Development of Gluten-Free Sago Starch Pasta

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In recent years, along with the cultivation of sago palm in wetlands, the trend of cultivating sago palm in peatlands is once again picking up, leading to a great increase in the overall output of the sago palm industry. As a consequence to this increase, development of suitable usages for sago starch is necessary, with creating 'added value', or a 'Unique Selling Point' for products containing sago starch being considered a key element for the future success of this industry. Considering the above, the global expansion of gluten-free foods came to mind as one possibility for expanding the usage of sago starch. Pasta, a food that is typically prepared using high protein content durum wheat flour, was determined as the subject of this research, and the development of gluten-free pasta made with sago starch was investigated.

【Experiment Materials】

Sago starch (T.Akiyama & Co., made in Indonesia) was used as the sample, and durum wheat flour, potato starch, corn starch and tapioca starch were used as the comparisons. In the examination of sub-ingredients in pasta preparation the following ingredients were used: Potato, sweet potato panicum miliaceum flour and millet flour, white sorghum, corn flour, carrot powder and lotus root powder, non-glutinous rice flour, and glutinous rice flour. In the experiments on physical property improvement the following ingredients were used: Rice gel, and xanthan gum, locust bean gum, κ-carrageenan, and guar gum as thickeners.

【Preparation of the Sample】

For the pasta containing durum wheat flour (the control), 1.5 g of salt was added to 100 g of durum wheat flour, then, after the addition of 40 mL of distilled water the mixture was kneaded. The preparation method for the pastas containing the various types of starches was as follows: 15 g of starch was inserted into aluminum saucepan, then 80 g of distilled water was added and the contents were heated and stirred for 90 seconds, making a gel with a starch concentration of 18 %. Then 40 g of the starch gel was added to 55 g of corn flour, and after kneading the mixture by hand, 2 g of olive oil was added and a further kneading by hand was performed.

In the examination of physical property improvement, xanthan gum was found to produce pasta with the highest levels of chewiness, therefore it was selected as the substitute for 0.5, 0.75, 1.0 and 1.25 g of the corn flour, or 0.5, 0.8, 1 and 1.3 % of the total weight, pasta dough was prepared.

The various dough types were shaped into disk or noodle form and then measurements were performed on each type.

【Measurement Method】

1) The thickness and diameter of both the disk form dough, and the disk form pasta heated via

boiling were measured using a Digital Calipers.

2) The physical properties of both the dough of the noodle type pasta and the pasta itself heating were measured by performing a breaking test using a creep meter.

3) Sensory evaluation was conducted on pasta containing each of the various types of starch, and on sago starch pasta with the addition amount of xanthan gum adjusted.

【Examination Results and Observations】

I. Examination on Preparation Methods

In the production of noodles such as *harusame* (vermicelli noodles), a part of the starch is gelatinized and used as a carrier. It was decided to use this method in this research. Utilization of this method meant that, when sago starch was gelatinized, and kneaded with the different powder types, a dough with increased adhesiveness and that could be gathered together easily could be obtained.

II. Examination of Sub-Ingredients

When the sub-ingredient was mixed with sago starch (the main ingredient) and corn flour, an outcome that was similar in shape and color to pasta could be achieved.

III. Caracteristics of Pasta Containing the Various Types of Starch

1) In the physical property measurements, the results of the rupture stress test showed that strain rates had the same trends at 25, 50 and 75 %. Namely, corn starch pasta was the hardest, and tapioca starch the softest.

2) Results from the sensory evaluation showed that the color, chewiness, feeling when biting, and overall evaluation (no sauce) of the sago starch pasta was favored less than the potato starch pasta, however, with the addition of meat sauce there was no significant difference found in overall evaluation.

IV. Examination of Physical Property Improvement

1) For sago starch pasta, when xanthan gum was added to the degree of 0.5～1.3 % of the total weight, the values obtained at every strain rate showed a tendency to be high. Also, as the amount of added ingredients increased, the values showed a tendency to increase accordingly. For pasta with xanthan gum added to the degrees of 0.5 and 0.8 %, the strain rates at 25～75 % were found to be similar to the control.

2) Results from sensory evaluation on 4 types of sago pasta; without addition of xanthan gum, and with additions to the rate of 0.8, 1 and 1.3 %, showed that the 0.8 % addition xanthan gum pasta was preferred in the yellowness, hardness, chewiness, stickiness, and feeling when biting properties, and was most favored in the overall evaluation. However, when meat sauce was added, 1 % addition xanthan pasta was found to be favored.

Sago Palm (*Metroxylon sagu* Rottb.) Pollen Grains from Different Soil Layers in Leyte, Philippines

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Historical cultivation of *Metroxylon sagu* was investigated using its pollen grains varied in soil layers at Pangasugan, Julita and Dulag, Leyte, where form one of the centers of *M. sagu* growing area in Philippines. The pollen grains mounted on a glass slide were identified by a transmitting light microscope with the magnification of x100 and x400 after the treatment of KOH and acetolysis to remove organic matter in soil sample and cytoplasmic content and showed the frequency percentages of the disulcate grains of *M. sugu*; several % in the 0-16.5cm and 35-78.5cm in Pangasugan, 30% in the 0-16.5cm and 10-30% in the 32-47.5cm to the 78.5-90cm in Julita, and 5-15% in the 0-16.5cm to 47.5-63cm in Dulag. It is concluded that long time cultivation of *M. sagu* has been demonstrated by the presence and high frequency percentages of its pollen grains in Julita and Dulag.

Keywords: acetolysis, disulcate, microscope, pollen

Materials and Methods

1. Soil samples

The sampling sites are located in central lowland area of Leyte, Philippines. Soil samples up to 94 cm in depth were taken from Pangasugan, Julita and Dulag, Leyte.

2. Pollen analysis

Two g of air-dried soil samples was used for fossil pollen analysis. Fifteen mL of 10% KOH solution was taken into the soil sample in a 30 mL centrifuge tube and heated on the boiling water. The pollen sample was obtained from the sieving with the 0.045mm and the 0.250 mm sieve for water washing, centrifuged, and filtrated with No. 5 C filter paper. The sample including pollen was washing with water and centrifuged several times. Two mL of 10% HCl was put into the pollen sample to acidify. The pollen suspension solution was heated on the boiling water and centrifuged. The pollen sample was separated into two; one for the direct observation of non-treatment sample and another for the observation of acetolysis-treatment sample. The specimen slide was prepared by glycerol gel (Lion Dental Products Co. Ltd.), and directly by MGK-S (polystyrene) solution (Matsunami Glass Industry) after air-drying. The specimen slide for pollen observation using a transmitting light microscope (TLM) (Meiji Techno MT5000) with the magnification x100 and x400 was prepared. The morphological description of pollen samples was carried out according to the shape, size, aperture number and location, orientation and stratification, and exine ornamentation.

Results

1. Microscopic observation of *Metroxylon sagu* pollen

The pollen grain of *M. sagu* from Julita soil layers was medium (25-30 μm) in size, elliptic, reticulate, in apertural view and equatorially disulcate or bisulcate, and exhibited two germination apertures on the short equatorial axis, which is in accordance with the result of Ehara et al. (2006) using a scanning electron microscope (SEM).

2. Vertical distribution of *Metroxylon sagu* pollen grains in soil layers

The vertical distribution of *M. sagu* disulcate pollen grains in Pangasugan exhibited 7 frequency percentages of phytoliths at the surface (0-16.5cm) layer only and nothing in the subsurface layers. The monosulcate pollen grains from Arecaceae (*Areca*, *Arenga*, *Calamus*, *Caryota* and *Nypa*) were detected. On the other hand, in both Julita and Dulag, the eastern part of Leyte, large quantities of *M. sagu* pollen grains were found from the surface to subsurface layers. High frequency percentages of *M. sagu* pollen in Julita were detected in JL1 (0-16.5cm), JL3 (32-47.5cm), JL4 (47.5-63cm) and JL5 (63-78.5cm) layer, accounted for 20 and 30 %. In Dulag 15.4 and 28.0 frequency percentage were provided in DL1 (0-16.5cm) and DL3 (32-47.5cm) layer. There were 40-60 frequency percentages of monosulcate pollen grains in Julita and Dulag soil layers, and Pangasugan likewise.

Long time cultivation of *M. sagu* has been demonstrated by the presence and high frequency percentages of pollen grains in Julita and Dulag.

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The Historical Evidence of Sago Palm (*Metroxylon sagu* Rottb.) Cultivation in Leyte, Philippines - Phytolith Assemblages in Soil –

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The origin place of sago palm (*Metroxylon sagu* Rottb.) is supposed to be Papua Island and Maluku Islands from the large variations of local varieties (Ehara, 2015). Philippines is far from the center of sago growing area. It is interesting when and where Philippine people encountered *M. sagu*.

Phytolith (plant biogenic silica) is one of the potentially powerful means to sago cultivation history. We tried to show *M. sagu* cultivation history in Leyte, Philippines, based on Arecaceae phytolith assemblages in soil layers at Pangasugan, Julita and Dulag profile.

Keywords: Leyte, Philippines, phytolith, primary minerals, soil profile

Materials and Methods

Soil samples were taken from Pangasugan, Julita, and Dulag, Leyte, Philippines using a screw auger (0-16.5, 16.5-32, 32-47.5, 47.5-63, 63-78.5 and 78.5-94 cm in depth) in August, 2019. Soil samples were sieved with a 40 mesh sieve after air-drying. The air-dried and 40 mesh-sieved samples were divided into four; carbon and nitrogen content, primary mineral composition, and phytoliths. The sample for phytolith assemblage analysis was sieved with the 0.045 and 0.250 mm sieve. Less than 0.045 mm fraction in diameter were mainly collected for getting a small size of phytolith and the 0.045-0.250 mm fraction was supplementally used. The presence of around 300 phytoliths was recorded according to the description of International Code for Phytolith Nomenclature 1.0 (Madella et al., 2005) and 2.0 (Neumann et al., 2019).

Results and Discussion

Arecaceae phytoliths were identified as five groups; spheroid echinate (including *M. sagu* phytoliths), globular echinate, hat-shaped to conical, ellipsoid echinate and others. The spheroid echinate phytoliths to total phytoliths accounted for 6-57% in Pangasugan, 26-58% in Julita and 9-76% in Dulag. Spheroid echinate phytoliths in soil obviously showed high content in spheroid echinate phytolith assemblages at the depth of 0-16.5 cm for Pangasugan, 16.5-32 cm for Julita, and 32-63 cm for Dulag. This indicated the peak period of sago palm cultivation. The dominant size of spheroid echinate phytoliths was the 5-15 μm fraction of phytolith assemblages (47.0%) for Pangasugan, the 5-10 μm (24.7%) and the 10-15μm fraction (30.9%) for Julita, and the <5-15μm fraction (25.4-27.0%) for Dulag. Spheroid echinate phytoliths were found in the surface layer in Pangasugan and throughout the soil layers in Julita and Dulag, reflects the history of sago palm cultivation in Leyte.

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An overview of market opportunities for sago starch commercialization in Indonesia

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Introduction Sago palm was first mentioned in the 13th century by Marco Polo and was described by Alfred Russel Wallace in the 18th century as one of important food commodities. Recently, sago has become an important raw material for utilization in various industries. Thus, it is not only seen as food but also a functional commodity with economic value that contributes to poverty alleviation. In this overview study, trends in the global sago starch market and market growth opportunities were explained to identify the demand market of sago starch in the future.

Material and methods In the context of this study, a literature review is carried out in order to observe the trend of sago starch demand and market opportunities. Literature, namely scientific papers and annual reports were analyzed. In addition, other information such as encyclopedia and newspaper were reviewed to support the study.

Results and Discussion

1. Global sago starch market

The world production of starch is estimated to be around 85 million tons, which is dominated by corn, potato, and tapioca starches (International Starch Institute, 2020). Sago is one of the starches that is obtained from the trunk of *Metroxylon sagu* Rottb. with annual global production at approximately 656,000 tons, mainly from Sarawak and Indonesia. Sarawak exports about 41,000-51,000 tons of refined sago annually with Peninsular Malaysia and Japan as their main export destinations. Meanwhile, the export of sago starch from Indonesia reached its lowest point of 2,168 tons in 2011 before increasing up to 12,908 tons in 2018. The gradual increase in demand for sago starch was due to the increasing starch demand from food industries in other countries. The value of sago starch increased significantly, with the highest value being 4.2 million US$ in 2011. However, the value of exported sago starch fell to its lowest point at 1 million US$ in 2012. After that, the value of exported sago starch gradually increased to 3,1 million US$ in 2017.

The sago industry in Sarawak is well established with modernized sago-processing factories and has become an important source of export revenue. In contrast, the majority of sago starch in Indonesia is produced by smallholders, which are mainly focused on the domestic market. In Malaysia, sago starch is mainly used for addition (at 20–30%) to rice flour in the production of flat rice noodles and rice vermicelli. Despite the higher prices, as compared with cassava or corn starch, sago is preferred to create rice noodles and vermicelli less brittle to handle and chewier in texture (Jong, 2018). Meanwhile, in Indonesia, sago starch is used for the production of glass noodles (*sohun*), meatball, and other local foods.

2. Growth opportunities for sago starch commercialization in Indonesia

To assess the opportunities that can promote growth toward sago starch commercialization, the following aspects are taken into account: 1: Trend of sago demand in Java island and South Sulawesi: The trend in the domestic market reveals that the trade in sago starch from Riau to

Cirebon has grown by 15% from 2014 to 2018. Furthermore, the consumption of sago products may increase in the future due to the popularity of sago food processing (*kapurung*) and dried sago. The number of commercial *kapurung* restaurants has increased with an average growth of 28.7% during the last 14 years. Metaragakusuma et al. (2017) also mentioned that there are 26 *kapurung* restaurants that need approximately 11.7 tons of wet sago every month. In addition, an interview with a dried sago producer in Palopo, South Sulawesi, showed an increase of the sales quantity from 617 kg/month in 2014-2015 to 34 tons in May 2020. 2: Trend on food consumption in Indonesia: Participation in sago consumption by the Indonesian population has increased from 1.61% in 2013 to 2.09% in 2018 (Food Security Agency, 2019). In addition, total 63 various of sago-based food products are found in 21 of 33 provinces in Indonesia. This will trigger an increasing demand and increase the opportunities of sago starch commercialization in the future. 3. Replacement 10% of imported wheat flour to sago starch: The Indonesian government encourages food industries to substitute 10 % of imported wheat flour with sago starch to support sago-based industries under a cooperation agreement to utilize sago starch as a raw material for the food Industry. The replacement of imported wheat flour with sago starch is expected to increase sago starch demand by 1.1 million tons and produce up to Rp 2.4 trillion (US$ 170 million) of benefits annually. 4: Reducing the food vulnerability in Indonesia as a potential market for sago starch. Improving the competitiveness of sago products can optimize local food supply and minimize food insecurity. 5: Growth opportunities for sago starch in the international market: Apart from domestic consumption, sago starch is mainly exported to Japan. In Japan, sago starch is used as dusting flour for noodles, dumpling skins, starch sugar, and dextrin. Recently, it has been promoted as a gluten-free, non-allergenic food and for non-food industries where film formation and adhesion properties are needed. There is also a possibility that demand for sago starch will increase especially for aging people and where preference for healthy foods are likely to continue. However, the improvement of sago starch quality and product differentiation should be pursued to meet the quality standards of the purchaser and render it more competitive in Japan's import market.

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Comparison of Nutrient Status between Sago Palms Grown in Peat and Mineral Soil in Indonesia

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Introduction As a starch producing plant that can grow economically in various condition, sago palm is promoted to be cultivated in peatland. It was reported that nutrient deficiency is one of the major growth-limiting factors for crop cultivation in most tropical peatland. This study aims to investigate responses of sago palm to nutrient availability in growth media.

Materials and Methods A field survey was made in December 2019 at two sites in Indonesia: i) Deep peat soil in NSP plantation, Tebing Tinggi and ii) mineral soil in small farm, Bogor. Soil sample was taken from 25 cm depth by a core sampler and analyzed at the Indonesian Soil Institute. Morphologycal characteristics such as trunk length and diameter, number of leaves and leaflets, leaflet area, leaflet dried matter weight, spesific leaflet area and chlorophyll index of adult palms were measured. In addition, sago root, pith, petiole, and leaflet samples were collected to measure nutrient content in the plant. Nitrogen (N) content in plant samples were measured by C-N coder. Posphate (P) content was determined by ammonium molybdate method. Potassium (K) content were analyzed by ion chromatography (Shimadzu). Boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) were determined by inductively coupled plasma atomic emission spectrometer (ICP-AES, Nippon Jarrell Ash).

Results and Discussion The diameter of trunk, number of leaflets, leaflet area, leaflet dried matter weight, specific leaf area and chlorophyll index of sago palm grown in deep peat soil were significantly small. It was suspected that nutrient deficiency might account for the poor performance of sago palm growth in peat soil. The N and P contents on the basis of unit soil volume in peat soil were low. It might account for lower N and P contents in the plant in peat soil. The K content in the plant grown in peat soil was comparatively high. Former studies reported that sago palm can maintain higher leaf potassium even in problem soils such as salt or water stresses (Azhar, 2020; Ehara et al., 2008). Further investigation on potassium absorption ability in sago palm under severe environment is needed to utilize its physiological features under suboptimal growth conditions. A few reports about Cu and Zn deficiency in sago palm grown in peat soil exist (Nitta et al., 2000; Kakuda et al., 2015). In this study, not only Cu and Zn but also Fe and Mn contents in the plants were examined and they were significantly low in peat soil. Contrarily, the B content in the plant was higher in peat soil rather than in mineral soil. According to Kakuda et al. (2015), B deficiency is often observed in oil palm but no report in case of sago palm. From the current study, it is considered that boron deficiency may not be observed in sago palm in peat soil. Appropriate management techniques need to established for compensating the low availability of some nutrients in peat soil.

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Arbuscular Mycorrhizal Fungi Colonized in the Root of Sago Palm Grown in Mineral and Shallow Peat Soil

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Introduction It is well known that arbuscular mycorrhizal fungi (AMF; phylum Glomeromycota) form mutualistic associations with the roots of most terrestrial plants and enhance the plant's nutrient uptake by extending the root absorbing area. In the case of sago palm (*Metroxylon sagu*), colonization of AMF in the roots was observed when it was associated with mycorrhizal inocula (Asano et al. 2019). This study investigated the AMF colonization and community structures in the root of the sago palm grown in different soil environments.

Materials and Methods The soil and roots at the soil depth of 0-15 cm below the ground surface were collected from the sago palm grown in mineral soil (MS) in Universiti Teknologi MARA Cawangan Sarawak Kampus Samarahan (1º26.26' N, 110 º 27.11'E) and shallow peat soil (SPS) in Dalat, Sarawak (2 º 51.14'N, 111 º 49.38'E). The percentage of AMF colonization was determined by the grid-line intersect method. Soil properties were measured by the usual methods. Total DNA from the roots was extracted using cetyltrimethylammonium bromide (CTAB). PCR was conducted using the AMF specific primer pair AMV4.5NF/AMDGR which is coding 18S rRNA gene. PCR products were paired-end (PE) sequenced (2×300 bp) using an instrument of Illumina MiSeq amplicon sequencing at the Bioengineering Lab Co., Ltd. Representative sequences were aligned with known AMF taxa from NCBI Genbank and a neighbor-joining phylogenetic tree with 1000 bootstrap replicates was created using MEGA X software.

Results and discussion The soil bulk density was 1.03 g/cm^3 and 0.20 g/cm^3 in MS and SPS, respectively. The soil moisture content was 38.1% (MS) and 79.8% (SPS). The soil pH (H_2O) was 4.6 (MS) and 4.1 (SPS). The chemical properties were 66.2 kg C, 16.9 kg N, 1.6 g P_2O_5 in soil (m^3) (MS) and 69.7 kg C, 2.7 kg N, 1.9 g P_2O_5 in soil (m^3) (SPS). The structure of AMF was observed in both root samples using the microscope, and the colonization rate was 73.2% (MS) and 39.2% (SPS). A total of 122 AMF OTUs containing 78 OTUs from the MS sample and 50 OTUs from the SPS sample (6 shared OTUs) were obtained. The phylogenic analysis with reference sequence successfully classified the 118 AMF sequences into *Claroideoglomeraceae*, *Glomeraceae*, *Gigasporaceae*, and *Acaulosporaceae*. Some phyletic groups belonging to *Glomeraceae* and *Acaulosporaceae* include only the OTUs from the MS sample, and one phyletic group belonging to *Acaulosporaceae* includes only the OTUs from the SPS sample. It was suggested that the AMF colonization and its communities in the root of sago palm were influenced by the different soil physiochemical properties.

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The Occurrence of Indigenous VA-Mycorrhizal Fungi in the Rhizosphere of Two Types Sago Palms

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Introduction

Vesicular-Arbuscular Mycorrhizal Fungi (VAMF) are must an ecologically obligate symbionts with photosynthetic plants and aerobic microorganism. Sago palm (*Metroxylon sagu* Rottb.) was characterized as amphibious crops which can tolerate submerge and non-submerge soil conditions. This preliminary study was purposed to identify the occurrence of indigenous VAMF in the rhizosphere of two type sago palms.

Material and Methods

This experiment was conducted in Botanical Sago Garden of Halu Oleo University, which planted with sago Molat (non spiny, fruit without seed, original Southeast Sulawesi Province), multiplied from sucker and planted at 2010 (Fig.1). Manno F-1 sago (spiny, wild type, fruit with fertile seed, original Sentani, Jayapura, Papua Province) multiplied from seed, and planted at 2012 (Fig. 2). Plant distance was 7.0 m x 7.0 m.

Fig.1. Mother Palm of Molat sago.

Fig.2. Mother palm of Manno sago.

Soil and root samples were collected from three sago clumps of Manno, Molat and non sago area from two soil depths: 0-10 cm (top soil = TS) and 10-20 cm (sub soil = SS). Soil pH (H_2O) was determined by pH-meter, C-organic by Walkley and Black methods, total-N by Kjeldhal method, Total K and total-P determined after extracted by HCL 25 % (Olsen and Sommers, 1982). Soil texture was determined by pipet method. About 5 g of the fine lateral branch roots was collected from two soil depths TS and SS layers. Root sample soaked by 10 % KOH (w/v), bleached by 2 % HCL (w/v) and stained by 0.05% trypan blue (Giovannetti and Mosse, 1980). VAMF spore was determined from 50 g soil by sieving and decanting method (Kormanik and McGrow, 1982), and VAM's genera identification based on Schenck and Pérez (1988).

Results and Discussion

Soil texture in this sago garden and non-sago garden was sandy loam (Table 1), which indicated that soil medium from top to sub layers were dominated by sand (57.0 %), medium silt (36.0 %) and less amount (7.0 %) of clay minerals. This soil physical condition may not suitable for sago palm growth as shown in Fig.3 and Fig.4. This indicated that soil microorganism association *e.g.* VA-Mycorrhizal Fungi was very important especially in dry season. Soil pH is acidic, with low to medium organic C. Total N, K and P was low to medium levels as indicated in Table 1. VAM infection rate was not significantly different between Manno and Molat sago, however, Manno sago have a greater VAM infection rate (63 %) if compared with VAM infection rate in Molat sago (53 %) as shown in Fig.5. VAM infection rate in TS slightly higher than in SS layer. Average of VAM's spore density in Manno and Molat sago was not so different, however, both sago types was induced VAM's spore density about 200 % higher than with non-sago area as shown in Fig.6. This indicated that indigenous VAMF activities were induced by the presence of sago palm crops. We observed that at least three VAM's Genera *type-like* in sago palms rhizosphere namely: *Acaulospora sp., Glomus sp., and Gigaspora sp*. (Schenck and Pérez, 1988). Those genera should be identified in detail taxonomic analysis by total DNA analysis as explained by Asano et al. (2020). From the above explanation we can concluded that Manno and Molat sago palm cultivation was induced indigenous VAM's activities in the soil rhizosphere of Botanical Sago Palm Garden of Halu Oleo University.

Table 1. Soil chemical and physical properties in two soil layers

Sago type	Soil layer*	pH H_2O	Org.-C (%)	Total N (%)	Total K (% K_2O)	Total P (% P_2O5)	Soil texture
Non-Sago	TS	5.39	0.14	0.62	0.71	0.01	*Sandy Loam*
	SS	5.23	1.89	1.14	4.20	0.03	*Sandy Loam*
Manno	TS	5.31	3.12	0.85	4.48	0.02	*Sandy Loam*
	SS	4.60	1.22	0.81	9.07	0.02	*Sandy Loam*
Molat	TS	5.49	0.78	1.28	6.36	0.03	*Sandy Loam*
	SS	5.54	1.33	1.01	13.91	0.02	*Sandy Loam*

*TS-top soil and SS-sub soil


Fig.3. Growth of Manno Sago


Fig.4. Growth of Molat sago

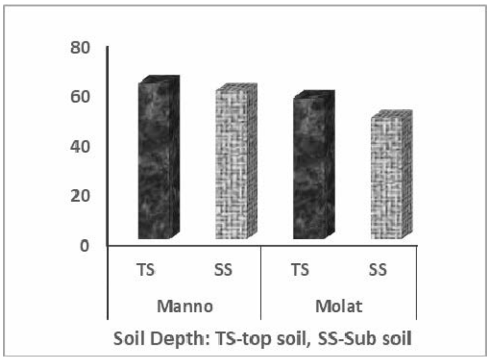

Fig.5. VAM infection rate

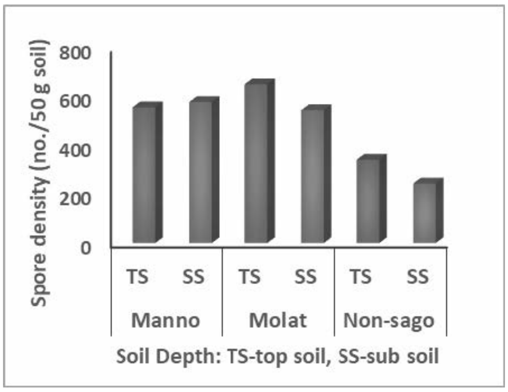

Fig.6. VAM spore density

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Effects of Purification and Modification of Sago Frond Cellulose on Its Dye Adsorption Capacity

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Introduction

Sago fronds are agriculture waste liberated from sago trunk harvesting. Native sago frond (without leaflet and rachis) consisted high cellulose, low lignin contents, and small amount of starch. Since *sago fronds* are a low-protein and high-fibre material, it that has been shown to be palatable and to have a good feeding potential for several herbivores.

Jamaludin et al. (1995) has reported the potency of sago palm fronds in pulp and papermaking due to its durability, supported by Kasim et al. (1995) reported that sago frond has long fibre and high L/D ratio. But Abd Rahman et al. (2018) reported the utilization of natural cellulose fibre for waste water treatment. The reactivity of cellulose hydroxyl groups, has a dominant role in the adsorption of dyes. Its ability to adsorb dyes can be increased by purification of cellulose and suitable chemical modification of its surface.

In this research sago frond fibre (SFF), its sago frond cellulose fraction (SFC) produced from extracted and delignified SSF, and modified cellulose by carboxymethylation (CMC) were investigated to their capabilities to bind the cationic dye (methylene blue). The influences of contact time, pH and the concentration of dye to the adsorption efficiency and capacity were determined by using the simulated dye effluent. This made sago frond and its cellulose fraction potentially can be used as environmentally friendly adsorbent to minimize the water pollution caused by dyes.

Materials and Methods

Preparation of Sago Frond Fibre (SFF)

Fresh sago fronds without leaflet and rachis were obtained from ten years sago (*Metroxylon sago*) trunk cultivated in *ex-situ* BPPT experimental field in Balubang Jaya, Bogor City. The fronds were divided into two parts, the upper parts (A) and the lower parts (B). The fresh frond was crushed and added with water; then the starch was eliminated by hydrolysis with α-amylase (Thermamil, Novo Enzyme) and boiled for 30 min. The filtrate was removed and the residue was sundried and pulverized by hammer mill until passed the 40 mesh screens.

Preparation of Sago Frond Cellulose (SFC)

Cellulose fraction was obtained by purification through delignification and bleaching process according to Tasaso (2015) method. TFS was delignified in alkali hydrothermal treatment by using 10% of NaOH solution in high temperature and pressure. Residue from this treatment was washing by distilled water several times. Dried residue was bleached by the addition of 30% of H_2O_2 at 70ºC until the residue turn into bleached white material, and then dried.

Preparation of Carboxymethylcellulose (CMC)

Preparation of CMC was conducted by Tasaso (2015) method, consisted of alkalization, esterification with MCA and then neutralized by acetic acid solution.

Dye Adsorption by Sago Frond fibre and its Derivatives

Methylene blue was selected as cationic dye in simulated dye effluent. The experiments were designed by investigating the effects of contact time (0-90 min), pH of simulated water (pH 2-8), and dye concentration (5-20 ppm) to the efficiency and adsorption capacity. Separation between adsorbent and adsorbate was conducted by decantation. The OD spectroscopy of filtrates was determined at λ 665 nm. Procedure for the determination of dye adsorption was modified from Raghuvanshi *et al.* (2004) method.

Results and Discussion

Carbohydrate and fibre were the main components of sago frond flour. Purification through delignification and bleaching process caused the increasing of cellulose content from 28-37% to 60-71%, reducing the hemicellulose and lignin contents. Carboxy methyl cellulose produced from frond cellulose has low degree of substitution with DS 0.26-0.31.

Almost of all adsorbent can adsorb the dye in short time, but the maximum dye adsorption obtained from the adsorbate with pH 8. For SFF, SFC and CMC the maximum dye adsorption occurred after 15, 30 and 60 min. The highest adsorption capacity was produced from SFC, which can adsorb 1.397 mg of dye per g of sago frond flour at dye concentration 15 ppm or 92.58% of efficiency, followed by SFC as 0.977 mg of dye per g of cellulose at dye concentration 10 ppm or 97.5% of efficiency.

Conclusion

The sago frond fibre, its cellulose and carboxymethylcellulose can be used to adsorb the methylene blue from simulated waste water. Delignification and bleaching improved the purity of cellulose components and increased the adsorption capacity and efficiency. Carboxymethylation of cellulose fibre increasing the amorphous fraction and made it more soluble in water. This made carboxymethylcellulose was difficult to be separated with the adsorbate.

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