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A Novel Ameliorant Biochar of Areca Nuts Skin and Sago Bark Waste for Increasing Soil Chemical Fertility

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***Abstract*— The waste of areca nuts skin and sago bark are alternatives of ameliorant material that can be used to support soil quality improvement. This research aims to study the potential of areca nuts and sago bark to be produced as biochar and to identify the chemical components they contain. The study employed a Completely Randomized Designed involving six treatments repeated three times. The observation parameters of soil chemical analysis, including the measurement of pH H_2O (pH meter); Total-N (Kjeldahl); Available-P (Bray I); Exchangeable Cations (NH_4OAC pH 7.0); and exchangeable-Al (KCl 1N). Data obtained from observation were statistically analyzed through the ANOVA method, and if they had a significant effect, the analysis was continued with Duncan's Multiple Range Test (DMRT) at the level of α=5%. Findings showed that the administration of biochar can improve soil quality. Based on the analysis, biochar from sago bark waste brings a significant effect on increases of pH (5.26), available-P (12.99 $cmol^+kg^-$), Exchangeable-K (2.16 $cmol^+kg^-$), Exchangeable-Na (0.21 $cmol^+kg^-$), Exchangeable-Ca (4.83 $cmol^+kg^-$), Exchangeable-Mg (3.80 $cmol^+kg^-$), and the reduction of soil Exchangeable-Al (6.65 $cmol^+kg^-$). In comparison, biochar from betel nut peel waste has a significant effect on Total-N (0.15%), C-organic (1.66%), and CEC (23.38 $cmol^+kg^-$). The results of this study will be the basis for further research in utilizing agricultural waste so that the right combination of fertilizers is obtained to increase soil fertility and will indirectly increase crop production, especially in West Papua.**

***Keywords*— Ameliorant; areca nuts skin; biochar; sago bark; waste.**

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I. INTRODUCTION

Indonesia is rich in natural resources. Among many areas in Indonesia, Papua has abundant natural resources. One of them, in the agricultural sector, is the commodities of Areca and Sago. Data obtained from the Indonesian Plantation Statistic indicated that the area of sago farms in Papua and West Papua was 37,017 ha, with an estimated production of 29,818 tons. While the area of areca nuts plantations in Papua Province 1s 1,653 ha, with a total production of 350 tons. Areca nuts and sago are typical Papuan fruits, and Papuan societies widely use Areca nuts as stimulants mixed with betel and lime. Besides that, areca nut is also used for food, industrial raw materials such as fabric dyes, medicine, and antioxidants [1], [2].

In comparison, sago is the staple food of local indigenous people and is used as an alternative material for boats [3], [4]. Based on an earlier study, sago waste can be used as a vegetable herbicide [5], [6]. Sago waste can be used for feeding animals, plant medium, and material for bio-foam [7]–[10]. Besides, Papua local sago extraction liquid waste is used as media to grow microalgae for biodiesel production [11], [12]. Many studies have been conducted to investigate the use of areca nut and sago waste, yet the agricultural sector is still very limitedly implemented. Unfortunately, the study about using areca nut waste to improve soil quality is limited. Processing areca nut and sago will result in solid, liquid, and gaseous waste. They produce two types of solid waste: bark and dregs, which are 75% in total [13].

The abundant amount of areca nut and sago bark waste has not been optimally used in Papuan societies, and it can turn into a serious environmental problem if not handled appropriately. Therefore, waste management is urgently needed. It is considered that most areas of Papua, especially West Papua, are dry and infertile, and it is important to add nutrients and manage them appropriately to utilize them. One of the methods to improve the quality of farmland is by utilizing waste of areca nut skin and sago bark.

The alternative utilization of waste of areca nut skin and sago bark is processing it as biochar as a soil ameliorant. Biochar is a soil ameliorant produced from burning organic matter (pyrolysis) with limited oxygen conditions [14]. The application of biochar can increase acid soil pH [15], [16] increase soil Cation Exchange Capacity (CEC), and provide the nutrition of N, P, and K [17]–[20]. Biochar maintains the soil moisture so that the capacity keeps the high level of water [21] and repairs soil contaminated with heavy metals like Cu, Pb, Ni, and Cd [22]–[25]. Besides that, biochar contained in the soil can boost growth and support the plants to absorb nutrients [26]–[29]. Sago bark is recommended to be used as biochar because the yield of charcoal from sago bark is higher than from sago pith [30]. It is because sago bark contains more lignin which produces more carbon. Thus the higher the lignin, the more the yield [31], [32]. The benefits of areca nut waste are that it can improve soil quality by acting as an ameliorant and binding heavy metals in solution [33]–[35].

Based on the background, the study aims to identify the potential of areca nut and sago bark waste as biochar and measure the decomposition of nutrient content for increasing soil chemical fertility. The use of waste of areca nut and sago bark is expected to provide initial data that can be used for further wider-scale studies. It can contribute to improving soil structure and quality to indirectly increase agricultural production in the eastern part of Indonesia, especially Sorong, West Papua.

II. Materials and Method

The study employed a completely randomized design consisting of 9 treatments including LP0 (0 ton ha^{-1} areca nut biochar), LP1 (40 ton ha^{-1} areca nut biochar), LP2 (80 ton ha^{-1} areca nut biochar), LS0 (0 ton ha^{-1} sago biochar), LS1 (40 ton ha^{-1} sago biochar), LS2 (80 ton ha^{-1} sago biochar), LPS0 (0 ton ha^{-1} areca nut + sago biochar), LPS1 (40 ton ha^{-1} areca nut + sago biochar), LPS2 (80 ton ha^{-1} areca nut + sago biochar), and each treatment was repeated three times.

The main material of the biochar was areca nut skin and sago bark, which had been dried to reduce the water content. After that, the stove was made by digging the soil to make a hole like half of the ball (diameter: 1.5 m; depth: 50 cm). We used a chimney (diameter: 30-35 cm) to supply oxygen. The main material is put into the chimney, and the combustion is started from inside the chimney using flammable material. Biochar produced from the combustion was then weighted according to the doses of ameliorant needed in each treatment.

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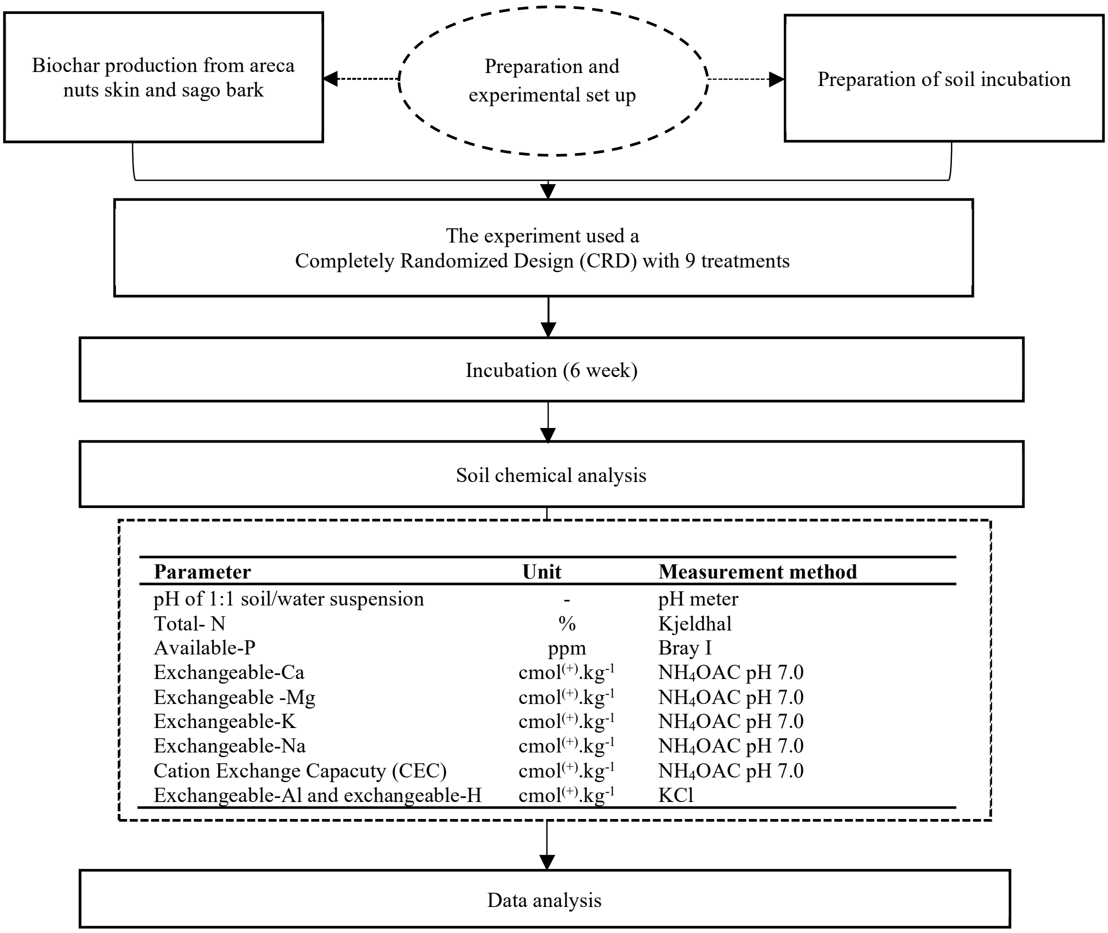


Fig. 1 Flowchart of research method

Soil for incubation media was taken from 0-20 cm depth in different locations and composited, air-dried, and filtered using a sieve with a hole diameter of 5 mm. After that, 0.5 kg (air dry weight) of it was taken and put into an incubation container and mixed with biochar based on the doses of each treatment. The incubation media is added with basic fertilizer: 0.06-gram pot^{-1} (100 kg ha^{-1} SP-36), 0.04-gram pot^{-1} (100 kg ha^{-1} KCl), and 0.14-gram pot^{-1} (300 kg ha^{-1} Urea). The incubation container was kept in the laboratory, and the soil condition was retained under field capacity conditions. After six weeks of incubation, the soil sample was taken and analyzed in the laboratory [36].

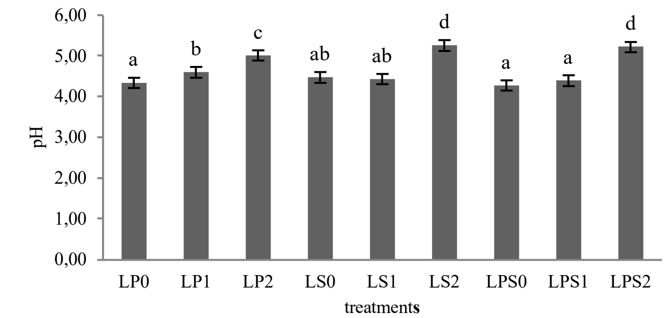
Chemical analysis of incubation media included pH H2O (pH meter); N-total (Kjeldahl); available-P (Bray I); exchangeable-K, exchangeable-Na, exchangeable-Ca, exchangeable-Mg and CEC (NH_4OAC pH 7.0); exchangeable-Al (KCl 1N). Data obtained from observation were statistically analyzed through the ANOVA method, and if they had a significant effect, the analysis was continued with Duncan's Multiple Range Test (DMRT) at the level of α=5%. The flowchart methodology of this research is in Fig. 1

III. Result and Discussion

The effect of sago bark and areca nut skin biochar on soil's chemical characteristics after incubation for six weeks is presented in Figures 1-5 and Table 1. Results of variance analysis show a real influence of ameliorant materials (biochar) on soil's pH, Organic-C, Total-N, available-P, exchangeable-Na, exchangeable-Ca, exchangeable-K, exchangeable-Mg, CEC, exchangeable-Al, and exchangeable-H.

A. Soil Reaction (pH)

Based on the statistical analysis as presented in Figure 1, it is identified that biochar increases the soil pH. Further analysis shows that LS2 had no significant difference from LPS2 but had a significant difference with other treatments. Based on the graph trend (Fig. 2), the soil pH increased by 4.10 with an average increase of 4.34 – 5.26



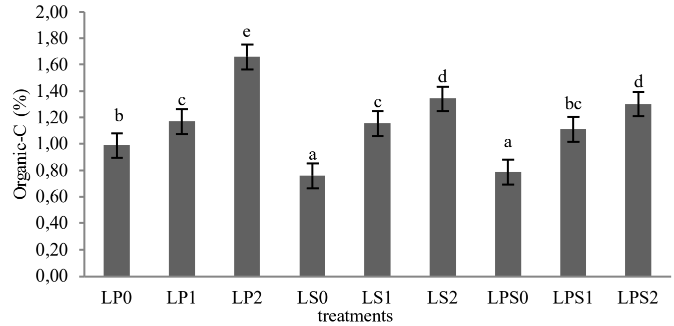
Numbers shown in the bar chart followed by similar letters show no significant difference on the 5% test level using Duncan's Multiple Range Test (DMRT).

Fig. 2 The influence of biochar on soil pH

The increase in soil active pH score (pH H_2O) from 4.01 to 5.26 was due to the high pH of the main material (pH 5-6). High pH shows that biochar that is used can be applied as an ameliorant for the soil. Biochar is more appropriate to be used as an amendment (ameliorant) for soil and as an alternative to organic fertilizers [37], [38]. The contribution of the biochar OH also causes an increase in pH. The measurement of the soil pH (pH H_2O) shows that the concentration of H^+ in the soil solution correspondences to the real environmental condition that is higher than the pH of potential soil (pH KCl or pH $CaCl_2$) [39]. In this case, the active pH expresses the concentration of H^+ in the soil solution, and the potential pH expresses the concentration of H^+ in colloidal soil. Previous studies strengthen that the alkaline nature of biochar is formed from H^+ ions which can be exchanged with the surrounding soil leading to the increase of soil pH from applying the biochar [40], [41]. The combination of ameliorant materials that is applied can increase the soil pH and reduce the use of lime for acid soil [42]–[45]

B. Organic Carbon and Total Nitrogen

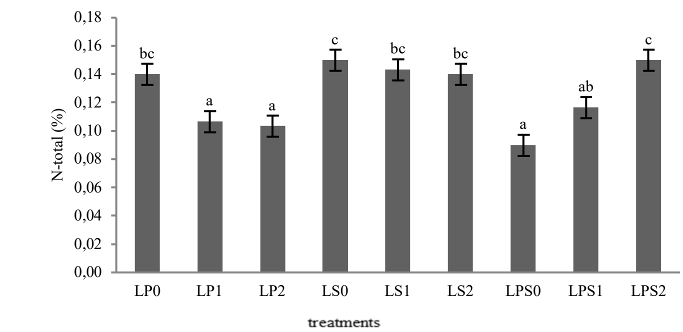
The statistical analysis shows that adding biochar to the soil can increase the Organic-C content. Based on further analysis, it was identified that LP2 treatment shows a real difference from other treatments (Fig. 3).



Numbers shown in the bar chart followed by similar letters show no significant difference on the 5% test level using Duncan's Multiple Range Test (DMRT).

Fig. 3 The influence of biochar on soil Organic-C content

Biochar can store carbon well, is more resistant to oxidation, and can be more stable in the soil [46], [47]. As per further analysis, it was identified that the treatment of LP2 was different from other treatments. LP2 treatment is applied to areca nut peel waste. Areca nut waste (skin) contains cellulose, water, and ash with a rate of cellulose of around 70,2 % that is suspected can act as the source of carbon for the production of active charcoal [48], [49]. It possibly leads to the LP2 treatment being better than others. However, based on Figure 2, it is identified that the Organic-C of the soil increases based on the dose of each main material used. Sago waste biochar can increase the soil's Organic-C, pH, and CEC [50]–[52]. It confirms [53] that biochar made from sago waste can increase the rate of carbon. Fig. 4 shows the Total-N content of the soil that is inversely proportional with the Organic-C it produces (Figure 2), except soil added with ameliorant produced from areca nut + sago bark waste (LPS0, LPS1, LPS2).



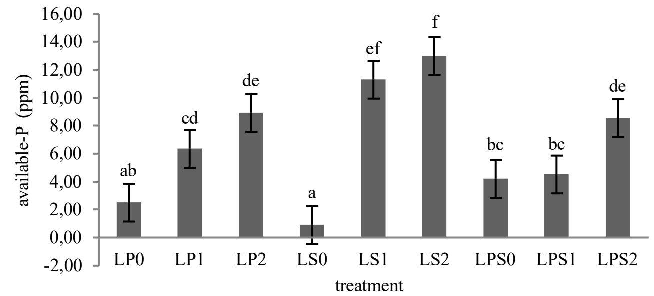
Numbers shown in the bar chart followed by similar letters show no significant difference on the 5% test level using Duncan's Multiple Range Test (DMRT).

Fig. 4 The influence of biochar on soil Total Nitrogen

Fig. 4 shows that the Total-N of the soil was inversely proportional with the Organic-C it produced (Fig. 2), except for the treatment using areca nut-sago bark waste (LPS0, LPS1, LPS2). It is possible because of the contribution of C from biochar and the increase of microorganism activities. The availability of a higher amount of C stimulates the activities of the microbes, leads to the increase of N demand, pushes immobilization, and recycles NO_3^-, reducing the availability of N [54], [55].

C. *Available Phosphor*

Based on Figure 5, the more main material used, the higher the available-P of the soil. Among all treatments, the use of sago bark waste shows the best result, although based on the trend (Figure 4), there was a drastic increase from treatments LS0 to LS1. It was also proved by the statistical analysis showing that LS2 treatment shows a striking difference compared to others.



Numbers shown in the bar chart followed by similar letters show no significant difference on the 5% test level using Duncan's Multiple Range Test (DMRT).

Fig. 5 The influence of biochar on available-P of soil

Among all treatments, the one using sago bark waste showed the best result, although based on the trend (Fig. 5), there was a dramatic increase from LS0 to LS1 treatments. It was also proved by the statistical analysis showing that LS2 treatment was different from others. The administration of biochar can reduce the A1 solubility and increase the soil pH so that the P binding can be avoided and the P available in the soil can increase. It follows that the solubility of metal ions such as Al and Fe can reduce the adsorption of P and available-P in the forms of PO_4^{3-}, HPO_4^{2-}, and $H_2PO_4^-$[56], [57]. Also, adding biochar indicates the increase of soil available-P [56] Because biochar can increase the soil enzymatic activities involved in C, N, and P cycles [57].

D. *Exchangeable Cations*

Based on the data presented in Table I, in general, treatments showing the best results were the ones applying the highest doses (LP2, LS2, and LPS2). The oxidation of C aromatic and the formation of the carboxyl group is believed to be the main reason for the increase in CEC [54]. While biochar has a high rate of cation exchange because of the big surface area capacity, leading to an increase in soil pH and water holding capacity, as well as an affinity for plant micro and macronutrients [58]. It confirms that applying biochar as a soil improvement agent on suboptimal and degraded land, besides increasing the soil pH, Total-N, and available-P, can also improve the soil's cation exchange capacity [59], [60]. In this case, it increases exchangeable-K, exchangeable-Na, exchangeable-Ca, and exchangeable-Mg. Applying organic material as an ameliorant can improve the quality of soil's chemical properties [61], [62]. Besides improving the soil pH, biochar can also reduce the leaching of nutrients in the growing media [63].

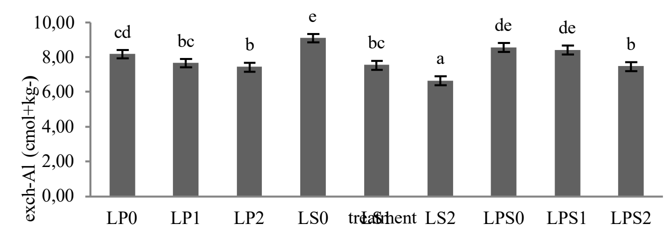
TABLE I
INFLUENCES OF BIOCHAR ON CATIONS THAT CAN BE EXCHANGE

Treatments	Exchangeable Cations ($cmol^+kg^-$)				CEC ($cmol^+kg^-$)
	Exc-K	Exc-Na	Exc-Ca	Exc-Mg	
LP0	0.55^a	0.14^a	3.50^a	3.60^{cd}	21.86^b
LP1	1.16^{de}	0.16^{ab}	3.98^b	3.50^{bc}	23.83^b
LP2	2.01^g	0.21^{cd}	4.43^c	3.75^{de}	22.80^b
LS0	0.84^{bc}	0.21^d	3.74^{ab}	3.73^{de}	19.41^a
LS1	0.98^{cd}	0.20^{cd}	3.54^a	3.76^{de}	23.75^b
LS2	2.16^g	0.21^{cd}	4.83^d	3.80^e	22.65^b
LPS0	0.61^{ab}	0.14^a	3.65^{ab}	3.22^a	22.32^b
LPS1	1.31^{ef}	0.18^{bc}	3.81^{ab}	3.41^b	23.42^b
LPS2	1.52^f	0.19^{cd}	3.79^{ab}	3.82^e	21.86^b

Numbers shown in the similar column followed by similar letters show no significant difference on the 5% test level using Duncan's Multiple Range Test (DMRT).

E. *Exchangeable Aluminum*

The statistical analysis shows that treatments that can significantly affect the reduction of soil exchangeable-Al were the LS2 (biochar from sago bark waste). The treatments indicated that LS2 treatment could reduce the soil exchangeable-Al from 9,11 $cmol^+kg^-$ to 6,65 $cmol^+kg^-$. Based on the graph in Fig. 6, the higher the doses, the lower the exchangeable-Al in the soil. In this case, administering 80 tons ha^{-1} of sago biochar (LS2) is the best dose to reduce the soil's exchangeable Al. While the interaction of both biochar materials shows a real effect, it is not as good as LS2 treatment in reducing soil's exchangeable Al. It indicated a reaction between materials causing the effect on the parameter reduction. It echoes those who argued that using sago waste biochar could reduce the soil's exchangeable Al [64]. While applying biochar on soil can reduce the concentration of exchangeable Al due to the reduction of Al, which can be exchanged through adsorption on the biochar surface, which is negatively charged from OH^-[54], [65].



Numbers shown in the bar chart followed by similar letters show no significant difference on 5% test level using Duncan's Multiple Range Test (DMRT

Fig. 6 The effect of biochar on soil exchangeable-Al

IV. Conclusion

The administration of biochar made of areca nut and sago bark waste as ameliorant materials can improve soil quality. It can be seen from the chemical characteristics of the soil after receiving biochar. The analysis shows that the addition of biochar from sago bark waste stimulates the increase of the pH (5.26), available-P (12.99 $cmol^{+}kg^{-}$), exchangeable-K (2.16 $cmol^{+}kg^{-}$), exchangeable-Na (0.21 $cmol^{+}kg^{-}$, exchangeable-Ca (4.83 $cmol^{+}kg^{-}$), exchangeable-Mg (3.80 $cmol^{+}kg^{-}$), and the reduction of the soil exchangeable-Al (6.65 $cmol^{+}kg^{-}$). While biochar from areca nut waste highly influences the rate of total-N (0.15%), Organic-C (1.66%), and CEC (23.38 $cmol^{+}kg^{-}$). The results of this study will be the basis for further research in utilizing agricultural waste so that the right combination of fertilizers is obtained to increase soil fertility and will indirectly increase crop production, especially in West Papua.

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