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PRODUCTION AND PERFORMANCE OF OKARA/SAGO AND OKARA/BANANA PEEL ORGANIC FERTILIZERS IN PLANTATION

JOSEPHINE C. H. LAI*, KHAIRUL H. MASRUN, NOORALINAH MADIN, RUBIYAH H. BAINI, NUR A. S. ABDUL SAMAT

Department of Chemical Engineering and Energy Sustainability, Faculty of Engineering, Universiti Malaysia Sarawak, 93400, Kota Samarahan, Sarawak, Malaysia
*Corresponding Author: lchjosephine@unimas.my

Abstract

The application of chemical fertilizer improved the growth rate in the plantation. However, chemical fertilizer itself was not environmentally friendly. Thus, organic fertilizer with low production cost should be undergoing thorough research. This study investigated the performance of organic fertilizer produced using okara/sago and okara/banana peel on the growth rate of the plants. The organic fertilizers were produced into five samples with different ratios and placed in incubator oven at temperature 100ºC for 4 hours for drying process. Both organic fertilizers were analysed using FTIR, SEM and moisture balance analysis. Both fertilizers were then applied on and Mustard Looseleaf plants. FTIR and SEM analysis proved the well combination of okara with banana peel and sago with smoother surfaces, respectively. Both organic fertilizers were oven-dried to remain as solid stage. The results obtained proved that both organic fertilizers with the highest content of okara was the most effective in enhancing the growth rate of Mustard Looseleaf plants in terms of height and leaf size.

Keywords: Banana peel, Okara, Organic fertilizer, Plantation, Sago.

1. Introduction

In agricultural field, most of the farmers used synthetic fertilizer to improve the growth rates of their plantation. In fact, the plants can survive without consuming any fertilizer. However, the plants need more time to obtain the nutrients from the soil for the growth. The application of synthetic fertilizer is simple yet effective for fast growth of plants, but this type of fertilizer is not environmentally friendly, and it destroys the soil structure and nutrients [1]. Therefore, organic fertilizer is required to be produced which can help in the recovery of the soil condition [2]. Organic fertilizer is expected to boost the production rate of the crops. Organic fertilizer helps the root to grow stronger and this indirectly improves the physical synthetic properties of the soil such as soil aggregation and soil water retention characteristics. Moreover, this also minimizes the pollution. However, both organic and synthetic fertilizer must be applied in appropriate amount to prevent any side effect to the plant growth. For this study, three types of organic wastes were selected to form organic fertilizer, namely okara, sago and banana peel.

Soybean curd residue, named as okara in Japanese is a white-yellowish by-product from soybean processing by removing the water-extractable fraction in order to produce tofu or milk [2]. From every production of soya bean product, about 1.1 kilograms of okara are produced. Both China and Korea produced okara with 2 800 000 tonnes and 310 000 tonnes of okara respectively each year while Japan produced the most okara every year with high amount up to 700 000 tonnes [2-3]. With the mass production of soybean products around the world, tonnes of okara are produced. This leads to disposal problem as okara is not utilized for any applications.

Besides, sago (*Metroxylon Sagu*) is one of the food sources in South East Asia. It lives naturally in the South Pacific region and extended to the west including Malaysia, Indonesia, and Thailand [4]. One of the biggest producers of sago in the world is Malaysia. Sago tree usually provides food to the human especially sago starch as well as to become fuel sources. Due to this advantage, sago can be utilized to produce organic fertilizer which is environmentally friendly and biocompatible to the soil condition.

Banana peel is another type of organic waste which is usually thrown due to no specific usage on it. However, based on the latest research, it is found that banana peel is suitable to be applied as fertilizer where banana peel contains calcium, magnesium, phosphorus, zinc, and copper [5]. All the mentioned elements greatly help in the growth of plantation. Besides, banana peel has been investigated and the results proved that banana especially the banana peel contains adequate amount of nitrogen (2.6%), phosphorus (0.6%) and potassium (3.5%) [5].

Due to the abundant amount of organic wastes such as okara, sago and banana peel without significant applications, they can be combined to produce organic fertilizer in different ratios to ensure it helps in the growth of plants. Although sago waste compost brings benefits towards plantations, it has big pore size that leads to high possibility of water storage and cause aeration [6]. Although okara is abundant and rich in dietary fibers, it brings potential prebiotic effects due to the complex cell wall of okara [7]. With all these organic wastes having different disadvantages, the combination of okara with sago and banana peel respectively are encouraged to reduce the disadvantages of the individual organic wastes in organic fertilizer production. Although banana peel has been one of the effective organic wastes to be utilized as organic fertilizer, banana peel organic waste is easier to attract unwanted insects as well as unpleasant smell [8]. Different wastes had different negative effects. Therefore, combination of two different types of organic wastes would be expected to produce better organic fertilizers for plantation that overcome negative effects of each type of wastes. The objective of this paper is to produce organic fertilizer using okara/sago and okara/banana peel. The organic fertilizer is applied on Mustard Looseleaf plant to investigate the effects of organic fertilizer on the growth of the plants.

2. Experimental Procedure

The okara was collected from the local soybean factory near Kuching, Sarawak. Unused okara was stored in the chiller or refrigerator to prevent the okara from staling. Both sago and banana peel were obtained from sago industry and local farmer in Kota Samarahan. The banana peel was blended to ensure it could be well mixed with okara. All the materials collected were weighed by using weighing scale based on desired weight. Soils and vegetable seeds were purchased from the same vegetable shop to ensure the quality of both soils and seeds were the same for experimental purposes.

2.1. Fabrication of okara/sago and okara/banana peel organic fertilizers

Okara/sago and okara/banana peel organic fertilizers were produced in the ratio stated in Table 1. Overall mass of each okara/sago and okara/banana peel organic fertilizers was 50g. All the okara/sago and okara/banana peel compositions were mixed evenly and placed in the incubator oven at 100℃ for 4 hours to fabricate the fertilizer stiff [9].

Table 1. Ratio of okara/sago and okara/banana peel organic fertilizers.

Mass of okara (g)	Mass of sago (g)	Mass of blended banana peel (g)
10	40	40
20	30	30
25	25	25
30	20	20
40	10	10

2.2. Characterizations of okara/sago and okara/banana peel organic fertilizers

The samples had undergone three analysis which are Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM) and moisture absorption test.

2.2.1. Fourier transform infrared spectroscopy (FTIR)

Fourier Transform Infrared Spectroscopy (FTIR) analysis is conducted using Shimadzu IRAffinity-1. This analysis is used to identify the functional groups presented in the sample with transmittance range between 4000cm^{-1} and 600cm^{-1}.

2.2.2. Scanning electron microscopy (SEM)

Scanning electron microscope (SEM) was conducted using scanning electron microscope (SEM) (JSM-6710F) supplied by JEOL Company Limited, Japan. This analysis is used to examine the interfacial bonding between okara/sago and okara/banana peel organic fertilizers. The specimen was coated with a thin layer of gold before undergo microscope analysis. The high-resolution images of the okara/sago and okara/banana peel organic fertilizers were created under magnification of 500 and 1000.

2.2.3. Base drag coefficient

Moisture absorption test was carried out by electronic moisture balance (MOC-120H) supplied by Shimadzu Corporation, Japan to identify the moisture absorption ability by okara/sago and okara/banana peel organic fertilizers. Both organic fertilizers which had dried were immersed in distilled water. The immersed organic fertilizers were removed and placed into moisture balance with display in percentage form. The moisture absorbed percentage, *W* is calculated as follows:

$$W = \frac{Ww - Wd}{Ww} x100\% \quad (4)$$

2.3. Application of okara/sago and okara/banana peel organic fertilizers on *mustard looseleaf* plants

Both okara/sago and okara/banana peel organic fertilizers were applied on *Mustard Looseleaf* plant. This was carried out to investigate the effectiveness of both organic fertilizers on *Mustard Looseleaf* plants. The observations were made by capturing photo of the plants on week 1 and 10 and measured the height and leaf size of the plants. The planting period was ten weeks.

3. Results and Discussion

3.1. Oven dried okara/sago and okara/banana peel organic fertilizer

Figures 1 and 2 shows the conditions of oven dried over three-month period for five different ratios of okara/sago and okara/banana peel organic fertilizers. In order to lengthen the lifespan of the organic fertilizers, oven-dried was applied to remove excess moisture within the fertilizers. In addition, oven-dried organic fertilizers were remained as solids which eased the transportation process due to lower weight [10]. From Figs. 1 and 2, all the ratios of oven dried okara/sago and okara/banana peel organic fertilizers remained as solid state after three months. Figure 1 shows that the colour of all the okara/sago ratio organic fetilizers are light yellowish as okara itself contains yellowish colour whereas the sago is transparent white in colour. Therefore, any okara to sago ratio remained the colour as light yellowish. Besides, 40:10 okara/banana peel organic fertilizer showed the brightest colour whereas 10:40 okara/banana peel organic fertilizer showed darker colour. This was because okara itself is yellowish white which led to brighter colour when more okara was introduced to the organic fertilizer. Overall, oven dried organic fertilizers remained as solid state which eased the transportation processes with lighter weight.

(a)

(b)

(c)

(d)

(e)

Fig. 1. Oven-dried (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/sago organic fertilizers.

(a)

(b)

(c)

(d)

(e)

Fig. 2. Oven-dried (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/banana peel organic fertilizers.

3.2. FTIR of okara/sago and okara/banana peel organic fertilizers

Figures 3 and 4 show the FTIR results for okara/sago and okara/banana peel organic fertilizers for five different ratios, respectively. Figure 3 shows that 40:10 okara/sago organic fertilizers showed dominant peaks in the 3800cm^{-1} to 3500cm^{-1} region which corresponded to O-H stretching vibration of the hydroxyl group that led to higher hydrophilic tendencies of fibers [11]. Other ratio of okara/sago organic fertilizers showed less changes in hydroxyl groups as the presence of amylose and amylopection in sago starch [12]. Combination of lower okara ratio and higher sago ratio reduced the hydroxyl groups with stronger C-H stretching bonds formed within the combination. The stretching of aromatic ring and vibration of C=C-C within the lignin component of sago was presented by the IR absorption bands within 1517cm^{-1} and 1529cm^{-1} region. In addition, the IR absorption bands at 1641cm^{-1}, 1649cm^{-1} and 16593cm^{-1} was appeared due to the adsorbed H_2O. Higher peaks were observed around 1000cm^{-1} and 1010cm^{-1} region due to the -C-O- stretching vibration of cellulose and hemicellulose [13]. Thus, it proved that okara and sago were successfully combined through strong organic bonds formed within the organic fertilizers.

From Fig. 4, all the ratios of okara/banana peel organic fertilizers showed less hydroxyl group due to the relative humidity [14]. Clear peaks were detected at 3300cm^{-1} region due to the strong O-H stretching of both okara and banana peel [15, 16]. The occurrence of peaks at 2950cm^{-1} region presented the methyl ester C-H stretching within banana peel. The peaks occurred around 1641cm^{-1} was due to the water adsorbed into the organic fertilizers [16]. In addition, peaks around 1600cm^{-1} were due to the N-H stretching within banana peel while absorption around 1450cm^{-1} was assigned to organic sulphate stretching within the banana peel [17]. Another clear peak detected in Fig. 4 was at 1000 cm^{-1} which was due to the Si-O-Si stretching of banana peel within the organic fertilizers. Through FTIR, it was clearly shown that okara was well mixed with sago as well as banana peel to form organic fertilizers.

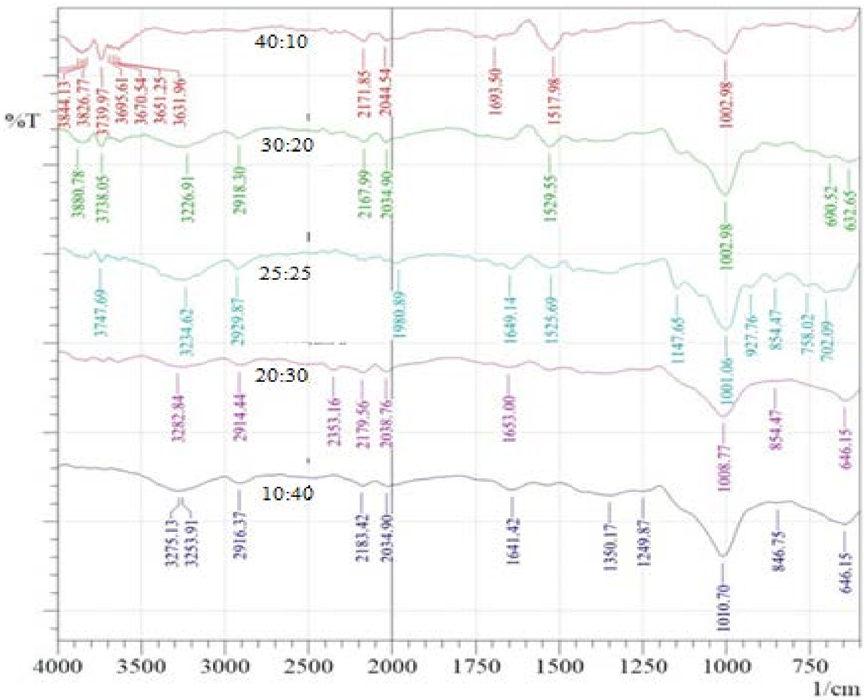


Fig. 3. FTIR graphs of five different ratio of okara/sago organic fertilizers.

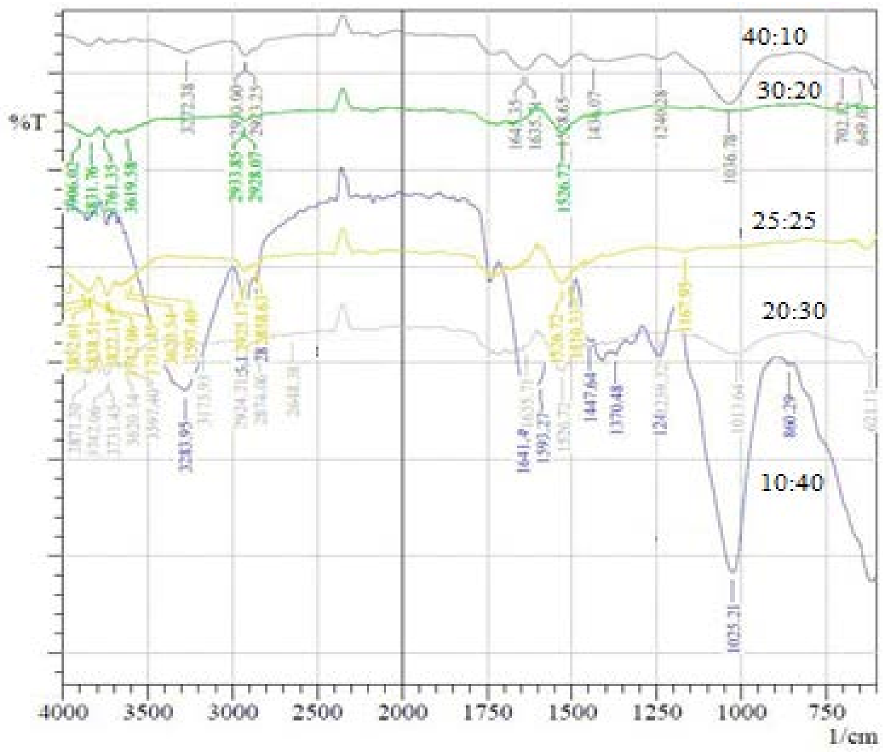


Fig. 4. FTIR graphs of five different ratio of okara/banana peel organic fertilizers.

3.3. SEM analysis of okara/sago and okara/banana peel organic fertilizers

Figures 5 and 6 show the SEM microscopy for okara/sago and okara/banana peel organic fertilizers for five different ratios. From Fig. 5, higher okara/sago ratio organic fertilizers showed smaller porous structures compared to lower okara/sago ratio organic fertilizers. This was due to the incorporation of okara molecules into sago structure that filled the porous structure.

Okara was introduced to provide additional areas to reduce the vacuoles within the organic fertilizers. The uneven surface areas were observed. Among all the ratio of okara/sago organic fertilizer, 40:10 okara/sago organic fertilizer showed the least pores. Figure 6 shows that 40:10 okara/banana peel organic fertilizer was well intercalated with less porous compared to other ratios, which was well proven by FTIR result (Fig. 2).

Okara acted as the adhesive agent that reduced the pores surfaces of the okara/banana peel organic fertilizer [18]. The higher content of polysaccharide, lactic acid, and energy within okara created tighter microporous structure and thus it improved the microstructure of banana peel [19]. Therefore, higher content of okara improved the microstructure banana peel. Overall, 40:10 okara/sago and 40:10 okara/banana peel organic fertilizers showed better surface morphology among all the organic fertilizers produced.

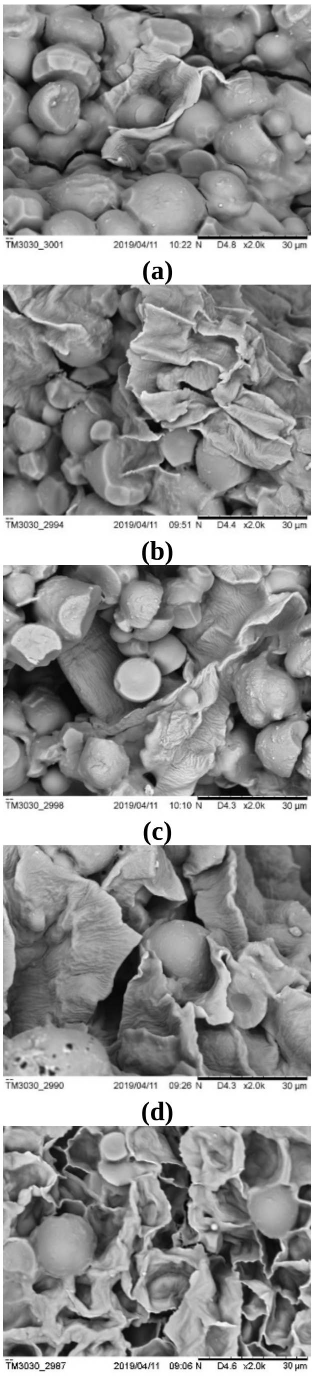


Fig. 5. SEM images of (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/sago organic fertilizers.

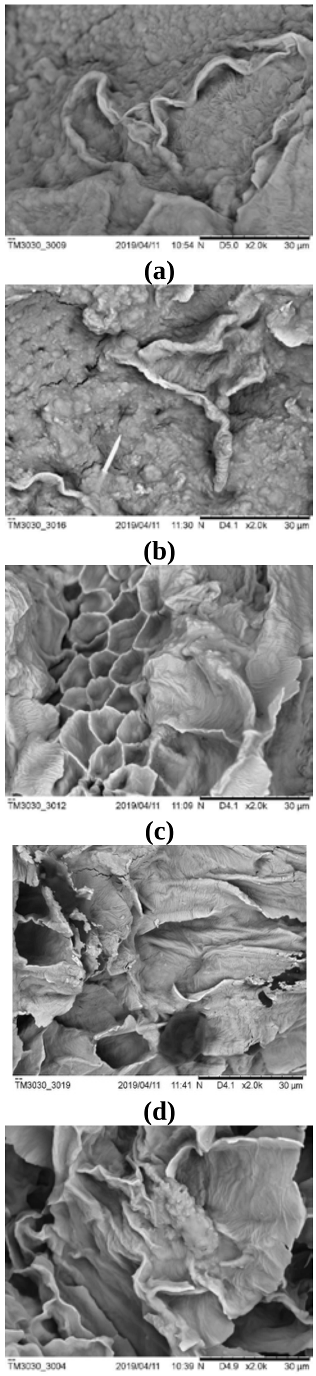


Fig. 6. SEM images of (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/banana peel organic fertilizers.

3.4. Moisture absorption of okara/sago and okara/banana peel organic fertilizers

Moisture content influences the durability of the fertilizer. Since the organic fertilizers were made from organic materials, higher moisture content shortened the applicability of the fertilizer and made it less durable. Hence, moisture absorption analysis has been carried out to identify the suitable temperature and period of time needed to remove the moisture. Figures 7 and 8 show the moisture absorption for okara/sago and okara/banana peel organic fertilizers for five different ratios at 100℃ for 120 minutes. This was clearly shown that rapid reduction of moisture content in the first 35 minutes and 15 minutes for okara/sago and okara/banana peel organic fertilizers, respectively, and the percentage of moisture reduced decreased slowly which related to the diffusion rate of water into the organic fertilizers. From Fig. 7, 40:10 okara/sago organic fertilizer showed the highest moisture reduction around 9%, followed by 30:20 okara/sago of 8.7%, 25:25 okara/ sago of 8.4%, 20:30 okara/sago of 8% and lastly 10:40 okara/sago organic fertilizer of 7.3%. Higher sago content reduced the water resistance of organic fertilizer as the hydroxyl group starch within sago had high tendency to absorb water [20]. In addition, the amylopection within sago starch easily absorbed more water molecules [21]. Figure 8 shows that 40:10 okara/banana peel organic fertilizer had the highest moisture reduction of about 13%, followed by 30: 20 okara/banana peel of 12%, 25:25 okara/banana peel of 10%, 20:30 okara/banana peel of 8.5% and lastly, 10:40 okara/banana peel of 7%. Banana peel as fruits skin fiber were highly hydrophilic which are more susceptible to water absorption as banana peel was rich in cellulose and that led to hydrogen bonds formed between water and banana peel, therefore, higher amount of banana peel absorbed more water and performed lower water resistance compared to higher okara/banana peel organic fertilizer [22]. Overall, 40:10 okara/sago and 40:10 okara/banana peel organic fertilizers showed the most reduction with the higher water resistance for ease transportation.

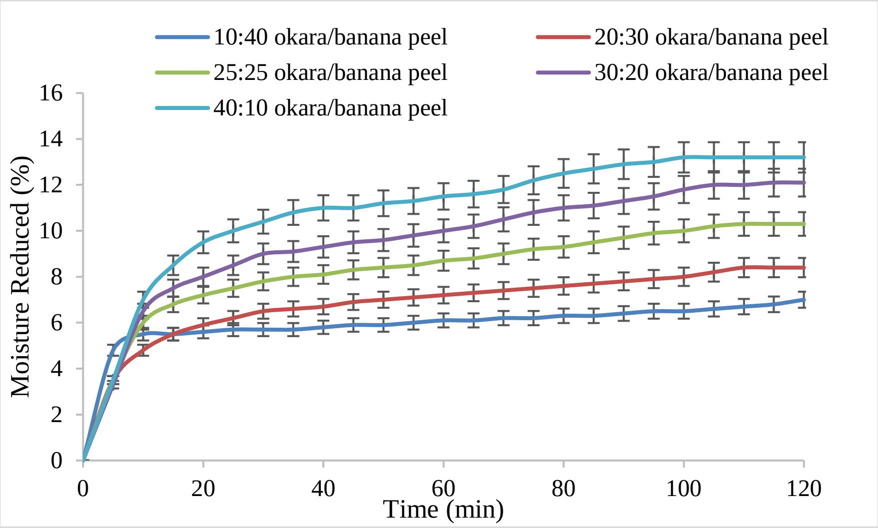


Fig. 7. Moisture absorption of five different ratio of okara/sago organic fertilizers.

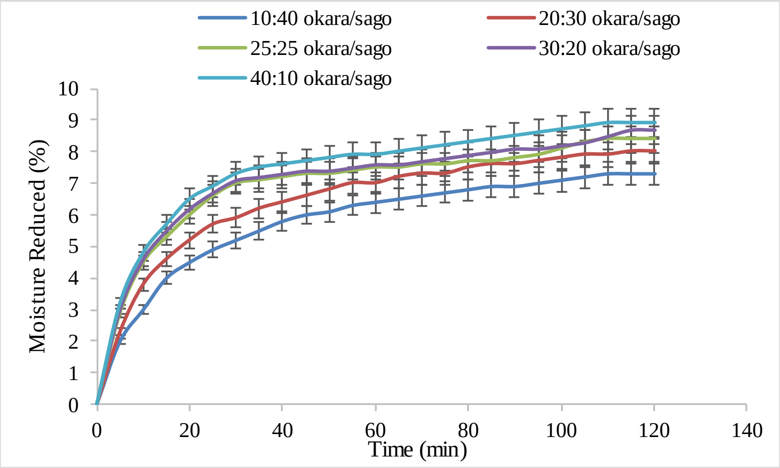


Fig. 8. Moisture absorption of five different ratio of okara/banana peel organic fertilizers.

3.5. Plant growth of mustard looseleaf plants with the introduction of okara/sago and okara/banana peel organic fertilizers

Figures 9 to 12 show the plant growth of *Mustard Looseleaf* plants with the introduction of 15g okara/sago and okara/banana peel organic fertilizers for five different ratios on week 1 and 10. Figure 9 shows *Mustard Looseleaf* plants at week 1 while Fig. 10 shows *Mustard Looseleaf* plants at week 10 with the introduction of okara/sago organic fertilizer at five different ratios. Figure 10 shows that all the plants grew up with heights and big size of leaves. Table 2 shows the height and leave sizes of *Mustard Looseleaf* plants at different ratios of okara/sago organic fertilizer. From Table 2, it was clearly proven that the higher amount of okara content improved the plant growth compared to higher sago content. 40:10 okara/sago organic fertilizer improved the plant growth with height increment of 23.7cm and leaf size increment of 120.80cm^2, while the introduction of 10:40 okara/sago organic fertilizer, the plant growth increment in height was 8.1cm and leaf size was 13.77cm^2. This was because organic fertilizers helped in crop yield enhancement as well as soil properties [23]. Figure 11 shows the observations of *Mustard Looseleaf* planted on week 1 with the introduction of 15g okara/banana peel organic fertilizers in five different ratios while Fig. 12 shows the plants growth at week 10. From Fig. 12, it was clearly proven all the plants manage to grow with the introduction of okara/banana peel organic fertilizers. Among all the organic fertilizer, 40:10 okara/banana peel organic fertilizer performed the best with height increment of 15cm and leaf size of 31.80cm^2 as presented in Table 3. The least increment of plant growth was performed with the introduction of 10:40 okara/banana peel organic fertilizer which led to height increment of 5.7cm and 3.42cm^2 in leaf size. This was due to the non-covalent bonds formed between okara and banana peels or sago waste. The higher amount of okara with lower amount of banana peel or sago waste ensured all the non-covalent bonds formed fully within the matrix [24]. Therefore, all the hydroxyl group could be fully bonded and thus, water intake towards the fertilizers was reduced and the nutritional content of the organic fertilizers formed from dilution. Thus, higher content of okara used improved the growth rate of the plantation more significant to lower content of okara. Overall, it was clearly proven that 40:10 okara/sago and okara/banana peel organic fertilizers were most suitable to be introduced to *Mustard Looseleaf* plants for better growth.

Table 2. Height Increment and Leaf Size Increment of *Mustard Looseleaf* Plants with introduction of Okara/Sago Organic Fertilizer.

Organic Fertilizer	Height Increment of plants (cm)	Leaf size Increment of plants (cm^2)
40:10 okara/sago	23.7	120.80
30:20 okara/sago	21.1	86.03
25:25 okara/sago	17.6	59.62
20:30 okara/sago	9.3	39.99
10:40 okara/sago	8.1	13.77

(a)

(b)

(c)

(d)

(e)

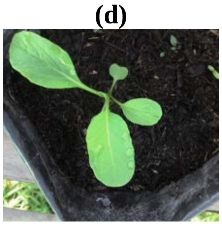
Fig. 9. Plant growth of (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/sago organic fertilizers on week 1.

(a)

(b)

(c)

(d)



(e)

Fig. 10. Plant growth of (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/sago organic fertilizers on week 10.

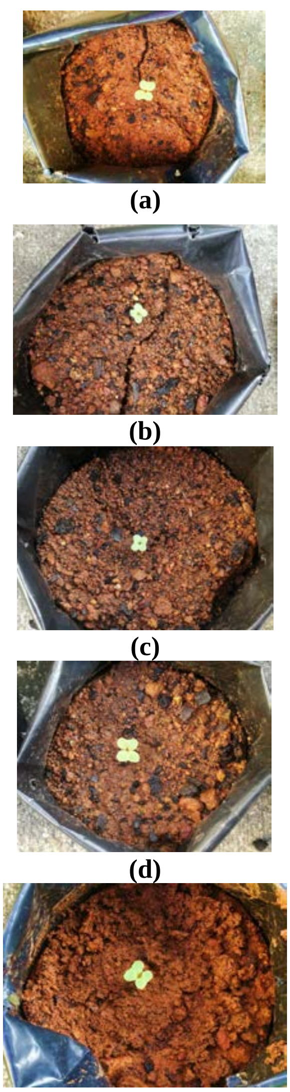


Fig. 11. Plant growth of (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/banana peel organic fertilizers on week 1.

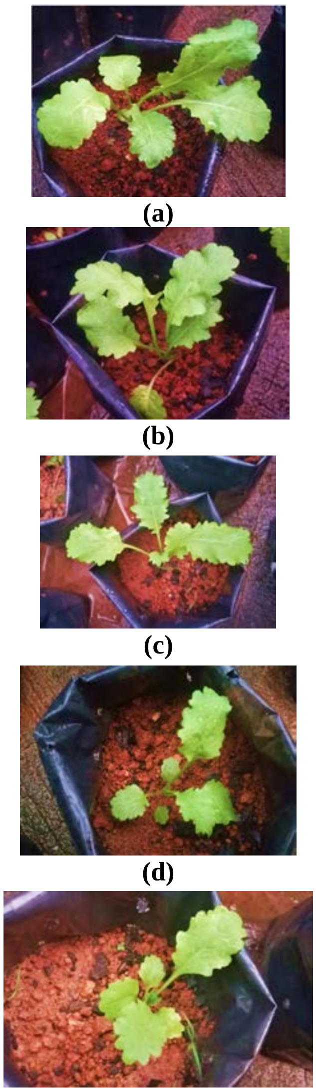


Fig. 12. Plant growth of (a) 40:10; (b) 30:20 (c) 25:25 (d) 20:30 (e) 10:40 okara/banana peel organic fertilizers on week 10.

Table 3. Height Increment and Leaf Size Increment of *Mustard Looseleaf* Plants with introduction of Okara/Banana Peel Organic Fertilizer.

Organic Fertilizer	Height Increment of plants (cm)	Leaf size Increment of plants (cm^2)
40:10 okara/banana peel	15.0	31.80
30:20 okara/banana peel	10.8	26.25
25:25 okara/banana peel	9.9	12.93
20:30 okara/banana peel	6.5	10.50
10:40 okara/banana peel	5.7	3.42

4. Conclusions

From this study, the performance of organic fertilizer produced using okara/sago and okara/banana peel on the growth performance of the *Mustard Looseleaf* plants was investigated. Both organic fertilizers were analysed using FTIR, SEM and moisture balance analysis. Some concluding observations from the investigation are given below.

- FTIR results showed that okara was compatible with sago and banana peel and the best ratio for the organic fertilizer production was 40:10 okara/sago and 40:10 okara/banana peel.
- SEM analysis proved that higher okara content towards both sago and banana peel reduced the porous structure and improved the surface morphology.
- Both okara/sago and okara/banana peel showed better water resistance when the okara was introduced in a higher amount such as 40:10 okara/sago and 40:10 okara/banana peel.
- Both organic fertilizers improved the growth of *Mustard Looseleaf* plants in terms of height and leaf size.
- Overall, the most suitable ratio for Mustard Looseleaf plants growth was to introduce 40:10 okara/sago and 40:10 okara/banana peel organic fertilizers.

Nomenclatures

W	Change of weight, g
W_d	Dry weight, g
W_w	Wet weight, g

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