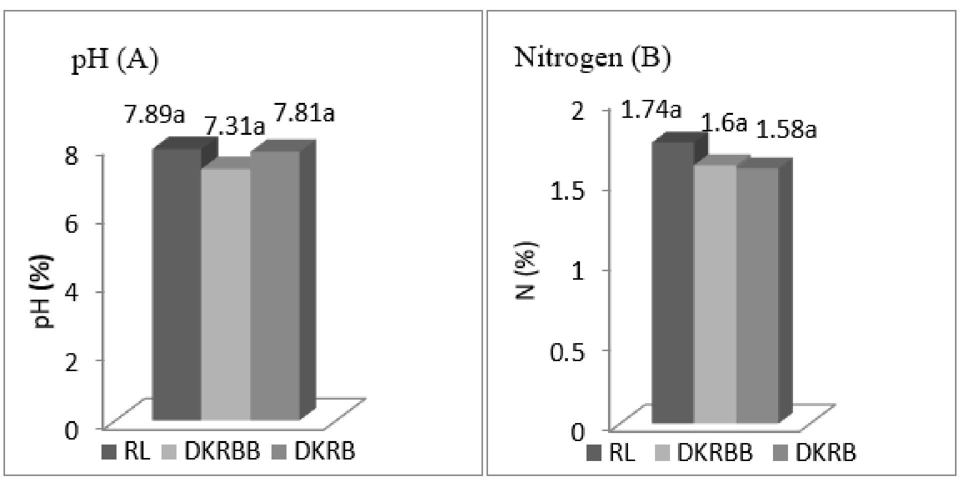
the decomposition of organic matter and release nitrogen. Low nitrogen content could be caused by nitrogen elements used by microorganisms for their needs and the change of nitrogen elements into gas form (43). Other factors that affected the high and low nitrogen content were the nature of the materials used, the types of microbes that grew and the fermentation process, fermentation conditions, and the length of fermentation time (44).

Nitrogen levels of seaweed LOF in this study were higher than the results of research by Basmal (2009)(8) LOF seaweed *Sargassum* sp. which had a nitrogen content of 0.012%. However, the nitrogen content of seaweed LOF in this study was lower than the results of research by Utomo and Asmawit (2012) (24) nitrogen content of seaweed coastal waters of Bengkayang Regency sargassum polycistum seaweed was 2.53%.

The nitrogen content of moringa leaf LOF in this study was higher than the results of research by Mulyanisngih et al (2024)(45) , the nitrogen content of moringa leaf LOF contained was 0.15%. Previous research results, Moringa leaf LOF with the addition of molasses nitrogen content was 0.24% (46). However, the nitrogen content of moringa leaf LOF in this study was lower than the results of Gandut *et al.* (2023) (47) with the nitrogen content of moringa leaf LOF was 2.71%. Previous research results, Ghani and Riszqina (2024) (48) reported that the nitrogen content of moringa leaf LOF was 4.7%.



Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 5: pH (A) and nitrogen (B) of moringa leaves and sea weed LOFs

Phosphorus

The highest LOF phosphorus content (1.17%) was found in moringa leaves from flowering twigs (Figure 6A), followed by phosphorus nutrients in moringa LOF from non-flowering twigs and phosphorus nutrients in seaweed LOF. Moringa leaf-based LOF materials provided higher

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phosphorus content than other sources. This related to the use of microorganisms such as EM4 (Effective Microorganisms) which could accelerate the fermentation process and improved the quality of the fertilizer produced. These microorganisms helped the decomposition of organic matter and increased the content of nutrients, including phosphorus. The increase in phosphorus levels was due to the EM4 activator (49).

Seaweed-based LOF materials provided lower phosphorus content than LOF made from moringa leaves. This related to the anaerobic fermentation process which could affect the availability of nutrients, including phosphorus. A fermentation time that was too short might not provide sufficient time for microorganisms to decompose phosphorus-containing compounds, while a fermentation that was too long might cause nutrient loss through further decomposition processes. According to Kusumadewi *et al.* (2019) (50) the longer the fermentation time, the more nutrients or food used for microorganism activity, so that over time the availability of nutrients would run out and resulted in the death of microorganisms, so that in this phase the activity of microorganisms in breaking down organic compounds would decrease and the results of phosphorus levels would be less than before. The phosphorus content of moringa leaf LOF in this study was higher than the results of research by Mulyaningsih *et al.* (2024)(51), the phosphorus content of moringa leaf LOF contained was 0.004%. The results of previous research showed that moringa leaf LOF with the addition of molasses contained phosphorus levels of 0.12% (46). The previous research also reported that the phosphorus content of moringa leaf LOF was 0.41 ppm (48).

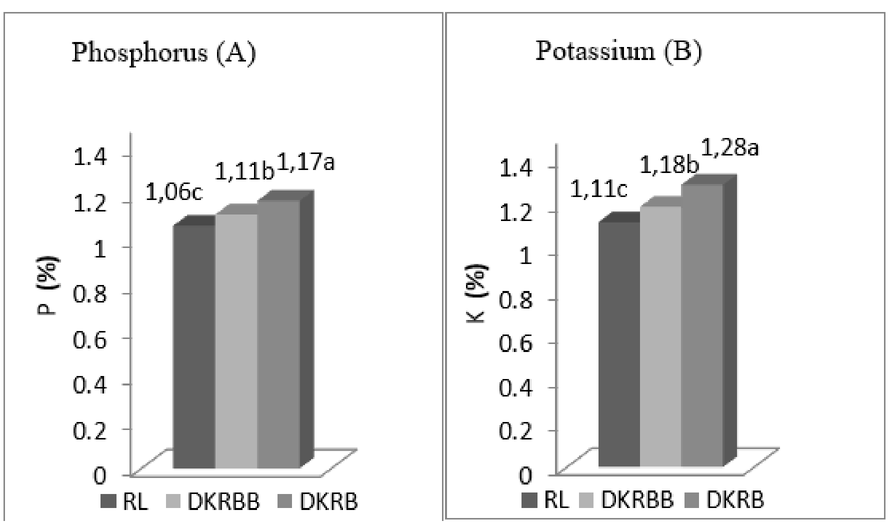
The phosphorus content of seaweed LOF in this study was higher than the results of Basmal's research (2009) (8) which reported that LOF seaweed of *Sargassum* sp. had a phosphorus content of 0.13%. The results of previous research Utomo and Asmawit (2012) (24) also reported that the phosphorus levels of seaweed coastal waters Bengkayang Regency, *Sargassum polycistum* seaweed was 0.672%. The results of research Supriyono *et al.* (2024) (52) reported that the phosphorus levels of seaweed *Caulerpa lentillifera* was 19.903 ppm, *Gracillaria* sp. was 16.762 ppm and *Eucheuma cottoni* was 24.031ppm.

Potassium

The highest potassium content (1.28%) was found in flowering twig moringa leaves (Figure 6B), followed by LOF of unflowered twig moringa leaves and seaweed LOF. Flowering twig moringa leaf LOF gave a higher potassium content than the other sources. This related to the flowering twigs of moringa leaves had a different chemical composition compared to other vegetative parts. Flowering twigs might contain more compounds that supported the release of potassium during the fermentation process. Anaerobic fermentation tends to produce products with higher potassium content, as this process could reduce nutrient losses and increased potassium availability in solution. Microorganisms active in anaerobic fermentation could also break down compounds that bound potassium, thus increasing potassium concentration. According to Kurniawan *et al.* (2013) (49) bacteria produced potassium compounds and use K+ ions contained in fertilizer raw materials for their metabolic purposes so that potassium levels would increase along with the growing number of bacteria.

Seaweed-based LOF materials provided lower potassium content than LOF based on moringa leaves. This related to the fact that during fermentation, the interaction between potassium and other nutrients such as sodium, magnesium, or calcium could affect the availability of potassium. According to Kusumadewi *et al.* (2019) (50) the longer the fermentation time did not mean the potassium content also increased. If the fermentation continued, the microorganisms would die because the nutrients from the microbes had been reduced, so that in this phase the activity of microorganisms in breaking down organic compounds would decrease and the results of potassium levels would be less than before. The potassium content of moringa leaf LOF in this study was higher than the results of research by Mulyaningsih *et al.* (2024) (51) which contained 0.04% potassium content of moringa leaf LOF. The results of previous research showed that moringa leaf LOF with the addition of molasses potassium content was 0.37% (46). Another previous results showed that the potassium content of moringa leaf LOF was 0.48% (48).

The potassium content of seaweed LOF in this study was lower than the results of Basmal's research (2009) (8) LOF seaweed *Sargassum* sp. had a potassium content of 1.22%. The results of previous research Utomo and Asmawit (2012) (24) potassium content of seaweed coastal waters Bengkayang Regency *Sargassum polycistum* seaweed was 2.65%.



Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 6: Phosphorus (A) and potassium (B) of moringa leaves and sea weed LOFs

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Calcium

The highest calcium content (1.25%) was found in moringa leaves without flowering branches (Figure 7A), followed by seaweed LOF and moringa leaves with flowering branches LOF. The LOF material based on moringa leaves without flowering branches provided higher calcium content than the other sources. This was related to the process of breaking down complex organic compounds into simpler compounds. Microorganisms, such as bacteria and fungi, played a role in this process, which allowed the release of calcium and other nutrients from the moringa cell tissue. During fermentation, microbial activity broke down compounds rich in calcium and other minerals. These microorganisms could convert the complex compounds in moringa leaves into a more bioavailable form, thereby increasing the availability of calcium in the LOF.

LOF materials based on moringa leaves with flowering branches provide lower calcium content than LOF based on moringa leaves without flowering branches. This related to the fermentation process, microorganisms broke down organic compounds in moringa leaves. If flowering twigs had a different chemical composition compared to unflowered twigs, then this breakdown might produce compounds that contained less calcium. Flowering twigs might have more compounds bound up with plant reproductive processes, which might reduce calcium availability. During fermentation, interactions between calcium and other nutrients such as magnesium or sodium may affect calcium availability. If the flowering twigs contain more competing elements, this might reduce the availability of calcium in the LOF.

The calcium content of moringa leaf LOF in this study was higher than the results of previous research that reported that the calcium content of moringa leaf LOF was 0.48% (48). However, the calcium content of seaweed LOF in this study was higher than the results of Basmal's (2019)(9) LOF, seaweed *Sargassum* sp. which had calcium content 0.06%. Previous research results, Sedayu *et al.* (2014) reported that the LOF seaweed of *Sargassum* sp. had calcium levels 109 ppm, *Ecottoni* 660 ppm and *Gracilaria* sp. 1028 ppm.

Magnesium

The highest magnesium content (1.18%) was found in moringa leaves without flowering branches (Figure 7B), followed by moringa leaves with flowering branches and seaweed LOF. The LOF material based on moringa leaves that had not yet flowered gave a higher magnesium content than the other material sources. This related to the fermentation method used, both anaerobic and aerobic, which could affect the final results. Anaerobic fermentation, which was carried out in conditions without oxygen, could help retain minerals such as magnesium in a more stable form.

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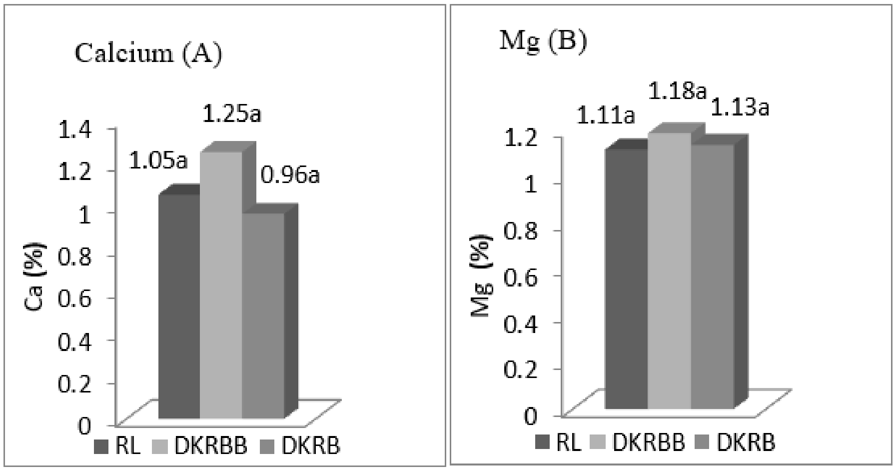

Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 7: Calcium (A) and magnesium (B) of moringa leaves and sea weed LOFs

Seaweed-based LOF materials provided lower magnesium content than Moringa leaf-based LOF. This related to Anaerobic Fermentation, which under anaerobic conditions could help to reduce magnesium availability. Under these conditions, microorganisms would focus more on breaking down compounds that did not contain magnesium, thereby reducing the concentration of magnesium in the final fertilizer. The addition of EM4 bioactivator accelerated the fermentation of organic matter to produce nutrients (53). Magnesium levels of seaweed LOF in this study were lower than the results of research Utomo and Asmawit (2012)(24) which reported that magnesium levels of seaweed coastal waters Bengkayang Regency*, Sargassum polycistum* seaweed was 1.4%. The results of previous research Basmal (2019)(9), LOF seaweed of *Sargassum* sp. had a magnesium content of 0.17%. As well as the results of research Sedayu *et al.* (2014)(54) LOF seaweed of *Sargassum* sp. had calcium levels of 48 ppm, *Ecottoni* 285 ppm and *Gracilaria* sp. 300 ppm.

Organic Carbon

The highest organic carbon (C) content (3.00%) was found in LOF produced by using moringa leaves unflowering branches (Figure 8A), followed by that use moringa leaves of flowering branches and seaweed. The LOF material based on moringa unflowered twigs provided a higher organic C content than the other material sources. The unflowered twigs of moringa contained high fiber and organic compounds, which contributed to the organic carbon content. This part generally had a higher carbon ratio compared to other plant parts, such as young leaves. The fermentation process, either anaerobic or aerobic, could affect the release and stability of organic carbon. Anaerobic fermentation tended to produce more dissolved organic compounds, thus increasing the organic carbon content in liquid fertilizer. According to Widyabudiningsih *et al.*

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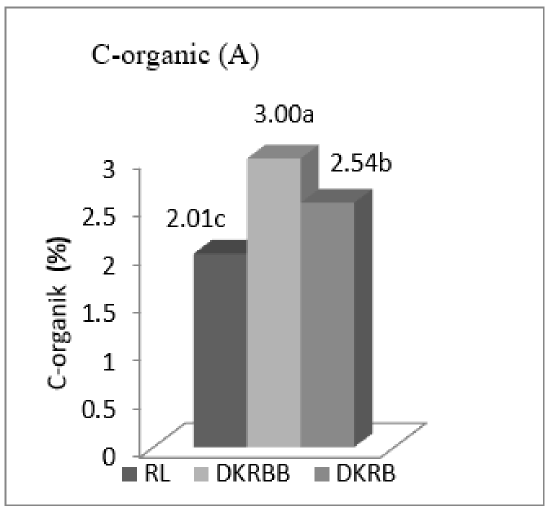
(2021)(55), organic carbon in organic matter was useful as an energy source for microorganisms for metabolic activities.

Seaweed-based LOF materials provided a lower C-organic content than Moringa leaf-based LOF. This related to the fact that during the fermentation process, microorganisms broke down organic matter into simpler compounds. If the activity of microorganisms was too high or uncontrolled, they could decompose too many organic compounds, thus reducing the C-organic content in the resulting liquid fertilizer. The quality and freshness of the seaweed used also affected the C-organic content. Seaweed that had begun to rot or was not fresh tended to have a lower C-organic content. The reducing of carbon content because carbon was used as an energy source by microorganisms for their metabolic activities and would decompose into the air in the form of CO2 (56).



Notes: RL (Seaweed), DKRBB (Moringa leaf from unflowering twig), DKRB (Moringa leaf from flowering twig).

Fig. 8: C-organic (A) of moringa leaves and sea weed LOFs

The C-organic content of moringa leaf LOF in this study was lower than the results of research by Mulyaningsih *et al.* (2024), where the C-organic content of moringa leaves contained 7.01%. The results of previous research by Pandi *et al.* (2023) (57)analyzed the C-organic content of LOF from *L. leucocephala* forage at 6.84%, *C. odorata* at 7.81%, *T. diversifolia* at 6.20%, and *Indigofera* at 8.30%.

C-organic levels of seaweed in this study were lower than the results of research Wahyudi *et al.* (2018) (58) which reported that seaweed C-organic content was 3.92%. The results of previous research Utomo and Asmawit (2012) reported that level of C-organic of seaweed coastal waters of Bengkayang Regency, *Sargassum polycistum* was 7.66%.

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4. CONCLUSION

1. The highest nitrogen, phosphorus, and magnesium contents were found in unflowering moringa leaves, followed by flowering moringa leaves and seaweeds. Meanwhile, the highest potassium and calcium were found in seaweeds, followed by unflowering moringa leaves and flowering moringa leaves. The highest lignin content was found in flowering moringa leaves, followed by unflowering moringa leaves and seaweeds. In addition, the highest cellulose content was found in seaweeds, followed by flowering moringa leaves and unflowering moringa leaves.
2. Liquid organic fertilizer (LOF) produced by using seaweeds had the highest of nitrogen, followed by those LOF of unflowering moringa leaves and flowering moringa leaves. Meanwhile LOF produced by using unflowering moringa leaves had the highest calcium, magnesium and organic carbon C, followed by those LOF of lowering moringa leaves and seaweeds. In addition, LOF produced by using flowering moringa leaves had the highest pH, phosphorus, potassium, followed by those LOF of flowering moringa leaves and seaweeds.

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