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Properties of Biochar from Coconut Waste and Application in Agriculture

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Abstract: Coconut plantation waste was in massive quantities affecting the environment in the community. Hence, the coconut plantation was charcoal full of carbon. The objective of this research was to study the properties of biochar from coconut plantation waste and the consequences of adopting biochar to mix with organic fertilizer on the growth and lettuce productivity by analyzing the physical and chemical properties of biochar from coconut plantation waste. The organic fertilizer mixed with the biochar on lettuce growth and productivity was investigated by three treatments no application of organic fertilizer (control), the application of organic fertilizer, and the application of organic fertilizer added with potassium humate. The result showed that the highest level of biochar from coconut shells had the total density, total porosity, water holding capacity, C/N ratio, and humidity at the highest level, equaling 0.58 gram/cubic centimeter, 56.50%, 54.25%, 67%, and 2.41%, respectively. The biochar from the coconut leaves had the highest air gap, pH, conductivity, organic carbon, phosphorus, calcium, and magnesium quantity, respectively (13.50%, 9.90, 2.34 dS/m, 58.94%, 0.12%, 1.25%, and 2.26%, respectively). The biochar from the fallen young coconut fruits had organic matter, cation exchange, nitrogen, and phosphorus quantity at the highest level: 72.37%, 36.19 cmol/kg, 0.57%, and 2.11%, respectively. The results of the organic fertilizer mixed with biochar and Potassium Humate added formula led to the growth and productivity in all 3 types of lettuce more than not applying organic fertilizers ($p<0.05$).

Keywords: Biochar; Agricultural Waste; Coconut Charcoal

1. Introduction

Thailand is an agricultural country that created agricultural waste or biomass at approximately 43 million tons [1]. The value and policy of the New Sustainable Growth Engine (Bio-Circular-Green Economy) partly create zero-waste agriculture. Most agricultural wastes can be beneficial as valuable economic waste. They can reuse by adopting efficient technology. Adopting biomass through the pyrolysis process will cause the dissolution of raw material full of carbon. The charcoal created has high porosity and the highest nutrient level, especially phosphorus, potassium, calcium, and magnesium. In addition, it also has alkaline properties and a high positive cation exchange capacity which causes the ability to modify the acidic soil to highly acidic soil. Once biochar was adopted into the soil, it was revealed that it would reduce the use of fertilizer application and reduce the release of Carbon Dioxide from the soil, which affected the work of beneficial microbes in the soil. The biochar used for the soil's physical and chemical properties depends on the conditions in the pyrolysis process and the raw materials deployed [2,3,4]. In Samut Songkram province, there are many coconut plantation wastes, such as coconut shells, fallen young coconut fruit, and coconut leaves which impact the environment. Hence, these wastes need to be demolished. Adopting the coconut plantation waste into raw materials for biochar making to help with soil improvement in coconut plantations would reduce the expenses on fertilizers, create fertile soil, and strengthen the coconut trees with good growth. Furthermore, it helps with soil improvement for other plants as well. Using biochar as organic fertilizer at the ratio produced from agricultural waste at 100 kilogram/rai results in that durian has grown in both growth and productivity. It can also prevent phytophthora in the soil [5]. In this research, the objectives were to study the properties of biochar from coconut plantation waste and the results of adopting biochar from coconut plantation waste as a mixing ingredient of organic fertilizer for lettuce growth and productivity.

2. Materials and Methods

Properties of biochar from coconut plantation waste and application in agriculture can be classified into 2 parts: the analysis of physical and chemical properties of the biochar from coconut plantation waste and the results of the application of organic fertilizer mixed with biochar towards lettuce growth and productivity by using coconut plantation waste at Samut Songkram province such as parts of coconut shells, fallen young coconut fruits, and coconut leaves. After that, the raw material would be brought to dry and passed through the pyrolysis process at 600 – 700 Celsius for 2-3 hours until the biochar turns shiny. Then, it would get crushed for property analysis.

2.1 The analysis of physical and chemical properties of biochar from coconut plantation waste

Physical properties of biochar from coconut plantation waste: the study of biochar structure with the Scanning electron microscope (SEM), the density, total porosity, air gap, and the water holding ability. Chemical properties of biochar from coconut plantation waste: electric conductivity, pH, organic material, organic carbon, C/N ratio, cation exchange capacity, moisture, nitrogen, phosphorus, potassium, calcium, magnesium, and brimstone sent for analysis at the department of land development.

2.2 The effects of the organic fertilizer mixed with biochar on the growth and productivity of lettuce

The test planning was done by using Latin Square Design (LSD) divided into 3 treatments with 4 replications: 1) no application of organic fertilizer (control), 2) the application of organic fertilizer, and 3) the application of organic fertilizer mixed with potassium humate treatments. The organic fertilizer was compost fertilizer derived from mixed with the biochar the ingredient of banana peels: biochar: phosphate stone: rice bran with a ratio of 70:10:10:10. The treatment of the fertilizer application, which added potassium humate of 1 gram/raw material in the making of the compost of 100 kilograms. Later on, fermented add oxygen for 45 days. Data on chemical properties were pH, electric conductivity, organic matter quantity, nitrogen, phosphorus, and potassium, and the growth and productivity of 3 types of lettuces: green cos, baby cos, and red Batavia. Data were analyzed using the analysis of variance (ANOVA) and different comparisons of statistical averages at the significant level of 0.05.

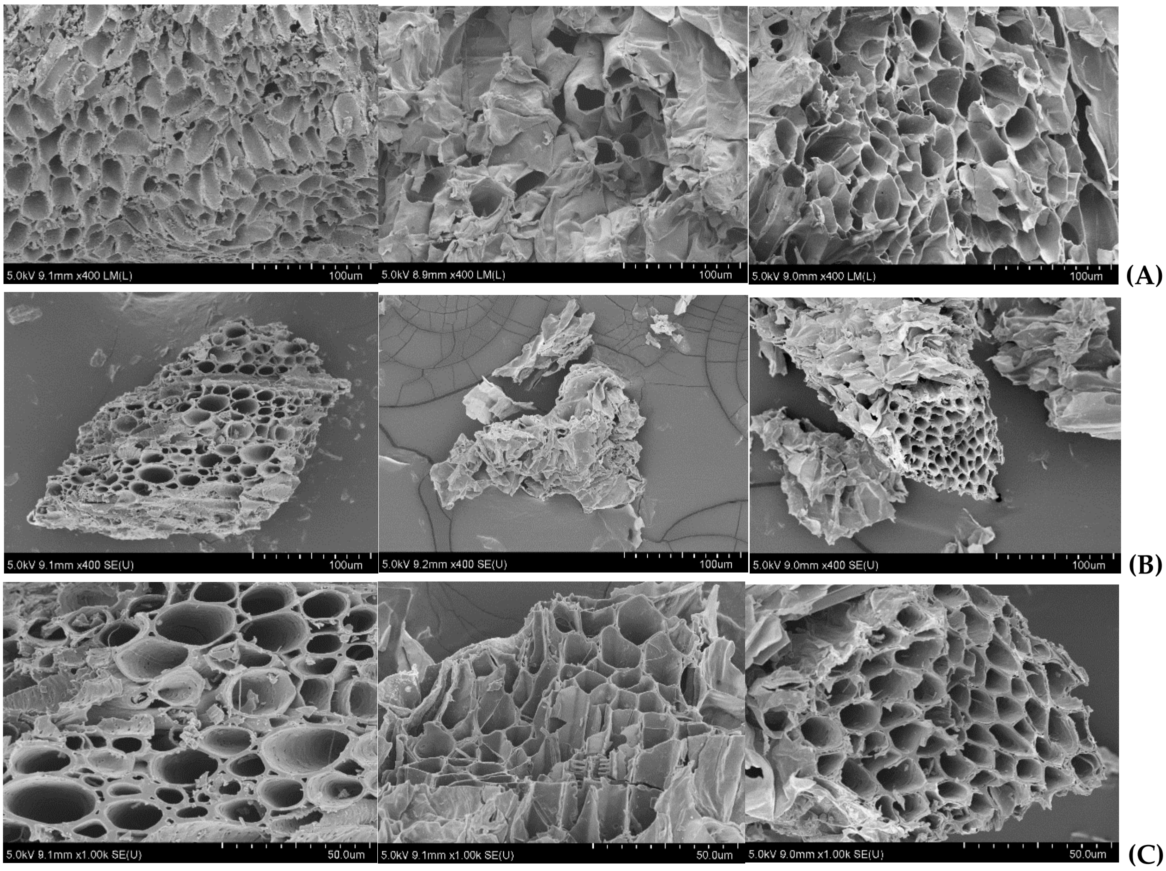
3. Results and Discussion

3.1 Biochar from coconut plantation waste properties

3.1.1 Physical properties of biochar from coconut plantation wastes

Each biochar was burnt using a Pyrolysis process at 400-500 degrees Celsius for 2 hours until the materials turned black to form the biochar from coconut plantation waste. They had different structures when looking through the SEM with the magnifying power of 30 LM showed that crushed biochar with a size of no larger than 0.5 centimeters received from the coconut shells was strengthened with a lot of porous and small size. Regarding biochar from fallen young coconut fruit and coconut leaves, it was found that the structure was fragile, had a smaller quantity of porous, and was larger than biochar from coconut shells. Once using magnifying power, it showed a clearer image of the space. Biochar from coconut shells had a high amount of porous and smaller in comparison with biochar from the fallen young coconut fruit and coconut leaves to bring each of the biochar for crushing into power and dent to the SEM at the magnifying value of 400 LM and

1.00 K showed that biochar from coconut shells had empty area, the small size of the space with the clearer structure than biochar from fallen young coconut fruit and leaves; figure 1:



Biochar from coconut shell Biochar from fallen young coconut fruit Biochar from coconut leaf

Figure 1. The SEM of (A) 400 LM of < 0.5 cm biochar, (B) 400 LM for biochar that crushed into powder, and (C) 1K for biochar that crushed into powder.

Biochar from coconut shells had the highest density, total porosity, and water-holding ability at the highest level, equaling 0.58 gram/ m^3, 56.50%, and 54.25%, respectively. Biochar from coconut leaves had the highest air gap at 13.50% (Table 1). Biochar with the highest amount of air gaps or porous and small size would help with storing water for plant benefits while also absorbing nutrients along with the fact that these air gaps were the living area of microbe that was beneficial to the plants. Moreover, biochar has a strong structure with carbon at a high composition. The degradation will be slow once fertilizers or soil improvement materials are adopted, impacting fertilizer application reduction and better soil structure. [2, 4]

Table 1. Physical properties biochar from coconut shell, fallen young coconut fruit, and coconut leaf

Property	Coconut shell	Fallen young coconut fruit	Coconut leaf
Total density (gram/m^3)	0.58	0.43	0.29
Total porosity (%)	56.50	48.23	50.00
Air gap (%)	3.61	3.50	13.50
Water holding ability (%)	54.25	53.00	36.50

3.1.2 Chemical properties of biochar from the highest coconut plantation waste

The biochar from coconut shells had the C/N ratio and moisture content at 67 and 2.41%, respectively. The biochar from coconut leaves had the pH, electric conductivity, organic carbon, amount of phosphorus, calcium, and magnesium at the highest value of 9.90, 2.34 dS/m, 58.94%, 0.12%, 1.25%, and 2.26%, respectively. The biomass from fallen young coconut fruit had the organic matter, cation exchange capacity, and amount of Nitrogen and Phosphorus at the highest value of equal to 72.37%, 36.19 cmol/kg, 0.57%, and 2.11%, respectively (Table 2).

The pH value of biochar from coconut leaves was equaled to 9.90, which were alkaline found results similar to biochar from coconut husks and shells in Florida, the United States, Indonesia, and Malaysia [6,7]. However, the biochar from coconut shells and fallen young coconut fruits was equal to 6.38 and 7.42, respectively. It was mild acid appropriate with the difference in the adoption of soil improvement. The C/N ratio of the biochar in all 3 types was at a high value; hence, the degradation was slow and, once placed in the soil, can last for a long time. The number of nutrients in biochar from coconut shell and coconut leaf differed depending on the structure and the composition. The dry materials that passed the pyrolysis process showed much nitrogen loss but not for phosphorus, potassium, calcium, magnesium, or Sulfur. In comparison with the study of nutrients in coconut leaf and bearing a dwarf variety of coconut [8], they had no different nutrients from biochar from coconut leaf

Table 2. Chemical properties of biochar from coconut shell, fallen coconut fruit, and coconut leaf

Chemical properties	Coconut shell	Fallen young coconut fruit	Coconut leaf
pH	6.38	7.42	9.90
Electric Conductivity (dS/m)	0.88	1.78	2.34
Organic Matter (%)	43.67	72.37	58.94
Organic carbon (%)	25.33	41.98	58.94
C/N ration	67	74	78
Cation Exchange Capacity (cmol/kg)	21.84	36.19	29.47
Moisture content (%)	2.41	4.86	11.13
Nitrogen (%)	0.38	0.57	0.44
Phosphorus (%)	0.09	0.11	0.12
Potassium (%)	1.39	2.11	0.84
Calcium (%)	0.27	0.44	1.25
Magnesium (%)	0.15	0.48	2.26
Sulfur (%)	1.48	1.63	1.39

3.1.3 Effects of the organic fertilizer with the addition of biochar on the growth and productivity of lettuce

The properties of organic fertilizer mixed with biochar through the process of fermentation for 45 days revealed that the pH value, EC value, OM value, and amount of nitrogen, phosphorus, and potassium of all organic fertilizer treatments were higher than the standardized criteria of high-quality organic fertilizer determined by the Department of Land Development [9] (Table 3).

The results of organic fertilizer mixed with biochar on the growth and productivity of 3 types of lettuce such as green cos, baby cos, and red Batavia, found that the number of leaves per green cos lettuce had no statistical difference ($p \geq 0.05$). Still, the fresh weight of lettuce had a statistical difference ($p<0.05$), for green cos lettuce fresh weight, which received organic fertilizer with potassium humate added, had the highest level of weight in the fresh plant at 61.17 grams. For the lettuce, the fresh weight that did not receive the fertilizer had the lowest level of weight at 34.66 grams (Table 4). Baby cos lettuce had the amount of leaves at the statistical difference ($p<0.05$) at 7, 14, and 28 days. Baby cos lettuce had the highest number of leaves once applying organic fertilizer but had no difference with applying organic fertilizer added with potassium humate. The fresh weight of baby cos lettuce differed statistically ($p<0.05$). Baby cos lettuce with organic fertilizer mixed with potassium humate had the highest level of fresh weight at 60.16 grams. The fresh weight was the lowest at 33.66 grams for the lettuce with no fertilizer applied (Table 5). The red Batavia lettuce had the number of leaves at a statistical difference ($p<0.05$) at 28 days. Red Batavia had the highest number of leaves when applying organic fertilizer mixed with potassium humate at 18.33 grams. The fresh weight of red Batavia lettuce was a statistical difference ($p<0.05$). Red Batavia, which applied organic fertilizer mixed with potassium humate, had the highest level of fresh weight at 42.83 grams. The lettuce with no organic fertilizer had the lowest weight at 28.83 grams (Table 6). The biochar added to high-quality fertilizer helped with the modification of air and soil transfer, modified water holding ability, reduced the hardening of the soil, and affected the operation of beneficial microbe in the soil [2,3,4]. Hence when mixing it with other materials until they become high-quality fertilizer, it will have sufficient nutrients for the growth of lettuces.

Table 3. Chemical properties of high-quality organic fertilizer from banana and coconut waste

Chemical properties	Organic Fertilizer	Organic fertilizer with added Potassium Humate
pH	8.41	8.62
EC (dS/m)	1.73	1.80
OM (%)	21.73	22.02
N (%)	1.53	1.57
P (%)	2.84	2.88
K (%)	1.60	1.77

Table 4. Results of fertilizer on the growth and productivity of Green cos lettuce

Treatment	Number of Green Cos leaf				Fresh Weight plant (gram)
	7 Days	14 Days	21 Days	28 Days	
-No fertilizer applied	5.50	9.00	12.33	17.50	34.66 b1/
-Organic fertilizer	6.00	9.16	11.83	18.16	37.83 b
-Organic fertilizer with added Potassium Humate	5.16	7.66	11.00	18.33	61.17 a
T-test	ns	ns	ns	ns	*
C.V. (%)	13.42	15.91	15.91	14.03	21.13

Note: 1/ the different alphabets represent statistical differences at the level of confidence of 95% by using the LSD method

Table 5. Results of fertilizer on the growth and productivity of Baby cos lettuce

Treatment	Number of Green Cos leaf				Fresh Weight plant (gram)
	7 Days	14 Days	21 Days	28 Days	
-No fertilizer applied	5.00 b1/	7.16 b	10.50	14.16 b	33.66 b
-Organic fertilizer	5.83 ab	8.83 a	10.83	15.83 a	34.33 b
-Organic fertilizer with added Potassium Humate	6.33 a	8.16 ab	10.83	15.67 ab	60.16 a
T-test	*	*	Ns	*	*
C.V. (%)	12.89	13.02	8.74	8.48	24.25i

Note: 1/ the different alphabets represent statistical differences at the level of confidence of 95% by using the LSD method

Table 6. Results of fertilizer on the growth and productivity of red Batavia lettuce

Treatment	Number of Green Cos leaf				Fresh Weight plant (gram)
	7 วัน	14 Days	21 Days	28 Days	
-No fertilizer applied	5.66	7.66	10.83	15.66 b[1/]	28.83 b
-Organic fertilizer	5.50	8.00	10.66	14.83 b	30.50 b
-Organic fertilizer with added Potassium Humate	5.33	7.83	10.16	18.33 a	42.83 a
T-test	ns	ns	ns	*	*
C.V. (%)	11.66	11.05	16.04	12.84	20.75

Note: [1/] the difference in alphabet represents the difference in confidence level statistically at 95% by using the LSD method

4. Conclusions

Biochar from the coconut shells, fallen young coconuts, and coconut leaves had a lot of porous and small air gaps. The biochar from coconut shells had the total density, porosity, and water-holding capability at the highest level. However, the biochar from the coconut leaves had the most air gaps. The chemical properties of all 3 types of biochar were different in pH, EC, OM, OC, C/N ratio, CEC, humidity, and other quantity of nutrients. All of them can be used to mix with organic fertilizer. The organic fertilizers that had the mixing of biochar in both formulas could be high-quality organic fertilizers according to the standard specified by the Department of Land Development. They all had high nutrient quantities. The results of organic fertilizers mixed with biochar on the growth and productivity of both 2 formulas and the new formula with added potassium humate led to the growth and productivity of all 3 types of lettuces such as green cos, baby cos, and red Batavia more than not applying high-quality organic fertilizer ($p<0.05$). The newly developed formula, which added potassium humate, led to the growth and productivity of all 3 types of lettuce at the highest level ($p<0.05$).

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[9] Land Development Department. (2019). High quality organic fertilizer. Available online: http://ofs101.ldd.go.th/LDDNews/PAPR/ปุ๋ยอินทรีย์คุณภาพสูงสูตรกรมพัฒนาที่ดินโดยใช้สารเร่งพด/ปุ๋ยอินทรีย์คุณภาพสูงสูตรกรมพัฒนาที่ดินโดยใช้สารเร่ง พด.pdf. (accessed on 11 October 2022).