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SAGO 2023 TOKYO

The Role of Sago in Achieving the Sustainable Development Goals

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14ISS01

Recent Achievements toward SDGs through Collaborative Activities between Sago -producing Countries and User Countries

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Abstract Recently, the demand for sago palm has been increasing in response to the new normal of society after COVID-19 and SDGs. Such demand increase for sago starch comes against the backdrop of the deterioration of the environment due to climate change, unforeseen social problems, and the need to strengthen food security and the resilience of the food system with also the growing global desire to ensure a healthy life. This paper highlights recent activities based on interdisciplinary multidisciplinary approaches that contribute toward meeting SDGs through cooperation between sago palm-producing countries and user countries as follows: (1) specific nutrient-use efficiency—the nutrient absorption and translocation characteristics of sago palm that aid in the efficient uptake of potassium even from poor soil or salt-damaged land; (2) the development of sustainable nutrition management in the nursery and field based on the analysis of the symbiosis between useful microorganisms, nitrogen fixation bacteria (NFB), and/or arbuscular mycorrhizal fungi (AMF), and sago palm; (3) the development of optimal applications for cooking or processing that utilize the characteristics of sago starch, which does not contain gliadin, one of the allergen components of food allergies; (4) the recycling of the agricultural residues after sago starch utilization; (5) the streamlining of the supply chain to add value to sago starch produced by small-scale farmers—providing knowledge and technology to manufacture commodities that will meet growing market requirements.

Key words: Food security, Healthy living, Resilience of the food system, Supply chain, Sustainable development

Introduction

Sago palm (*Metroxylon sagu* Rottb.), a starch resource plant distributed in Southeast Asia and Melanesia that adapts to adverse environments, is not only a food crop but is also expected to be utilized as a raw material for allergy-free foods, biofuel, and other industrial uses. Sago palm and related species grow in swampy, alluvial, and peaty soils where almost no other major crops can grow without drainage or soil improvement (Sato et al., 1979; Jong, 1995, Ehara et al., 2018). Sago palm is a highly important bioresource for not only sustainable agriculture but also rural development in swampy areas of the tropics. Moreover, *Metroxylon* palms, including sago palm, are recognized as unexploited or underexploited plants (Ehara, 2006) because this species has been harvested mainly from natural forests and/or has been semi-cultivated with very simple maintenance.

Considering the social background for two decades that a new competition between biofuel production and food production has occurred, and as food demands diversify, an efficient use of carbohydrates from sago palm and related species is currently anticipated, followed by a predicted increase in the development and utilization of land in swampy areas. Recently, the demand for sago palm has been increasing in response to the new normal of society after the coronavirus disease (COVID-19) and Sustainable Development Goals (SDGs). Such an increase in the demand for sago starch comes against the backdrop of the deterioration of the deterioration of environment due to climate change, unforeseen social problems occurred in Europe in February 2022, and the need to strengthen food security and the resilience of the food system. Another factor is the growing global desire to ensure a healthy life. This paper highlights recent activities and efforts based on interdisciplinary thinking and multidisciplinary approaches that contribute toward meeting SDGs through cooperation between sago palm-producing countries and user countries. Some of these developments include: (1) specific nutrient-use efficiency—the nutrient absorption and translocation characteristics of sago palm that aid in the efficient uptake of potassium even from poor soil or salt-damaged land; (2) the development of sustainable nutrition management in the nursery and field based on the analysis of the symbiosis between useful microorganisms, nitrogen fixation bacteria (NFB), and/or arbuscular mycorrhizal fungi (AMF), and sago palm; (3) the development of optimal applications for cooking or processing that utilize the characteristics of sago starch, which does not contain gliadin, one of the allergen components of food allergies; (4) the recycling of the agricultural residues after sago starch utilization; (5) the streamlining of the supply chain to add value to sago starch produced by small-scale farmers—providing knowledge and technology to manufacture commodities that will meet growing market requirements.

1. Specific nutrient-use efficiency: Resistance of sago palm against abiotic stress

Sago palm is generally considered to have higher resistance against abiotic stresses such as salt stress, acid-soil, submergence and flooding.

1-1. *Salt stress*

As mentioned above, *Metroxylo*n palms can grow in problem soils. Here, the salt resistance of sago palm and related species is introduced. Fig.1a shows the Na^+ concentration in different plant parts of sago palm seedlings grown in a hydroponic system after 342 mM NaCl treatment (corresponding to 2% NaCl) for 1 month (Ehara et al., 2008a). In the leaflets and petioles of the treated plants, the Na^+ concentrations were higher at lower leaf positions than at higher leaf positions. The difference in the Na^+ concentrations in both the leaflets and petiole between the control and treated plants was remarkable at lower leaf positions. The Na^+ concentration in the leaflets was less than one-half of that in the petiole. On the other hand, the Cl^- concentration increased with the change in Na^+ concentration.

Although the K^+ concentration decreased in the roots during the NaCl treatment, it did not decrease in the leaflets and petiole. These tendencies were found in the seedlings at more advanced leaf ages as well and under a wide range of NaCl concentrations in culture solution (Ehara et al., 2006). At some leaf positions, the K^+ concentrations were higher in the treated plants than in the control plants (Ehara et al., 2008a, b). The K^+ concentration in the petiole tended to be higher at higher leaf positions than at lower leaf positions, especially in the treated plants. In some species, plant growth is not affected when the K^+ concentration is maintained under NaCl treatment (Yeo and Flowers, 1983; Jeschke et al., 1985). The K^+ concentrations in the top part did not decrease, regardless of the leaf position in the case of sago palm. It appears that Na^+ absorption clearly did not depress K^+ absorption and translocation to the leaves in sago palm, and the K^+ distribution in the top part tended to increase rather than have no effect. Yoneta et al. (2006) also reported that sago palm was able to uptake K^+ from soil, and K^+ was accumulated in leaflets through the root systems in response to NaCl stress. They reported also that proline was under the detection limit in leaflets and roots, and a small amount of glycinebetaine was found in leaflets.

According to Ehara et al. (2008a, b), new leaf emergence was delayed slightly with the NaCl treatment, although senescence of the lower leaf did not accelerate. In *M. warburgii* and *M. vitiense* also, the K^+ concentration in the leaflets did not decrease under salt stress conditions (Ehara et al., 2007, 2008b). These results in sago palm and related species strongly support the assumption that salt tolerance is related to the exclusion of K^+ by Na^+ absorption in the leaf blade (Yeo and Flowers 1983; Jeschke et al., 1985). Considering these results, K^+ assumes the role of osmotic adjustment, especially at higher leaf positions in most active leaves. According to Asano et al. (2023), K absorption and translocation were not restricted by a reduction in the application of nutrients. It is therefore considered that the nutrient absorption and translocation characteristics of sago palm that aid in the efficient uptake of potassium even from poor soil or salt-damaged land.

Fig.1b shows the Na^+ concentration in different parts in the adventitious roots (Ehara et al., 2008a), and Fig.1c shows a schematic of transverse section of root. The Na_+ concentration was lower in the stele (central cylinder) than in the cortex. According to the study on Na distribution revealed by X-ray microanalysis from the cortex to the stele in the adventitious roots of the treated plants, much more Na was detected in the cortex than in the stele (Ehara et al., 2008a). The highest distribution of Na was found at the inner region of the cortex near the stele. In this region, the endodermis where suberin or lignin (Casparian strip) develops also was observed in sago palm (Prathumyot and Ehara, 2010). From only this finding, it is difficult to discuss the information in detail, although it is clear that the region including the endodermis has a mechanism to trap some of the over-influx of Na into the root. This mechanism will be very important in restricting translocation of Na^+ from the root to the top parts under salt stress. Sago palm exhibits the mechanism to maintain low Na^+ concentration in the leaflets by storing Na^+ in the roots and petioles, especially at lower leaf positions, the mechanism of which can be understood as salt avoidance. However, the photosynthetic rate and transpiration rate decreased by 40% with NaCl stress in sago palm seedlings (final 18th leaf age) grown for 4 months in a hydroponic system including 224 mM NaCl (corresponding to 1.3%) (Prathumyot et al., 2011).

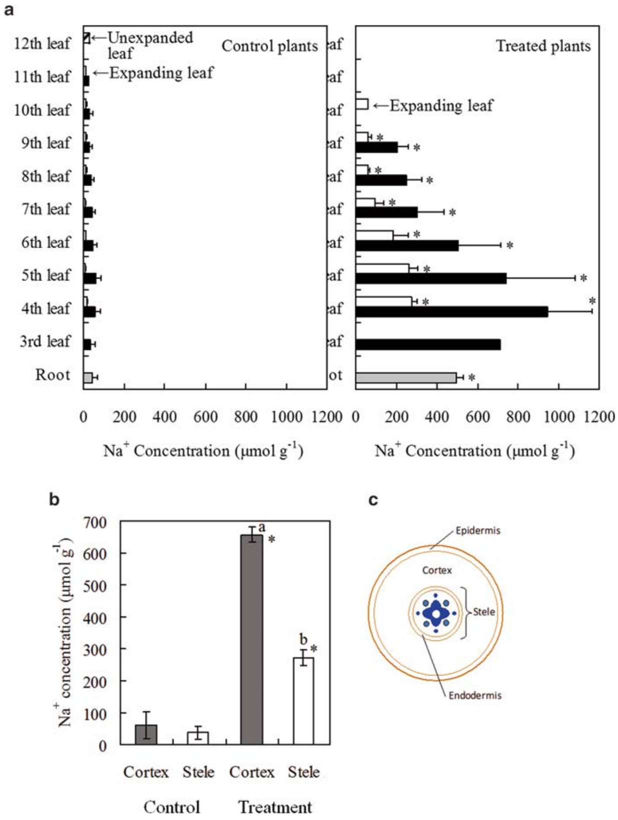

Fig.1. Na^+ concentration in roots and leaflets and petiole at different leaf positions (a) and in the cortex and stele of adventitious roots under NaCl treatment (b) (Source: Ehara et al., 2008a) with schematic of transvers section of root (c). Horizontal and vertical lines indicate the standard deviation (n = 3). Asterisks indicate a significant difference in each part between the control and treated plants at a 0.05 probability level, according to the t-test. Different letters indicate significant differences in different parts within the treated plants at a 0.05 probability level, according to the Tukey-Kramer test deviation (n=3). Asterisks indicate a significant difference in each part between the control and treated plants at a 0.05 probability level, according to the t-test. Different letters indicate significant differences in different parts within the treated plants at a 0.05 probability level, according to the Tukey-Kramer test.

1.2 *Acid stress*

Nowadays sago palm populations are often found in swamps and peat soil where soil pH is low, such as in the Malay Archipelago. Sago palm has been considered to be tolerant of acid soil. From the results of growth analysis of sago palm seedlings grown at different pH conditions (pH 5.7, 4.5, and 3.6, adjusted with 1N HCl) in a pot filled with vermiculite and culture solution for 4.5 months, it was clear that there were no significant differences in any growth parameters among the three treatments (Anugoolprasert et al., 2012). When sago palm seedlings were planted in a pot filled with vermiculite and culture solution at pH 3.6 (adjusted with 1N H_2SO_4) that included different levels of $AlCl_3•6H_2O$ corresponding to 0, 10, 20, 100, and 200 ppm Al (as initial Al concentration before applying to the pots), the weekly increments of plant length, total weight for 4.5 months were largest in 10 ppm, d followed by 0, 20, 100, and 200 ppm Al (Anugoolprasert et al., 2014). The root system under 200 ppm Al was apparently different from that under 0–100 ppm Al, and the branched roots were stunted, brownish, and thick. The root dry weight was also less than the other plots. The change in P, N, K^+, Ca^{2+}, and Mg^{2+} concentrations with the Al treatments was moderate. The Al^{3+} concentration tended to be lower in the leaflets at higher leaf position and the stele of the adventitious roots, while it tended to be higher in the cortex of adventitious roots (values ranged from 190 to 950 mg kg^{-1} DM in all the plant parts, even at 200

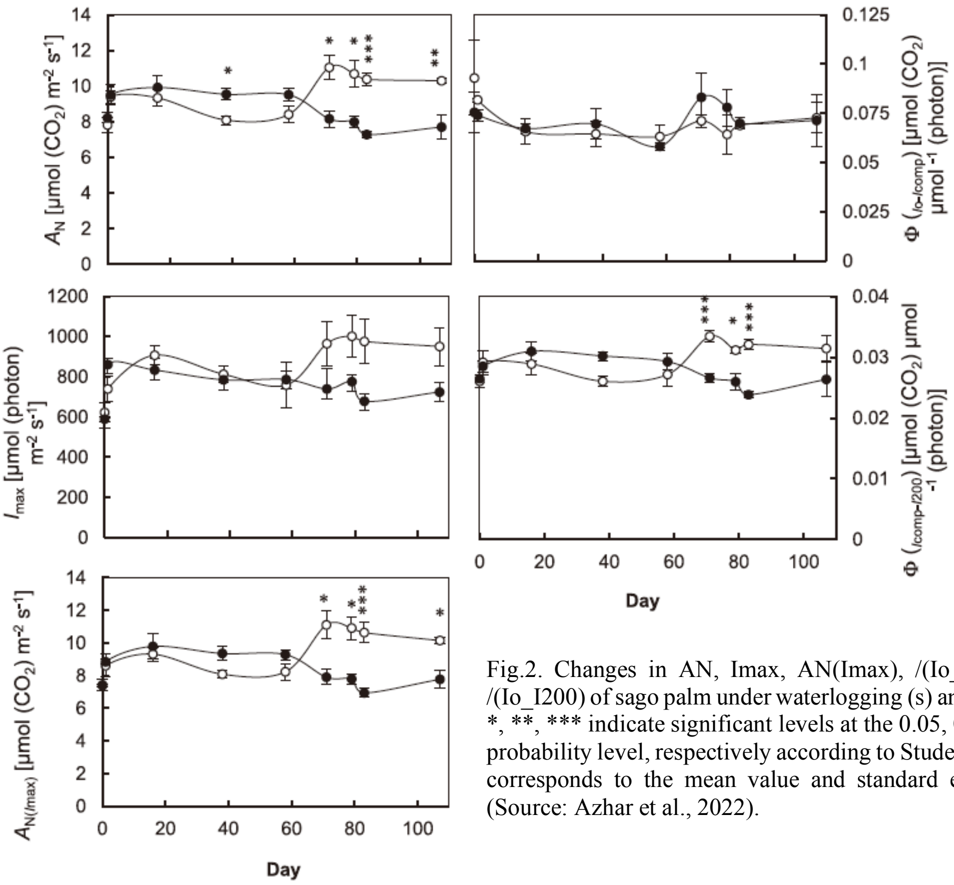

Fig.2. Changes in AN, Imax, AN(Imax), /(Io_Icomp), and /(Io_I200) of sago palm under waterlogging (s) and control (d). *, **, *** indicate significant levels at the 0.05, 0.01, 0.001 probability level, respectively according to Student t-test. Data corresponds to the mean value and standard error (n = 3) (Source: Azhar et al., 2022).

ppm Al). According to Chenery (1948), thousands of plant species are classified as Al accumulators (≥1000 mg kg^{-1} DM) or Al excluders (<1000 mg kg−1 DM). Based on the Al concentrations in the plant tissues, sago palm is considered to have Al-exclusion ability under acidic conditions. However, the diameter at breast height (DBH) that was one of the most important parameters limiting the pith dry matter yield correlated with soil pH in the Malay Archipelago (Ehara et al., 2000). Even if sago palm exhibits the mechanism to exclude excess Al under low pH condition, the growth and yield will be affected by soil acidity.

1.3 *Water-logging*

Azhar et al. (2022) reported evaluating sago palm photosynthetic performance in waterlogged conditions: utilizing pulse-amplitudemodulated (PAM) fluorometry as a waterlogging stress indicator. Water-logging enhanced photosynthetic performance of sago palm seedlings at particular period and they can stand in submerged condition up to 2 months (Fig.2). However, when the water-logging duration was prolonged, their physiological performance was depressed. These results will suggest appropriate water control in swampy peat land to achieve sustainable cultivation management with acceptable dry matter production and starch yield.

2. Useful Microorganisms

The development of sustainable nutrition management in the nursery and field based on the analysis of the symbiosis between useful microorganisms, nitrogen fixation bacteria NFB), and/or arbuscular mycorrhizal fungi (AMF), and sago palm attracts attentions.

2.2 *Nitrogen fixation bacteria*

In Oral Session 6 (AAACU Session), Asano et al. reported on nitrogen-fixing bacterial community in sago palm roots in different soil environments of east Malaysia and south Thailand (see Paper 28). The soil bulk density, clay content, volumetric water content, pH, EC, exchangeable cation contents, and total N affected both communities of endophytic bacteria and NFB. The result of Asano et al. (2023) was as follows: NifH adjacent to *Bradyrhizobium*, *Burkholderia*, *Cupriavidus*, *Frankia*, *Geobacter*, *Anaeromyxobacter*, *Desulfovibrio*, *Clostridium*, and *Spirochaeta* were highly detected. Surprisingly, NifH close to *Burkholderia xenovorans* was dominant (> 30% relative abundance) in the strong acidity (pH 4.1) of shallow peat soil in Malaysia. The relative abundance of aerobic or facultative anaerobic NFB (*Bradyrhizobium*, *Burkholderia*, *Frankia*, and *Cupriavidus* genera) was negatively correlated with the relative abundance of anaerobic NFB (*Clostridium*, *Geobacter*, *Anaeromyxobacter*, *Desulfovibrio*, and *Spirochaeta*). It is suggested that the key players of root endophytic NFB in sago palm roots shifted by the oxygen level in the root interior affected by waterlogging in the soil.

2.3 *Arbuscular mycorrhizal fungi*

About AMF, Asano et al. (2021) reported that the AMF colonization rate was significantly lower in shallow peat soil SPS (39.2 ± 12.5%) than in mineral soil (73.2 ± 4.6%). The lower abundance and diversity of AMF in shallow peat soil are possibly caused by abiotic factors, including soil physico-chemical properties. Glomus and Acaulospora species detected in SPS might have strong tolerance against acidity and high soil moisture content. Then, it is possible that AMF's symbiotic association existed in the roots of sago palm seedlings when commercial inocula were used (Fig.3) (Asano et al., 2019). Verification of the effect of commercial inocula on the growth of sago palm seedlings and environmental conditions in which

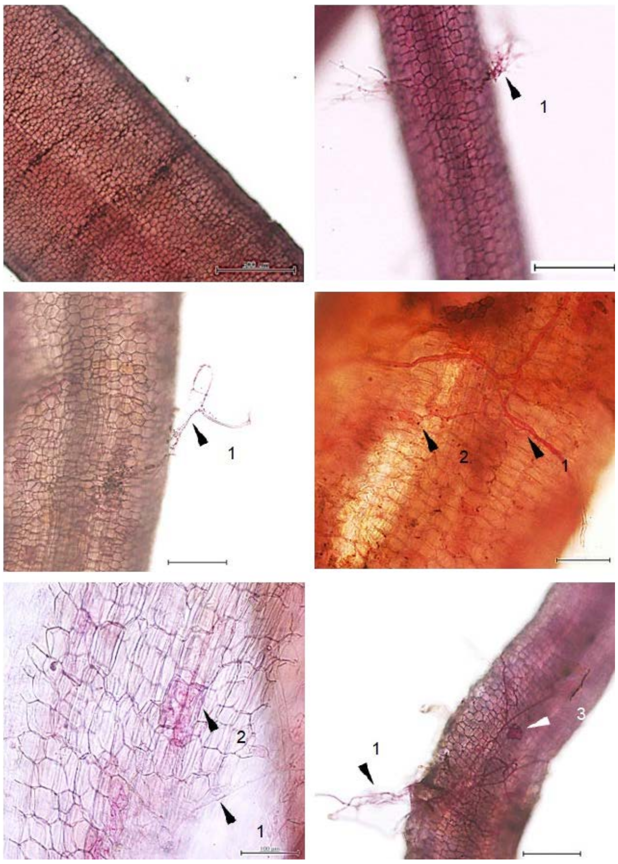

Fig. 3. Photomicrograph of root samples of sago palm seedlings inoculated with Mycogel (left) and Yukimotogoenotaumi (right) Left top: root from 5 cm below soil surface, bar = 500 μm; left mid: root from 10 cm below soil surface, bar = 200 μm; left bottom: 15 cm below soil surface, bar = 100 μm; right top: root from 5 cm below soil surface, bar = 200 μm; right mid: root from 10 cm below soil surface, bar = 100 μm; right bottom: 15 cm below soil surface, bar = 200 μm; arrow 1: hypha, arrow 2: arbuscule, arrow 3: vesicle (Source: Asano et al., 2019).

AMF works effectively associated with sago palm are future subjects that must be studied to contribute to environmentally friendly cultivation in intensive production. The application of AMF to sago palm seedlings accelerated shoot growth with leaflet expanding (Asano, 2023).

Ehara et al. (1998, 2001) revealed the reason why sago fruits showed lower germinate percentage and improved the germinability with physical treatment removing seed coat tissues. Then, sago palm could be introduced into Tanzania with transportation of seeds and utilization seedlings germinated from seeds as planting materials (Ehara et al., 2006). As Toyoda et al. reported, UN-FAO employed utilization the method developed by Ehara et al. (2001, 2006) for FAO Technical Cooperation Program entitled "Enhancing food security and combating climate change through scaling up sago palm production" in Papua New Guinea (PNG), and the first sago palm nursery named "Ehara Sago Nursery" was opened in Moem Village, East Sepik Province, PNG in May 2023 (see Paper 34). The one hundred seedlings grown in that nursery were transplanted to 1 ha field in Moem in August 2023. The other sago palm nurseries were set to open in the other two villages in East Sepik.

3. Development of optimal applications for cooking to utilize the characteristics of sago starch

The development of optimal applications for cooking or processing that utilize the characteristics of sago starch, which does not contain gliadin, one of the allergen components of food allergies are pressing demand considering recent increase in persons with allergy symptoms.

3.1 *Gluten-free pasta using sago starch*

In poster session 1, Kondo et al. reported their results from comparative study on the properties of various commercial sago starches and examination of gluten-free pasta using sago starch (see Paper 03). The authors (Kondo et al., 2023) examined to compare a total of nine types of sago starch (provided by private sectors in Indonesia and Japan), including sago starches sold in Indonesia and sago starches imported to Japan from Indonesia. A focus was also put on gluten-free, which is receiving much attention nowadays, and the development of gluten-free pasta made with sago starches imported to Japan was attempted. As the results by Kondo et al. (2023), 1) the nine Indonesian sago starches showed remarkable differences in quality, in their viscosities, and in the physical properties of their gels; 2) non-cooked pasta substituted with modified starch (hydroxypropylated tapioca starch and enzyme-treated starch), showed a tendency to be softer than pasta made with sago starch, but after boiling, the hardness of the pastas was similar; 3) 15 minutes after boiling, the hardness of the sago pasta roughly doubled. They stated when 5%, or 7%, of the sago starch was replaced with the two types of modified starch, a tendency for the increase in hardness to be suppressed was seen, meaning, retrogradation suppression could be confirmed.

3.2 *Application of sago starch in Japanese steamed cake*

In the other poster presentation, Hirao et al. introduced application of sago starch in karukan (Japanese rice flour Steamed Cake) (see Paper 17) that rice flour was substituted for sago starch, which is expected to improve the utilization and palatability of karukan, and the results were compared with those of karukan made with other starches. According to the results by Hirao et al. (2023), 1) the karukan with 50% sago starch substituted for rice flour did not differ significantly from the reference in terms of all the determined value; 2) though in terms of preference, the appearance and color items were significantly lower, there were no significant differences in the good texture, taste, hardness, and elasticity items; 3) cassava starch was significantly less preferred than the reference, corn and sweet potato starches, while, sago starch showed no significant differences from the other starches; 4) while some panels liked the distinctive light pink color of sago starch karukan, others said it tasted a little astringent. Their results suggested that improving the taste of sago starch would improve the preference of sago starch karukan, which is truly important for highly utilization of sago starch.

4. Recycling of the agricultural residues after sago starch utilization

The recycling of the agricultural residues after sago palm utilization has been investigated and some results were reported in the 13th International Sago Symposium. They were compiled in Ehara et al. (2018). For example, sago pith residue, a solid waste of sago wet extraction industry, is a potential source for use as fiber reinforcement on starch-based foam production due to its composition that contains starch and fiber which are necessary for producing biofoam: according to Utami et al. (2014), partial acid hydrolysis of sago ham- development of optimal applications for cooking or processing that utilize the characteristics of sago starch, which does not contain gliadin, one of the allergen components of food allergies are pressing demand considering recent increase in persons with allergy symptoms. The residue of sago pith has been used as pig feed in some areas according to Connell and Hamnett (1978). On the residue of sago pith which is left after processing, certain kinds of mushrooms grow, and they are eaten as supplementary food (Yoyoda 2018). When the residue is left for a certain period, larvae of grubs (mostly *Rhynchophorus ferrugineus*) appear, and the larvae are eaten by local people as a sort of delicacy (Mitsuhashi, 2015). According to Avé (1977), the pith residue as waste can be used as a medicine, a pesticide, and also as a poison for fish. Mishima (2018) proposed specific utilization of the starch residue (hampas) by establishing a conversion method to make it into a sweetener. In 14ISS, two studies from new points of view rather than the former studies were delivered.

4.1 *Sago leaves as animal feed*

The potential of sago frond as large-scale animal feed (see Paper 35). Ahmad and Bujang (2023) produced sago silage from mashed and fermented sago fronds with feeding trials and tested on individually caged Malin sheep for a duration of three months. According to their results, the sago frond silage from growing sago palm not only provides an elegant solution to the shortage of feed supply but also offers novel opportunities to sago farmers to generate extra income while waiting for the sago palm to be harvestable.

4.2 *Utilization of rachis for fishing gear*

Paper 40 in 14ISS was relating to utilisation of sago palm rachis to woven local fishing gear at Nakhon si Thammarat Province, Thailand. Chankaew et al. (2023) studied on the weaving of traditional fishing gear with sago rachis material of villagers sago palm household and fishing type at Inkeree Sub-district PhromKhiri District Nakhon Si Thammarat Province, Thailand. At the sites, the sago rachis was collected from the remaining sago leaves after leaves were sutured to thatched roofs. It was to prepare the surface of the sago rachis for weaving fishing tools such as eel basket and large upright basket trap there. The community value and utilization of fishery in sago palm swamp can be assessed through a socio-economic indicator from fish use, such as, fishing and the direct use of sago palm, and the water quality of fishing area in the sago palm swamp were criteria suitable for aquatic life (Chankaew et al., 2023).

5. Streamlining of the supply chain

The streamlining of the supply chain to add value to sago starch produced by small-scale farmers—providing knowledge and technology to manufacture commodities that will meet growing market requirements is required for sustainable development of sago business to share benefits commensurate with each effort between different layers. In this paper, some studies published in our society journal "Sago Palm" and in related journals are compiled.

5.1 *Value chain of small-scale sago industries*

From a case study of South Sulawesi, Indonesia for a value chain analysis of small-scale sago industries, the dried sago production is the most profitable and has the highest significant value-added process as compared to wet sago and *dange* (molded dried-sago) (Trisia et al., 2018). Trisia et al. (2021) studied the role of the sago supply chain for rural development in Indonesia from a review and perspective and reported as follows: the weak bargaining position sago farmers have due to inefficiencies in the sago supply chain and lack of market information; the direction in which future actions should be taken as guidelines in order to achieve a high level of efficiency along the sago supply chain.

5.2 *Distribution channel and factors relating to international trade*

Distribution channels and added value of sago products in East Java, Indonesia−from producers to consumers was analyzed by Trisia and Ehara (2020). The distribution of sago products, such as dried sago and roasted sago (*sagu kotak*), in East Java is classified as indirect distribution, which relies on intermediaries and sago pudding has a highly profitable value-added process as compared to that of roasted sago (Trisia and Ehara, 2020).

The factors determining sago starch import demand was studied as empirical evidence from Japan. Trisia et al. (2020) reported that the price of sago starch, GDP, aging population rate and tariff-rate quota policy are significant factors influencing sago starch importation in Japan.

As described above, recent activities and efforts in each specific field and those based on interdisciplinary concept and multidisciplinary approaches were compiled in this paper to provide an overview of sago palm studies in these two decades. The quantitative demand for sago palm has been increased reflecting the influence of climate change recent decades, while it has been increasing even further in response to the new normal of society after the coronavirus disease (COVID-19) and the new world policy of sustainable Development Goals (SDGs). Actually, we feel that the sago palm producing countries may be experiencing the greatest harvest pressure of sago palm in their history since the influence of COVID-19 started spreading. In not only quantitative agenda to secure enough food flour, but also in quality of food, the utilization of sago starch attracts attention. The need for effort to prepare foods reducing the impact of allergies has become apparent recently and will only increase in the future. Sago palm has the potential to contribute to a healthy life as well in terms of preventing allergies. We should utilize the results of basic research accumulated to date for social implementation and promote collaborative efforts in sago palm producing and user countries. Therefore, the potential of sago palms must be utilized in social life for food security, healthy living, and community resilience.

References

Anugoolprasert, O., S. Kinoshita, H. Naito, P. Chutimanukul, M. Shimizu and H. Ehara 2012 Effect of low pH on the growth, physiological characteristics and nutrient absorption of sago palm in a hydroponic system. Plant Prod. Sci. 15: 125–131.

Anugoolprasert, O., H. Ehara and H. Naito 2014 Growth response and nutrient concentrations of sago palm under aluminum stress. Thammasat Intern. J. Sci. Technol. 19: 37–52.

Ahmad, M. N. and K. B. Bujang 2023 The Potential of Sago Frond as Large-Scale Animal Feed. 14ISS, 35.

Asano 2023 Fundamental studies on arbuscular mycorrhizal fungi and endophytic nitrogen-fixing bacteria colonized in the sago palm (*Metroxylon sagu* Rottb.) roots. Ph.D. Dissertation, Nagoya University and Kasetseart University, pp.150.

Asano, K., R. Isoi, H. Murano, A. Azhar, Y. B. Pasolon and H. Ehara 2019 Colonization of roots in sago palm seedlings associated with commercial mycorrhizal inocula. Sago Palm 27: 9–14.

Asano, K., W. V. A. Kagong, S. M. B. Mohammad, K. Sakazaki, M. S. B. H. A. Talip, S. S. Sahmat, M. C. K. Yok, T. Isoi, M. Nakata-Kano and H. Ehara 2021 Arbuscular mycorrhizal communities in the roots of sago palm in mineral and shallow peat soils. Agriculture 11: 1161.

Asano, K., A. Azhar, F. Audia, H. Murano, H. Naito, B. Abbas, J. Romkaew, K. Sinma, D. Makihara and H. Ehara 2023 Changes in photosynthetic performance and dry matter production in sago palm seedlings by the application of different nutrient levels. Trop. Agr. Develop. 67: 90–97.

Asano, K., K. Sinma, J. Romkaew, S. M. B. Mohammad, M. C. K. Yok, T. Isoi, M. Nakata-Kano and H. Ehara 2023

Nitrogen-fixing bacterial community in sago palm roots in different soil environments of East Malaysia and South Thailand. 14ISS, 28.

Avé, J. B. 1977 Sago in insular Southeast Asia: historical aspects and contemporary use. In: Sago-76 papers of the first international sago symposium. (Tan, K. ed.) Kuching, July 5–7, 1976, pp 21–30

Azhar, A., D. Makihara, H. Naito and H. Ehara, H. 2020 Evaluating sago palm (*Metroxylon sag*u Rottb.) photosynthetic performance in waterlogged conditions: utilizing pulse-amplitudemodulated (PAM) fluorometry as a waterlogging stress indicator. J. Saudi Soc. Agr. Sci. 19: 37–42.

Chankaew, S., S. Chunta, B. Boonmart and W. Chankaew 2023 Utilisation of sago palm rachis to woven local fishing gear at Nakhon si Thammarat Province, Thailand. 14ISS, 40

Chenery, E.M. 1948. Aluminum in the plant world. Part I, general survey in dicotyledons. Kew Bull. 3: 173–183.

Connel, J. and M. P. Hamnett 1978 Famine or feast: sago production in Bougainville. J. Polyn. Soc. 87:231–242

Ehara, H. 2006 Diversity of economic plants. *In*: Sustainable crop production. (Morita, S., Daimon, H. and Abe, J. eds.) Asakura Shoten (Tokyo), 25–28.

Ehara, H., H. Shibata, W. Prathumyot, H. Naito and H. Miyake 2008a Absorption and distribution of Na^{+}, Cl^{-} and some other ions and physiological features of sago palm under salt stress. Trop. Agr. Develop. 52: 7–16.

Ehara, H., K. Kakuda, A. Miyazaki, S. Nakamura, H. Naito, Y. Nitta, M. Okazaki, Y. Sasaki, K. Toyoda, A. Watanabe, M. Watanabe, Y. Yamamoto, S. D. Kimura and Y. Goto 2021 Sago palm in peatland. *In*: Tropical Peatland Eco-management. (Osaki, M., Tsuji, N., Foead, N. and Rieley, J. eds.) Springer (Singapore), 477–507.

Ehara, H., C. Komada and O. Morita 1998 Germination characteristics of sago palm and spine emergence in seedlings produced from spineless palm seeds. Principes 42: 212–217.

Ehara, H., O. Morita, C. Komada and M. Goto 2001 Effect of physical treatment and presence of the pericarp and sarcotesta on seed germination in sago palm (*Metroxylon sagu* Rottb.). Seed Sci. Technol. 29: 83–90.

Ehara, H., H. Naito, A. J. P. Tarimo, M. H. Bintoro and T. Y. Takamura 2006 Introduction of sago palm seeds and seedlings into Tanzania. Sago Palm 14: 65–71.

Ehara, H., H. Shibata, W. Prathumyot, H. Naito, T. Mishima, M. Tuiwawa, A. Naikatini and I. Rounds 2008b Absorption and distribution of Na^{+} and some ions in seedlings of *Metroxylon vitiense* H. Wendl. ex Benth. & Hook. f. under salt stress. Trop. Agr. Develop. 52: 17–26.

Ehara, H., S. Susanto, C. Mizota, S. Hirose and T. Matsuno 2000 Sago palm (*Metroxylon sagu*, Arecaceae) production in the eastern archipelago of Indonesia: Variation in morphological characteristics and pith dry-matter yield. Econ. Bot. 54: 197–206.

Ehara, H., Y. Toyoda and D. V. Johnson 2018 Sago Palm: Multiple contributions to food security and sustainable livelihoods. Springer (Singapore), pp330.

Jeschke, W. D., C. A. Atkins and J. S. Pate 1985 Ion circulation via phloem and xylem between root and shoot of nodulated white lupin. J. Plant Physiol. 117: 319–330.

Jong, F. S. 1995 Research for the development of sago palm (*Metroxylon sagu* Rottb.) cultivation in Sarawak, Malaysia. Ph. D. Thesis of Agricultural University, Wageningen, The Netherlands.

Kondo, T., H. Ehara and K. Hirao 2023 Comparison study on the properties of various commercial sago starches and examination of gluten-free pasta using sago starch. 14ISS, 03.

Hirao, K., S. Mitsuboshi, Y. Yoneyama, N. Egi, T. Kondo and K. Kainuma 2023 Application of sago starch in karukan (Japanese rice flour steamed cake). 14ISS, 17.

Mishima, T. 2018 New sago palm starch resources and starch pith waste properties. *In*: Sago Palm: Multiple contributions to food security and sustainable livelihoods (Ehara et al. eds.). Springer (Singapore), 309–315.

Mitsuhashi, J. 2015 Uses of weevils. *In*: The sago palm—the food and environmental challenges of the 21st century. (The Society of Sago Palm Studies ed.) Kyoto University Press, (Kyoto), 314–319.

Prathumyot, W. and H. Ehara 2010 Identification of casparian strip in roots of *Metroxylon sagu*, a salt-resistant palm. Trop. Agr. Develop. 54: 91–97.

Prathumyot, W., M. Okada, H. Naito and H. Ehara 2011 Physiological response and mineral concentration of sago palm under diurnal changes of NaCl Concentration in culture solution. Trop. Agr. Develop. 55: 11–20.

Sato T, T. Yamaguchi and T. Takamura 1979 Cultivation, harvesting and processing of sago palm. Jpn. J. Trop. Agric. 23:130–136.

Toyoda, Y. 2018 Life and livelihood in sago-growing areas. *In*: Sago Palm: Multiple contributions to food security and sustainable livelihoods (Ehara et al. eds.). Springer (Singapore), 31–42.

Trisia, M. A. and H. Ehara 2020 From producers to consumers: An analysis of distribution channels and added value of sago products in East Java, Indonesia. Sago Palm 28: 49-55.

Trisia, M. A., A. P. Metaragakusuma, K. Osozawa and H. Ehara 2018 A value chain analysis of small-scale sago Industries: A case study of South Sulawesi, Indonesia. Sago Palm 26: 1−12.

Trisia, M. A., M. Tachikawa and H. Ehara 2021 The role of the sago supply chain for rural development in Indonesia: A review and perspective. Rev. Agri. Sci. 9: 143–156.

Trisia, M. A., H. Takeshita, M. Kikuta and H. Ehara 2020 Factors determining sago starch import demand: Empirical evidence from Japan. J. Intern. Logis. Trade 18: 159–167.

Utami, A. S., T. C. Sunarti,N. Isono, M. Hisamatsu and H. Ehara 2014 Preparation of biodegradable foam from sago residue. Sago Palm 22: 1–5.

Yeo, A. R. and T. J. Flowers 1983 Varietal differences in the toxicity of sodium ions in rice leaves. Physiol. Plant. 59:189-195.

Yoneta, R., M. Okazaki and Y. Yano 2006 Response of sago palm (*Metroxylon sagu* Rottb.) to NaCl stress. Sago Palm 14: 10–19.

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Sago Development and Use Policy as Local Food Diversification for Food Security

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Abstract Food security is a very challenging matter, in the midst of intensifying climate change, conditions of world economic pressure, environmental degradation, and the situation that Covid-19 pandemic is still not over. A sustainable agri-food system should provide a variety of sufficient, nutritious and safe foods at affordable prices for everyone, so that no one suffers from malnutrition or hunger of any kind. Indonesia has the largest sago area of around 5.5 million ha and sago area spreads over the large islands of the archipelago, and it spreads widest in Papua Province. The area, distribution and potential for sago production are quite large, but the reality is that harvesting and processing sago into starch still faces various obstacles; sago productivity is still low, the location of sago is far from residential areas, harvesting is difficult and expensive due to limited infrastructure and social culture, and not much of the sago starch goes to downstream products. Papua Province is the center of diversity of sago palm germplasm. The area of sago forests in the province is around 90% of the total area in Indonesia. The results of research on sago exploration, morphological characterization, productivity observations, molecular markers show that the greatest genetic diversity of sago is found in Papua Province, especially around Lake Sentani, Jayapura Regency. Dozens of types of spiny sago (*Metroxylon rumphii* Mart.) and non-spiny (*Metroxylon sagu* Rottb.) have been identified by various researchers from universities, research institutes, as well as sago observers, and researchers from Japan. During the time of 2010-2022, four superior varieties of sago have been released, namely: Sago Molat, Sago Selatpanjang Meranti, Sago Bestari, and Sago Tana Luwu, with starch productivity of 250-650 kg/tree. The innovative sago agro-industry model supporting food security was implemented in 2021 in North Luwu Regency which aims to increase added value and high competitiveness, and to support a sustainable sago industry. The government needs to adopt the policies which develop sago palm as local food security.

Key words: Accession, Agroindustry, Local food security, Productivity, Variety

Introduction

World Food Day is celebrated on 16 October 2022 by all countries in the world, to increase awareness and attention regarding the importance of handling food problems at the national, regional and global levels in a sustainable manner. The Food and Agriculture Organization/FAO said that World Food Day is celebrated in one year with various global challenges including ongoing pandemics, conflicts, climate change, rising prices, and international tensions. All of these affect global food security. In particular, sustainable agri-food systems that provide a variety of sufficient, nutritious and safe foods at affordable prices for everyone, so that no one suffers from malnutrition or hunger of any kind. FAO has warned that many countries will face food insecurity. FAO notes that a total of 970,000 people will face hunger. Food security is a very challenging matter, in the midst of intensifying climate change, conditions of world economic pressure, environmental degradation, and the Covid-19 pandemic is still not over.

The Minister of Agriculture of the Republic of Indonesia who also serves as Chair of the G20 Agriculture calls for strengthening collaboration and strong support for farmers in the world. The world condition, which is not in a good condition, requires all parties to join hands for the sufficiency of world food. As Chair of the G20 in agriculture, Indonesia calls for solidity for world food adequacy. Moreover, for the 273 million Indonesian people who are not allowed to ask questions (RI Minister of Agriculture, 16/10/2022).

Sago palms grow a lot in the tropics, especially in Indonesia, Malaysia and Papua New Guinea. The largest sago area in the world is Indonesia, which has a sago area of around 5.5 million ha and is spread over the major islands of the archipelago, the largest in Papua. The widest distribution of sago is found in Papua and West Papua Provinces, which are around 5.2 million ha as sago forests (Bintoro, et al., 2010; Bintoro, et al., 2016). While the land used for sago plantations is only around 314,663 ha, and the widest is in the provinces of Papua 156,015 ha, Riau 74,364 ha, and Maluku 38,844 ha. The largest starch production is from Riau Province, which is around 356,658 tons/year, or around 81% of the national sago starch production (Balitbangtan, 2022). Most of this sago starch is exported to Cirebon, Indonesia. Private sago plantations, namely Nasional Sago Prima (NSP), which has developed 16,000 ha of sago land, with a production of 5,000-6,000 tons/year, and 40% of which is exported to Japan (Asmono, 2022).

The research results reported that Indonesia as the center of origin of sago, has a diversity of sago germplasm in dozens of accessions, both spiny and non-spiny sago. These various types and varieties of sago are superior plant materials to support the development of upstream sago. Downstream, the technology for processing sago starch into noodles, sago rice, instant papeda, and various types of food/beverages is available and ready to be used for market production.

The readiness of sago products at the on-farm level must be prepared immediately to provide sufficient raw materials, competitive in terms of price, and easy to obtain to support off-farm activities. A harmonious combination of upstream sago activities must be well integrated with downstream activities. The model of cooperation between farmers and sago craftsmen in the upstream as providers of sago starch raw materials with sago industry partners in the downstream as processing sago starch into various modern food, beverage and non-food products, is a collaboration model that needs to be developed for sago as a local food for sustainable food security national.

Frame of Mind And Current Policy

Some of the food commodities to meet people's needs are still imported, such as: rice, soybeans, corn, sugar, milk, beef, and wheat. The pattern of high rice consumption needs to be reduced, and replaced with the consumption of carbohydrates from non-rice foodstuffs, including sago. Sago is one of the main sources of food for some people in several parts of the world. The spread of sago palms in Indonesia is mainly on the islands of Papua, Maluku, Sulawesi, Kalimantan and Sumatra, especially Riau Province, Meranti Islands Regency and Indragiri Hilir Regency.

Sago is important as an alternative to local food, because from the land area and potential of sago available 5.5 million ha, sago starch is good for health because it contains low glycemic, environmental aspects can reduce the threat of global warming, economic aspects and farming is feasible because sago has a high value, high added, besides the economic aspect, sago is also important from the social and cultural aspects of society.

The area, distribution and potential for sago production are quite large, but the reality is that harvesting and processing sago into starch still faces several obstacles, including:

1. Of the 5.5 million ha of sago area in Indonesia, 5.2 million ha is in the Papua sago forest area, which is far from residential areas and cities,
2. Productivity of sago is still low, and varies, 2.5-10 tons/ha. The potential for sago starch production if managed properly can reach 20-40 tons of dry starch/ha/year,
3. The infrastructure in the sago forest area is very limited, so it requires a very large amount of cost to transport the harvest to the sago factory,
4. The people of Papua have not been able to accept modern business governance. The state is tasked with meeting the needs of the local community/local wisdom, by inviting the community to be involved in these activities,
5. The potential for sago is very large, but the availability of sago starch is limited and has not been spread evenly. As a result, starch and sago products are difficult to find and the price is more expensive than other foods, including rice.
6. Currently, the industry still produces only sago starch with thin margins, so that sago farmers/craftsmen still receive a low selling price for sago. The sago industry is expected to be more focused and prioritize downstream sago processing so that it is more developed, not just processing it into sago starch.

Food Security is the Key to Facing a Potential Global Crisis. The government is also making efforts to promote food security through various strategic and policy mixes. Food security is not only a priority but also a target for social welfare and distribution of welfare. The Government has formulated and implemented policies to strengthen national food security.

The government provides People's Business Credit assistance, and establishes the National Food Agency. This institution is given authority related to the management of government food reserves, implementation of supply and price stabilization activities, strengthening of food logistics systems, alleviation of vulnerable areas of food insecurity, development of food diversification and development of local food potential. In addition, the government is also diversifying local food by increasing production of corn, sorghum, sago and cassava through land expansion and opening of new areas in order to increase production as an alternative to imported food.

The various National Food Security policies above, which are supported by financing, institutional and infrastructure development factors, have so far seen more focus and priority on food commodities such as rice, corn, soybeans, beef and chili. Only recently has the government begun to pay attention to other carbohydrate food sources, such as cassava, sorghum and sago. Facing global climate change, and various problems in the world, there is a global threat of food and energy shortages. For Indonesia, the availability of vast sources of sago land is a huge potential and opportunity in the context of providing local food for rural communities, in addition to other local food sources. For urban communities, more modern industrial processing of sago can provide nutritious and healthy food for the community in the form of noodles, pastries, and so on.

Going forward, government policies should start prioritizing the development of local foods such as sago, and be supported with assistance from various aspects: infrastructure, capital, cheap credit, institutions, markets, training, and directly and actively involve local communities. In this regard, research related to the collection and conservation of germplasm, selection and release of superior varieties, as well as the development of integrated sago products is very important to support the sustainability of the sago industry.

Status of Sago Germplasm in Indonesia

1. Papua Island

Papua is the center of diversity of sago palm germplasm. The area of sago forest in Papua is around 90% of the total area in Indonesia. Thus, the greatest genetic diversity of sago is found in Papua. Pangkali (1994) divides 20 types of sago from Sentani, Jayapura into two types, namely spiny sago or Metroxylon rumphii Mart consisting of: Para Huphon, Para Hondsay, Rondo, Munggin, Puy, Manno, Epesum, Ruruna and Yakhalope), non-spiny sago or *Metroxylon sagu* Rottb (consisting of: Yepha Hongsay, Yepha Hongleu, Yepha Ebung, Osokhulu, Follo, Pane, Wani, Ninggih, Yukulam, Hapolo, Yakhe, Hili, Fikhela and Hanumbo). Initially, exploration of sago germplasm was carried out by researchers from the Research Institute for Coconut and Other Palms (IPCRI) in Kehiran Village, Sentani District, Papua in 1993, and identified the types of sago based on the diversity of its vegetative and generative morphology (Allorerung, et al., 1994) ; Novarianto, et al, 1996). Evaluation by Allorerung and Rembang (1995) in Jayapura showed that there were 6 species of which had high yield potential (150-200 kg of starch/palm). The results of a survey conducted by Widjono et al. (2000) identified 61 types of sago spread across: in Jayapura 35 accessions, 14 accessions in Manokwari, 3 accessions in Merauke, and Sorong 9 types of sago both spiny and non-spiny. Among these sago there is one unique type of sago, namely the Rondo accession which has its own characteristics where the pith can be eaten immediately after being burned like sweet potatoes. This type of sago has short and smooth spines, grows densely spread over the surface of the midrib and the growth of the petiole of the frond. Genetic relationship between sago accessions based on RAPD markers has been reported by (Barahima, et al., 2009)

2. Maluku Islands

The results of a survey of sago palms in the villages of Piru, Eti and Neniari, West Seram District, Central Maluku, obtained four accessions of sago, namely sago Tuni, Ihur, Makanaru and Molat (Miftahorrahman and Novarianto, 1996). Previously reported by Malia and Novarianto (1994) that in Tamilouw Village, Amahai District, Central Maluku Regency, there is a sago population with rather dry land and not waterlogged in the long term, and the potential for Tuni sago starch production is around 500 kg/palm.

3. Sulawesi Island

In Lakomea Village, Kendari Regency, Southeast Sulawesi, it was reported that there were three sago accessions, namely one non-spiny accession with the local name Tawaro roe classified as *Metroxylon sagu* or Molat sago. Sago with large spiny, the shape of a large tall stem is called Tawaro rungga manu belonging to *Metroxylon rumphii* or sago Tuni while those with shorter spiny and have small stem sizes are called Tawaro rui belonging to Metroxylon rumphii or sago

Ihur. The average yield of sago starch obtained was Tawaro roe 374.5 kg, Rungga manu 186.2 kg and Rui 89.6 kg (Tenda et al, (2003). Farmers prefer to cultivate this type of sago roe in addition to high yields also white starch. In North Sulawesi There are two accessions of sago, namely sago rumbia (Metroxylon sp) which is commonly planted. Results from Lay et al.(1998) average starch production per tree for sago Metroxylon sp is 250-375 kg. Sago rumbia is found in Minahasa, Bolaang Mongondow , Sangihe and Talaud Regions, North Sulawesi Province. Tana Luwu, South Sulawesi Province since the 18th century has been exporting sago starch to Singapore via the port of Palopo. Observations of sago palms in North Luwu Regency found two accessions of sago, namely spiny sago and non-spiny sago. Many of the stretches of sago plantations in Tana Luwu have changed their function into housing, roads, replaced by other crops, such as: Oranges, palm oil, cocoa, and have become fish and shrimp ponds. In recent years, the policy of the North Luwu Regent's Leader to plant sago was maintained and developed in several areas as one of the strategies for providing local food, such as Kapurung food.

4. Riau Province-Sumatera Island

Meranti Islands Regency, Riau Province is one of the main sago starch producing areas in Indonesia. This regency has 54,000 ha of sago plantations, included 16,000 ha which are managed by the private sector (PT. Nasional Sago Prima). The city of Selatpanjang was formerly known as the City of Sago, because this area used to produce large quantities of sago, even the largest in Indonesia. The results of exploration of the types of sago that grow in Meranti Islands Regency show that there are three accessions of sago, namely Sago Duri, non-spiny sago (Bemban sago), and rarely spiny sago (Sangka sago). The results of research on sago Duri accession showed that sago starch production varied between 134.53 kg – 354.61 kg dry sago starch/palm, with an average production of 226.34 (+ 56.03) kg/palm (Novarianto, et al., 2016).

5. Ex Situ Collection of Sago Germplasm

The sago collection was carried out by BSIP Palma Crops which was planted in North Sulawesi totaling 15 accessions, and most of the sago germplasm collections came from Papua, namely Osoghulu, Abesung, Yebha, Phara Waliha, Fikhela, Wanni, Phara, Ruruna, Rondo, Phui , Yakhali, Habela, and Yache. The results of the observation of vegetative characters showed that all the observed characters, namely stem circumference, number of leaves, plant height and number of suckers, varied greatly with the value of CV > 20%. The growth of the Phara Waliha sago type has the largest trunk circumference compared to other sago, namely 169 cm. The highest number of leaves is Yakhe, which is 18 leaves. Likewise, the highest number of suckers is found in Sago Yakhe, which is 20 suckers/cluster. The results of an evaluation of the potential for sago starch production carried out on a 12-year-old Rondo sago palm in the ex situ collection at the Kayuwatu Experimental Garden, North Sulawesi Province obtained starch production of 163.33 kg/palm (Tulalo, 2011). PT. Nasional Sago Prima (NSP) has ex situ collection of sago germplasm 33 accessions. These sago accessions mostly introduce from Papua 24 accessions, East Kalimantan 2 accessions, and 7 accessions from Seram island, Maluku (Asmono, 2022).

High Yielding Sago Varieties

Until now, four national superior sago varieties have been released by the government through the Indonesian Ministry of Agriculture, with starch productivity of 250-650 kg/palm. The four high yielding sago varieties are (1) Molat Sago from Maluku, (2) Selatpanjang Meranti Sago from Meranti Islands Regency, Riau, (3) Bestari Sago from Indragiri Hilir Regency, Riau, and Tana Luwu Sago from North Luwu Regency, South Sulawesi.

1. Sago Molat Variety

Maluku Province is one of the main sago producing regions in Indonesia. The area of sago in Maluku is 58,185 ha with a production potential of 465,000 tons of dry starch/year. The use of sago starch as a staple food has been going on for a long time in Maluku in the form of foods such as papeda, sago plates, sinoli, karu-karu and uha as well as snacks such as mashed sago, bagea, sarut and cendol. Research for the release of superior sago varieties in Maluku Province aims to increase the willingness of businesses from the public and the private sector in order to be used to increase land area and sago starch production. In Maluku, five types of sago are known, namely *Metroxylon rumphii* Mart., M. sylvestre Mart., M. longispinum Mart., M. micrachantum Mart., and M. sago Rottb. These five types of sago are divided into two major groups, namely those with spiny including *Metroxylon rumphii* Mart., M. sylvestre Mart., M. longispinum Mart., and M. micrachantum Mart, and the second group is those without spiny including M. sago Rottb. Five types of local sago grow and develop in Maluku, namely Molat sago, Tuni sago, Ihur sago, Makanaru sago and Duri Rattan sago. But what many people are trying to get their sago starch from is Molat and Tuni sago. Sago Molat is a not spiny species and its presence in nature averages 22.6 trees/ha. The height of the Molat sago palm is around 13.9-22.3 m, the shape of a single tree and the production age is over 9 years. Bula District, West Seram island, Maluku Province is one of the centers for the growth of Molat sago. In 2011, a superior sago variety named Molat sago variety was released which has the potential to produce 640 kg of starch/tree, with a main carbohydrate content of around 86%. (Louhenapessy, et al., 2011).

2. Selatpanjang Meranti Sago Variety

Sago palms in Meranti Islands Regency, Riau Province have been around for a long time. The city of Selatpanjang was formerly known as the City of Sago, because this area used to produce large quantities of sago, even the largest in Indonesia. The origin of the sago palm in Meranti Islands Regency is not known clearly, but it has existed and been used since the Kingdom of Siak, even since the Dutch colonization.

Meranti Islands Regency, Riau Province is one of the main producing areas for sago starch to be exported to Cirebon as a raw material for vermicelli, in addition to being used for various foods and cakes, such as sago noodles and dried sago cakes. In 2012 there were 63 sago factories in this regency. Sago plants in the Meranti Islands Regency have been cultivated in semi-cultivation. It was reported that the area of semi-cultivated sago palms in the Riau Archipelago was around 20,000 ha (Balitbanghut, 2005), and the largest was in the Meranti Islands Regency. In this regency a sago plantation has also been built on tidal land, which is currently being managed by PT. National Sago Prima (PT. NSP) with an area of 22,000 ha, and has been planted with sago and production with an area of around 16,000 ha until 2022. In order to increase the productivity of sago palms and supply superior sago palm materials in the Meranti Islands Regency. From 2011 to 2013, the Selatpanjang Meranti sago variety was studied and evaluated as a superior sago variety.

The results of exploration of the types of sago that grow in Meranti Islands Regency show that there are three accessions of sago, namely Sago Duri, non-spiny sago (Bemban sago), and rare spiny sago (Sangka sago). Of the three types of sago, it turns out that the widest spread and the most processed by the community of sago craftsmen is the Duri sago type. The results of research on the type of sago Duri in three different locations for three years showed that the production of sago starch varied between 134.53 kg – 354.61 kg of dry sago starch/tree, with an average production of 226.34 (+ 56.03) kg /tree. From the three sago locations studied, it was found that the sago population in Darul Takzim Village, Tebing Tinggi Barat District, in general, had higher sago starch productivity than the sago population in Sungai Tohor Village and Tanjung Village. The results of the proximate analysis showed that Selatpanjang Meranti sago starch had a carbohydrate content of 88.19%, with a moisture content of 10.36%. Other content on average is below 0.5%, namely protein, fat, ash and crude fiber. At the end of 2013 it was successfully released as a superior sago variety with an average productivity of 226 kg of dry sago starch per tree, with the name of the variety being Selatpanjang Meranti sago (Novarianto, et al., 2014).

3. Bestari Sago Variety

Indragiri Hilir Regency is the second main sago starch producing area in Riau Province, after Meranti Islands Regency. In order to increase the production and productivity of sago palms and provide superior sago palm materials in Indragiri Hilir Regency, from 2015 to 2017 research has been carried out on types of non-spiny sago or what local people call it Bemban sago. The research objective of this sago palm is to release a local non-spiny sago variety that has been growing and spreading for a long time in Indragiri Hilir Regency, Riau Province. The research method is by direct observation and gathered data morphology and production of the Bemban sago palm at its distribution center. The research locations were conducted in three locations or villages, namely Iliran Village and Teluk Pantaian Village, for the Gaung Anak Serka (GAS) District, and Belaras Village for the Mandah District. Observation of sago begins from the determination of the sago sample population, then randomly selected 10 sample sago trees in the three villages. Observations were made on the morphological characters of stems, crowns and leaves, as well as production components to determine the potential for sago starch production. As supporting data, proximate data of sago starch and soil samples were also analyzed for analysis of soil fertility and nutrient content both macro and micro. As a source of suckers, the best population has been determined and selected Selected Sago Parent Clumps (SSPC) as a source of tillers for plant material. All SSPCs have been identified and marked with a plate iron label in the form of a long pole, and the location coordinates are recorded with a GPS device. The results showed that the type of non-spiny sago or Bemban sago has long been developed in the community and its main origin is not known, but the results of studies on the diversity of sago species through molecular markers that have been carried out show that sago on the island of Sumatra/Riau has genetic similarities with sago from Papua.

Observations on the morphology of sago stems and leaves show that starting from the character of the leaf crown which is V-shaped, the color of leaves, midribs and shoots is generally very uniform. Characteristics of sago stems such as rootstock diameter, number of leaf scars on sago stems, distance between fronds, number of green leaves, length of fronds, width of fronds, thickness of fronds, length of rachis, length of leaflets, width of leaflets and number of leaflets is fairly uniform. Where the value of the coefficient of diversity of all these vegetative characters is below the standard of 20%. The results of observations of the Bemban sago starch production component obtained an average height of 13.75 m, while the height of the leaf-free stem was known to be around 8.0 m and the circumference of the rootstock was 148.52 cm. The results of observations on the potential production of sago starch obtained an average wet starch production of 495.08 kg and 254.94 kg of dry starch (Novarianto, et al., 2020). The main character trait that distinguishes Bemban sago from the two previous sago varieties is the non-spiny fronds and red shoots of the tillers. Based on the results of the research above, the development of Bemban sago in Indragiri Hilir Regency has the potential to increase its productivity to 20 tons/ha/year. Based on the results of research for these three years (2015-2017) a sago variety with a high starch yield under the name Bestari sago has been released.

4. Tana Luwu Sago Variety

Research on the morphology and productivity of sago from North Luwu Regency, South Sulawesi Province has been carried out for 5 years (2017-2021). Sago palms in Tana Luwu, South Sulawesi Province have existed and been used by the community since the 18th century, as a main food ingredient, and were even exported to Singapore. The results of observations of sago palms in North Luwu Regency, South Sulawesi Province found non-spiny and spiny types of sago, but the most widely distributed and used by the community as a raw material for local food with the name Kapurung is non-spiny sago. The results of morphological observations and production of Tana Luwu sago starch obtained an average stem free leaf length of 14 m (±3.07), rootstock circumference 162 cm (±12.40), wet starch production 1,110 kg (± 397) per trees, and dry starch production of 598 kg (± 178) per tree. The selection criteria for Tana Luwu sago SSPC as a source of sago suckers were based on the character traits of leaf-free stem length above 12 m, and rootstock circumference above 150 cm. The potential for suckers production in the North Luwu Regency location, 94,000 tillers as a source of plant materials, can be utilized for the development of 500 ha of sago (Novarianto, et al., 2022). This type of non-spiny sago is released as a national superior sago variety, with the name of the Tana Luwu sago variety.

Model of Agroindustry Sagu in North Luwu Regency, South Sulawesi Province

The North Luwu Sago Agro-industry Model is a model that is implemented as an innovative sago agro-industry model that supports food security to increase added value and high competitiveness. This model is a sustainable agro-industry activity which is one of the successful activities of the Indonesian Agency Agricultural for Research and Development. The sago agro-industry model that is formed includes the availability of raw materials (cultivation and selection of sago mother groves), integration with fish and livestock cultivation, release of Tana Luwu sago varieties, data/map of sago potential area, availability of upstream to downstream processing machines, development of innovations for processed sago products, processing farmer/small-medium groups, forming marketing networks, strengthening institutions and skills of farmers and entrepreneurs. The need for raw materials has been produced by 5 farmer groups in North Luwu Regency, with marketing covering the provinces of South Sulawesi and Java Island. Meanwhile, the implementation of processed sago ready-to-serve products has developed in Makassar, Bogor and Jakarta as a form of forming a market chain up to the final consumer level.

Increasing production and productivity of sago starch upstream and utilizing sago starch into various sago products with high economic value downstream must work together and support each other to achieve a sustainable sago industry. The production potential of sago starch from sago forests in Papua is reported to be around 5 tons/ha/year. Meanwhile, in the Meranti Islands Regency, Riau Province, with a stretch of natural sago which is classified as semi-cultivated, it is reported to have a productivity of around 10 tons/ha/year (Novarianto, 2013). In South Sorong Regency, West Papua Province, from the results of observations it is known that the potential for sago starch production is around 10 tons/ha (Jong, 2011). On the island of Tebing Tinggi, Riau Province, the highest sago production with semi-intensive maintenance was obtained at around 13.7 tons/ha/year (Yamamoto, et.al., 2007). If intensive cultivation is carried out, it is estimated that the potential yield of sago starch can increase to 15 tons/ha/year. Even some research results with better cultivation techniques, it is estimated that the productivity of sago starch can be increased to 20 tons/ha/year (Jong, 2007). Even the results of other studies were reported to reach 25 tonnes / ha (Flach, 1983).

The Sago Agro-industry model in North Luwu Regency, South Sulawesi Province is carried out in an integrated manner starting to increase the production of sago starch raw materials through activities: Selection of sago cluster blocks, arrangement of sago palms, integrated sago cultivation, analysis of sago starch yield, fertilizing sago, nutrient content of sago leaves , study of sago land cover, biophysical study of land characteristics, soil classification, analysis of remote sensing imagery using satellite imagery, and improvement of sago cultivation. Activities in the downstream of sago have been carried out by innovating agricultural tools and machinery to accelerate the development of the sago agroindustry, e.g. Sago extracting machines, sago starch filings, sago starch drying houses, and various machines for making sago noodles, sago cakes, sago pellets, and so on. This local sago food agro-industry model has been carried out in several districts, Tana Luwu, South Sulawesi Province, such as: Implementation of innovative sago refineries, technological interventions, institutional strengthening, marketing of sago, outreach to sago farmers and the community, as well as technical guidance from upstream to downstream of sago (Balitbangtan, 2022).

Closing and Policy Advice

First, utilizing the diversity of Indonesian sago germplasm to provide a source of quality sago seedlings, increasing the release of superior sago varieties, and building sago plantlets gardens, as well as accelerating the assembling of mass propagation of sago through tissue culture technology,

Second, sago in Papua, it needs infrastructure that connect sago forests to the national economic area. To provide long-term local food, each village plant the high yielding sago varieties near their villages. Papua have been designated as the Integrated Sago Management Model, from upstream to downstream,

Third, development of sago in Maluku, North Maluku through the development of sago villages, which are close to residential areas and sago trees grow mixed with other commodities such as nutmeg, cloves, horticulture fruits and other foods. Sago plantation areas in Sulawesi, Kalimantan and Sumatra are conserved and developed for the sufficiency of the surrounding community, as an alternative local food,

Fourth, in particular, the sago area in Riau, Meranti Islands Regency, which already has community and private sago plantations, is used as a sago starch processing center, a downstream industrial center for better and higher quality sago products, for national marketing and export abroad,

Fifth, development of an innovative local food agro-industry model made from sago supports food security and increases added value. To assist sago processing/craftsmen/farmers in a sago area with various sago processing equipment to produce various kinds of sago products whose processing technology is available,

Sixth, collaboration of the roles of academics, researchers, the business world and community participation supported by the Central and Regional governments in developing sago in an integrated manner, and benefiting all parties from upstream to downstream.

References

Allorerung, D., J.H.W. Rembang dan Miftahorrachman. 1994 Rehabilitasi sagu. Kumpulan makalah Pra panen pada Simposium II Hasil Penelitian dan pengembangan Tanaman Industri. Cipayung-Bogor, 21-23 Nopember 1994. Puslitbangtri, Bogor.

Allorerung, D. dan J.H.W. Rembang. 1995 Pola rehabilitasi hamparan sagu. Buletin Balitka. No. 18. 1-9.

Asmono, Dwi. 2022 Transformasi industri sagu untuk mendukung ketahanan pangan nacional. Sharing Session BRIN 7#, Webinar Sagu, 23 Nopember 2022.

Badan Litbang Kehutanan. 2005 Potensi hutan sagu, kendala pemanfaatan dan prospek pengembangannya. Makalah Badan Litbang Kehutanan. Bogor.

Balitbangtan. 2022 Pengembangan Model Agroindustri Pangan Lokal Inovatif Mendukung Ketahanan Pangan dan Peningkatan Nilai Tambah. Balitbangtan. 288 pp.

Barahima, A., M.A. Bintoro, Sudarsono, M. Surahman, and Hiroshi Ehara. 2009 Genetic Relationship of Sago Palm (*Metroxylon sagu* Rottb.) in Indonesia Based on RAPD Markers. Biodiversitas. 10(4): 168-174.

Bintoro, M.H., H.Y.J. Purwanto dan S. Amarillis. 2010 Sagu di lahan gambut. IPB Press. 169 pp.

Bintoro, M.H., Pratama AJ., Ahmad F., Nurulhaq, MI. 2016 Penataan hutan sagu. Bogor (ID): Lembaga Penelitian dan Pengabdian kepada Masyarakat. 53 hal.

Flach, M.F. 1983 The sago palm: Domestication, exploitation and products F.A.O. palm production and protection paper. AGPC/MISC/PREPRINT. A development paper presented at the FAO sponsored expert consultation on the sago palm and its product. FAO. Rome.

Jong, F.S. 2007 The commercial potentials of sago palms and methods of commercials sago palm (Metroxylon sagu Rottb.) plantation establishment. P. 51-62 In: Prosiding Lokakarya Pengembangan Sagu di Indonesia. 25-26 Juli 2007, Batam.

Jong, F.S. 2011 Growth and yield parameters of natural sago forests for commercial operations. Abstract In Program Book: The 10th International Sago Symposium. Sago for Food Security, Bio-energy, and Industry from Research to Market. IPB International Convention Center. 29-30 October 2011, Bogor, Indonesia.

Lay. A, D. Allorerung, Amrizal, M.Djafar. 1998 Pengolahan Sagu Berkelanjutan, Hasil-hasil Penelitian Kelapa dan Palma Lain, Balitka, Bulletin, 29: 73-75.

Louhenapessy, J.E. A. Sarjana, M. Luhukay, H. Talahattu, F. Polnaya, H. Salampessy, R.B. Riry, A. Ngingi, S. Handal, Ilyas Nurdin, J. Latuputty, M. Hursepuny dan A. Patimukay. 2011 Usulan pelepasan varietas sagu Molat Maluku. Dinas Pertanian Provinsi Maluku dan BBP2TP Ambon Ditjen Perkebunan-Kementrian Pertanian. 52 hal.

Malia, I.E. dan H. Novarianto. 1994 Karakteristik sagu Tuni (metroxylon rumphii Mart) asal Maluku Tengah. Buletin Balitka. 23: 13-19.

Miftahorrachman dan H. Novarianto. 1996 Keragaman dan kemiripan jenis-jenis saguasal Seram Barat, maluku Tengah. Buletin Plasma Nutfah Vol. 1 No. 1 (16-28). Komisi Nasional Plasma Nutfah. Departemen Pertanian.

Novarianto, H. 2013 Potensi sagu Kepulauan Riau. Warta Penelitian dan Pengembangan Pertanian. 35(1): 1-3.

Novarianto, H., Ismail Maskromo, Meity A.Tulalo, Elsje T.Tenda, Jeanette Kumaunang, Donata S. Pandin dan Sukmawati Mawardi. 2020 Karakteristik dan potensiproduksi pati varietas sagu Bestari.Buletin Palma. 21(1): 29-37.

Novarianto, H., MA.Tulalo, J.Kumaunang dan C.Indrawanto. 2014 Varietas unggul sagu Selatpanjang Meranti. Buletin Palma. 15(1): 47-55.

Novarianto, H., MA. Tulalo, J. Kumaunang, E. Manaroinsong dan E. Sulistyowati. 2016 Seleksi dan pelepasan varietas Selatpanjang Meranti untuk pengembangan sagu. Jurnal Metroxylon Indonesia. 1(1): 1-9.

Novarianto, H., MA.Tulalo, J. Kumaunang, S. Karouw, Asthutiirundu, Y. Matana, E. Manaroinsong, A.Manambangtua, M. Nur, I. Maskromo, A. Rampisela. 2022 Usulan pelepasan varietas sagu Tana Luwu. IPCRI-IAARD-Hasanuddin University-North Luwu Regency-South Sulawesi Province. 67 pp.

Novarianto, H. Miftarrochman, I. Maskromo dan H.F. Mangindaan. 1996 Keragaman dan kemiripan tipe sagu asal Desa Kehiran, Kecamatan Sentani, Kabupaten Jayapura, Irian Jaya. Jurnal Litrri 1(5) 227-239.

Pangkali, L.B. 1994 Taksiran kandungan tepung jenis sagu Yepha (*Metroxylon sagu* Rottb) berdasarkan tempat tumbuh di Sentani, Kab. Jayapura. Skripsi Fakultas Pertanian Universitas Cendrawasih.

Tenda, E., H. Mangindaan, dan J. Kumaunang. 2003 Eksplorasi jenis-jenis sagu potensial di Sulawesi Tenggara. Prosiding Seminar Sagu untuk Ketahanan Pangan. Balai Penelitian Tanaman Kelapa dan Palma lain. Manado 6 Oktober 2003.

Tulalo, A. Meity. 2011 Konservasi dan karakterisasi142 aksesi plasma nutfah kelapa, sagu, aren dan pinang. Laporan Hasil Penelitian, Balit Palma Manado. 58 pp.

Widjono, A., A. Rouw dan Aamisnapia. 2000 Identifikasi, karakterisasi dan koleksi jenis-jenis sagu. Makalah Prosiding Seminar Hasil Penelitian. Pusat Penelitian dan Pengembangan Sosial Ekonomi Pertanian.

Yamamoto, Y., K. Omori, F.S. Jong, A. Miyazaki and T. Yoshida. 2007 Estimate of annual starch productivity in sago palm, a case study at Tebing Tinggi Island, Riau, Indonesia. Paper presented a 9th Int. Sago Symp., Leyte, Philippines. 19-21 July 2007.

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Quality of Sago Starch for Worldwide Promotion

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Abstract Sago starch is harvested from the pith of *Metroxylon sagu*. Its starch is a pure carbohydrate containing almost no protein or fat. And it is a staple food in producing countries, where it is eaten in a gelatinous state after being cooked. In Japan, sago starch is used primarily as a dusting powder for making noodles. It is also used as a raw material for modified starch for paper manufacturing.
The export of sago starch is subject to the CODEX standard, which does not specify the pasting properties of starch, so a variety of starch with different properties is likely produced and exported. Therefore, we purchased several starches sold in the Indonesian market and exported them to Japan, and evaluated their physicochemical properties.
Starch is composed of amylopectin and amylose. The physicochemical properties depend on the plant's origin. We hypothesized that the physical properties of sago starch would not differ significantly among the samples. However, the results demonstrated a wide range of physicochemical properties. The results suggest that these properties may arise during the post-harvest conditioning stage.
In this study, we present these results and hope to contribute to further developing applications for sago starch.

Key words: Export, Quality, Sago Starch

Introduction

Sago starch is harvested from the pith of *Metroxylon sagu*, which is grown wild in Malaysia, Indonesia, and Papua New Guinea, mainly. In Japan, sago starch is used primarily as a dusting powder for making noodles in the 1980s.
Prior to that, it had been considered as a raw material for High Fructose Syrup (HFS) in the 1980s. But it never replaced corn starch. Because different sago starch lots had different viscosities and could not be used as its materials. Prior to that, it had been considered as a raw material for High Fructose Syrup (HFS) in the 1980s. But it never replaced corn starch. Because different sago starch lots had different viscosities and could not be used as its materials.
This research shows the difference in the physicochemical properties of various sago starch from the local market of Indonesia, imported starch and oxidative it in Japan, and self-oxidative starch.

Materials and Methods (or Research Methods)

We collected the sago starch from Wewak, PNG as a not effective starch. It was purified by ourselves. And we collected 8 local market samples at Acango, North Sulawesi, Sentani, Sidorajo, South Sulawesi, Wira, and West Java in Indonesia. Imported sago starches were kindly provided by Joetsu Starch Co., Ltd. from Malaysia, Shikishima Starch from Malaysia, and T. AKIYAMA & Co. from Malaysia.

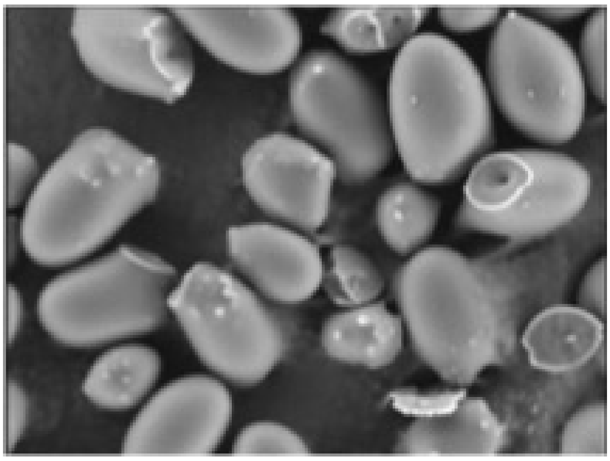
Four acetylated starches are kindly provided by Shikishima starch.

Oxidative starch was prepared by ourselves using the imported starch by AKIYAMA&Co.

SEM images were taken using TM1000 (Hitachi Hightech, Japan). Oxidative samples were treated using various sodium hypochlorite content. Viscosity property was measured using Rapid Visco Analyser (RVA-3D, Foss).

Results and Discussion

The shape of the starch surface, we can see the small holes on the surface of the starch granules (Fig.1). Kainuma *et al.* reported that the strain of black mold was isolated from a pith of sago palm (*M. sagu*) sampled at PNG. The mold was identified as *Chalara paradoxa*. And it produced a strong amylase activity to hydrolyze starch granules. When the sago starch was purified in the local factory or kept at the log style, the black mold may be digested the granules.



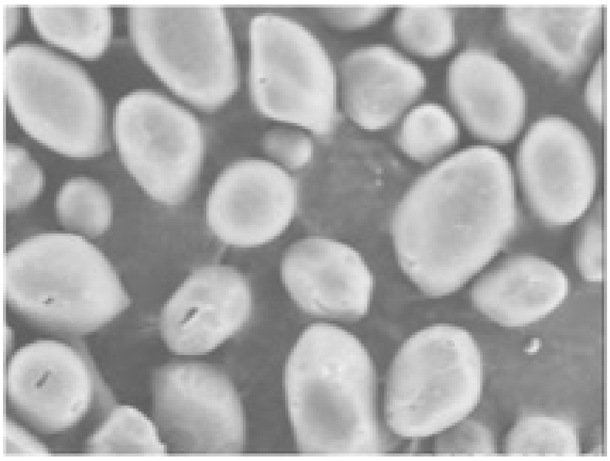


Fig. 1 SEM image of the Sago starch from Wewak, PNG (Up) and North Sulawesi, IDN (Down). Magnification is x1200.

This may be evidence of enzymatic degradation. The carboxy residue contents of each sample were low, and the crystallinities were not significantly low (Data not shown).

The viscosity of oxidative samples showed a lower tendency

(Fig. 2).

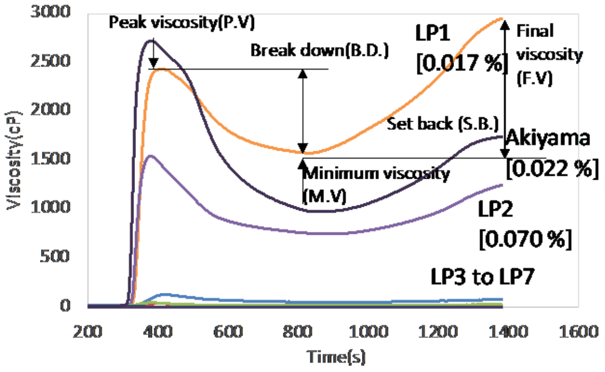


Fig. 2 The viscosity profiles of oxidative sago starches. The viscosity was measured by RVA-3D

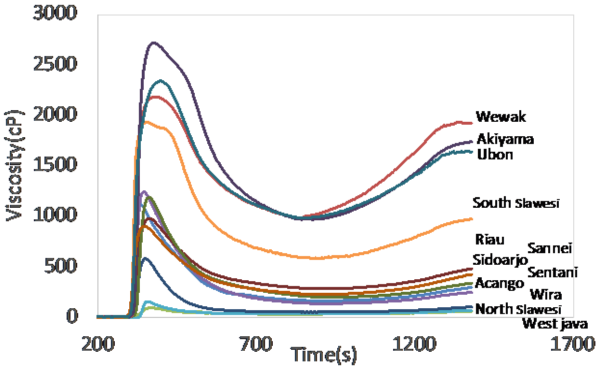


Fig. 3 The viscosity profiles of local sago starches from Indonesia market. The viscosity was measured by RVA-3D

The viscosities of local samples showed various patterns (Fig. 3). This figure shows that Wewak (prepared by ourselves), Akiyama (Imported from Malaysia), and Ubon (Imported from Malaysia) showed strong viscosity. On the other hand, local market samples showed lower viscosity. This tendency is similar at the Fig. 1. But when we measured the carboxy residues content, they showed low values (Data not shown). So, we concluded that this result was due to *Chalara paradoxa*. enzymes.

Sago starch has been used as an inexpensive starch resource because pure starch can be easily extracted. Considering more advanced use, we believe it is necessary to add the viscosity grade as one of the qualities as well as the CODEX standard. High viscosity starch is suitable as a food material, while low-viscosity starch is suitable as an HFS material or an industrial material.

Reference

Kainuma, K. , Ishigami H. and, Kobayashi, S. 1985 Isolation of a Novel Raw Starch-Digesting Amylase from a Strain of Black Mold *Chalara paradoxa*. Journal of the Japanese Society of Starch Science 32(2):136-141.

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Potential for Up-scaling Sago Production in Manus Province, Papua New Guinea

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Abstract

Manus Island in Papua New Guinea is a food insecure province with low-income level and low economic activities at provincial, district and household levels. Sago starch is a staple food that provide food security for the island province. Manus Island has a rich natural sago palm resource. A pre-feasibility study was conducted in three sample locations – Maraman, Laues and Wireh representing the main island of Manus between 17 – 24 September 2022. The Rapid Rural Appraisal (RRA) method was used to assess the utilization of sago palm for food security and for cash sale at the local markets in Lorengau town.

It is estimated that there is 2,000 ha of natural sago forest resource on Manus Island and are located along the coast. At a conservative dry starch yield of one ton/ha/yr, the existing sago resources has a potential to produce 2,000 ton of dry sago starch per year. Currently, utilization of the sago palm resource is confined to close proximity to villages and hamlets. It is estimated that only 10% of is utilized as staple with limited trading. Large areas are left untouched and underutilized. Traditional and inefficient processing techniques have greatly impaired sago starch productivity in Manus. There are 5-6 folk varieties identified by the locals, namely *pao, pamat, pomolou, nduri* and *amoi*. All are claimed to be high in starch yield. The average starch yield of 32% is lower than those of cultivated sago palms in Indonesia and Malaysia (av 40% wet starch). Nonetheless, higher yields are expected if these palms are grown under better light condition and growing environments. Most varieties are reasonably high starch yielding. To improve sago starch yield and income on Manus Island, a sago value chain is proposed through increased sago starch production and marketing.

Key words: Food, Manus, Sago, Value Chain, Yield

Introduction

Sago starch extracted from sago palm (*Metroxlyon sagu*) pith is one of the main staple foods for 30% of Papua New Guinea's estimated 9 million people. Sago provides food security, cash income and meets other cultural obligations for lowland, atolls, and wetland communities. It provides sufficient calorie for food security and sustains life in coastal rural communities during natural disasters such as droughts, floods, and cyclones.

Main sago producing provinces in Papua New Guinea (PNG) are East Sepik, West Sepik, Gulf, Western and Manus provinces. Manus especially, an island off the New Guinea mainland, is a food insecure province (National Statistical Office and ICF 2019) due mainly to poor soil fertility (Burke and Harwood 2009). Sago thrives in waterlogged wet areas and can tolerate low pH. It is abundantly available in natural forests as well as cultivated and consumed as the main staple food on Manus Island. Manus Islanders depend on sago for their livelihood, for food security and source of income.

However, sago making in PNG is using rudimentary tools and practices that are passed on down generations for centuries. Yield of sago starch using traditional methods are low despite the time and labour committed in making sago.

The objectives of this study were to assess the feasibility of developing a community-based commercial sago value chain for Manus Island.

Materials and Methods

A pre-feasibility study was conducted in three sample locations representing the main island of Manus between 17 – 24 September 2022. According to information from Manus Provincial Agriculture Office active locations for sago production are mostly along lower reaches of larger rivers near to the coasts. These areas are Maraman, Lowa, Wireh, Liap, Laues, Gunralis, Patu, Powai, Bundahi, Nyada, Buliso and Lessau. Three areas representing the main Manus Island were selected for this study. They were Maraman to the north, Laues to the South and Wireh to the West of Lorengau town, the administration capital of Manus province. Maraman and Laues were accessed by sea transport while Wireh was accessed by road transport on the Somare Highway. The Rapid Rural Appraisal (RRA) method was used to assess the utilization of sago palm for food security and for cash sale at the local markets in Lorengau town and the potential for community-based commercial utilization of sago palm. Google Imagery was used to estimate the area of natural and cultivated sago palms, potential yield and volume of sago starch.

Average height and diameter of the sago palm were measured using a tape measure from palms previously felled and the pith proceed. Pounded pith residues were collected from the three sample sites rewashed to measure residual starch recovery. Wet sago cake from the locals making sago at the time of the visit were sampled to observe sago starch sieving quality by traditional methods.

Pounded pith samples were collected from a few sites at Maraman and Laues. These were milled using a food grade blender and starch extracted by filtering through a 100 – 150 micro mesh nylon sieve.

Discarded pith residue samples were collected from processing sites, milled using a food grade blender and rewashed through a 100 – 150 micron mesh sieve to determine the amount of starch discarded.

To demonstrate the inconsistent and rather poor quality of the locally produced sago starch, samples were collected from the market and at processing sites for rewashing and filtering using 100 – 150 micro mesh nylon sieve for the examination of impurities.

A market survey was conducted at Lorengau town market to determine the volume and quality of sago starch sold for cash.

Results

Sago Palm Resources on Manus Island

Manus Island has a rich sago palm resource. Most of the sago palms are natural stands distributed along the coastal areas in scattered patches near to the lower reaches and banks of larger rivers. Sago cultivations were observed in small numbers close to villages and along creeks mainly in the centre of the island along the highway from east to west. Those that are cultivated at creeks are locally regarded as good varieties selected and brought in from other locations. Cultivation in other areas cannot be easily distinguished. Based on Google imagery there are approximately 1,000 ha of sago palm stands (natural and cultivated) on Manus Island.

Natural environment characteristics of soils, water and climate, and farming practices of sago cultivation, harvesting and processing at the sample locations studied are:

(i) Maraman

The soils at Maraman River are generally characterized as low-lying containing deposits of organic matter originating from mineralization upstream that are ideal for sago palm growth. The color of river water is brownish, caused mainly by the decomposition of organic matters like fallen leaves, trunks and other decaying vegetation. In the area where we visited, the water is brackish even at low tides.

Sago palm growth close to the riverbanks are generally poor, with yellowish or pale green leaves, most likely caused by the saline water during high tides that impedes growth. Further away from the riverbanks, the growth of palms is healthy.

There are 5 folk varieties identified by the locals, namely *pao, pamat, pomolou, nduri, amoi*. All are claimed to be high in starch production. One owner estimated that a felled palm (average diameter of about 45 cm, trunk length 8.6 m) will yield about 200-250 kg wet starch.

(ii) Laues

At Laues, sago palms are mostly found at the lower stretches of the Laues River and surrounding low lying lands. Higher densities of sago palm are located further away from riverbanks. The soils along the low-lying river resemble those of riverine alluvial. As the upstream, the elevation increases, and the soils on the riverbank are rather sandy/rocky with fewer stands of sago palms, but their growth is good.

The water is saline and brownish at the lower reaches but becomes increasing clear and fresh upriver.

(iii) Wireh

According to local knowledge, larger volume of sago starch is actively produced at Wireh and has the largest area of natural sago palms. This was evidently witnessed from a hilltop overlooking the vast areas covered by sago palm in this study.

The observation spot (2º 08' 25" S, 147º 03' 33" E) is about 40 km by road from Lorengau. A large area was observed to be covered with sago palm at the low-lying area (5 km from observation spot). Soils are similar to that observed at other two sites. However, further confirmation would require drone imagery.

At the top of the mountain ridges, with an elevation of 200-350 masl, the soil type is vastly red, yellow podzolic. Healthy sago palms are common in small patches especially located at creeks around hamlets and settlements. These are likely brought in from other areas and cultivated around the settlement areas for easy access.

Sago starch Production and Processing

Sago production on Manus Island is mainly subsistence using traditional methods and tools acquired and practiced from generations to generations. Sago processing for sale at Lorengau town market is limited to traditional methods of harvesting and processing.

Palm felling and trunk sectioning are carried out by axes. For a palm with trunk diameter of about 40 cm, around 5-10 minutes is required to fell the palm. As the numbers of palms to be processed is limited at individual household levels, the use of expensive chainsaws is beyond their reach and is not essential at this time.

Pith maceration is carried out manually using a traditional bow shaped tool called *kuai* or *kuel* in local Manus language. It performs two key functions namely chipping the pith from the trunk and pound the chipped pith tissues into smaller particle size to release the starch. The *kuai* has a blunt end that does both chipping and pounding in one motion. This task is carried out by hand. It is physically demanding and is normally carried out by man. One man can chip and pound 1.5-2m of palm pith of an average size sago palm trunk (average 40 cm diameter) per day, though it was claimed by a sago landowner at Laues, that it is possible to pound 5m of trunk if working full day.

Though effective in chipping and pounding in a single action, the blunt end of the *kuai* is not very efficient in chipping or ripping off the pith tissues from the trunk, especially at the lower trunk that contains long and tough fibrous tissues (vascular bundles). The pounded pith is coarse and much starch granules are left unreleased in the coarse pith particles. This inefficient rudimentary tool will continue to be used for sago making in Manus until a better more efficient pith milling techniques are introduced and adopted. As such, it is helpful if a more efficient *kuai* can be innovated in the near future.

Starch extraction from the pounded pith is done manually using sago frond sheath as a washing trough. This is normally done by a woman though it is also physical demanding task. The process of manual extraction of sago starch by traditional method involves few steps.

1. Fixing the sago frond sheath as a washing trough
2. A piece of nylon shade cloth is tied at the wide-open end to serve as a sieve to allow passage of starch while retaining the passage of fibers.
3. A starch collection tub commonly made from an open dugout canoe is used to collect and settle the extracted starch.
4. The pounded pith is then transferred to the washing trough. Water is added and the pounded pith is

churned by back-and-forth motion as well as pressing to wash out the starch particles. After a few rounds of water adding and washing, the washed pith residue is discarded.

5. Starch slurry that flows through the sieve is collected and settled in the canoe. Settled sago starch cake is dug out and packed into various weights.

The filter used for starch filtering is from locally available material such as mosquito nets, hessian bags, nylon shade cloth and coarse fabric. These materials have large pore sizes allowing pith particles and debris to pass through the sieve and contaminating the starch.

To demonstrate the inconsistent and rather poor quality of the locally produced sago starch, samples were collected from the market and at processing sites for washing and filtering. The impurities/residues retained by a 100 mesh (150 micron sieve) included pith tissues, bark fragments and other organic matters (Figure 1).

Fig. 1 Impurities washed out and collected on a 100-mesh sieve from starch sold at Lorengau market.

From the pith residues reprocessed, 31.9 % starch (wet starch, about 50% moisture) was recovered (Table 1). This is the amount of starch recovered using a food blender for milling to reflect its maximum yield by mechanical extraction (chemical digestion will give even higher yield). In traditional processing, the starch yield is substantially lower.

The average starch yield of 32% is lower than those of cultivated sago palms in Indonesia and Malaysia (av 40% wet starch). Nonetheless, higher yields are expected if these palms are grown under better light condition, such as removal of overhead shades, and modern processing methods are used.

Table 1. Starch recovered from discarded pounded pith residues are washing using traditional methods in Manus

Supplier of pounded pith	Pith weight (gram)	Raw starch weight (gram)	% Starch	Average
Ida	1500	500	33.3%	
John	4000	1500	37.5%	
Tommy Lucas	2800	750	26.8%	
Susan	2000	597	29.9%	31.9%

Sago Starch Consumption and Marketing

Sago palms are mainly used for subsistence as sago starch is the staple food (apart from imported rice) for most of the inhabitants on Manus Island. It was observed that most of the starch produced are consumed as staple especially in rural areas. Surplus sago starch is sold mostly at Lorengau town market as wet starch, in various packing from 1 kg to about 10 kg (Figures 2).

Fig. 2 Sago Starch packed with different packaging materials in various weights sold at Lorengau Town market, Manus Island.

The 1 kg packs are priced at K2 whilst larger packings wrapped in sago leaves or in nylon lags (4-10 kg/pack) are commonly sold for between K6 to K15/pack. On average wet sago starch is sold at Lorengau town market at K2.25 per kg.

About 200-300 kg/day of sago (in wet form) is sold at Lorengau town market. This is not reflective of the actual sago market as some might have been sold and some may not be sold on a particular day. All sago starch produced are consumed locally or transported to other provinces for self-consumption and not for sale.

The prices fluctuate according to daily supply. On the 24 September 2022 when we visited the market, there were more sago on sale and the price per pack (in sago leaves) was about K10 (usually K15 for similar packing).

Sun-dried sago starch is occasionally sold at the market too. Sago starch (dried and wet) is widely barter traded with inhabitants in the nearby islands for fish and other marine products.

Discussions

Manus Province is a food insecured island province due mainly to poor soil fertility. This was observed from the variety, quality and price of fresh food sold in local markets. Type, yield, quality and variety of food grown are direct result of soil type and fertility. While on the other hand sago thrives in waterlogged wet areas and can tolerate low pH. Most of the sago palms on Manus Island are natural stands distributed in patches scattered along the coastal areas, especially near to the lower reaches of larger rivers.

Sago cultivation was observed to be practiced further inland from the coast in small clusters close to settlement areas and along gullies and creeks. These cultivated varieties are locally regarded as good varieties selected and brought in from other locations. Cultivation in other areas cannot be easily distinguished. Along Pachu River, a tributary of Maraman River about 15 km North of Lorengau town, the capital of Manus province, some sago palms are well tended with good spacing (thinning out undesirable palms and bushes cleared).

These palms could have been cultivated earlier though no new cultivation was seen.

There is no inventory available on total area of natural sago palm forest on Manus Island. Nor there is any data available on cultivated sago palm. Using Google Landsat Imagery, it is estimated that there are 1,000 ha of sago palm on the main Manus Island. A detailed study employing high resolution satellite or drone images is needed to quantify the total area occupied by sago palms, both natural and cultivated.

Manus Islanders depend on sago for their livelihood, for food security and source of income. It was encouraging to see villagers cleaning and maintaining their existing sago palm clusters. Most of the palm varieties have reasonably high starch content and their off shoots can be used for propagation. Low starch yield in some sago palm varieties could be due to factors other than genotype, i.e. overshadowing by trees, salinity (for palms growing in areas inundated by high tide) and competition from neighbouring sago clusters.

The traditional tools and methods used for chipping and pounding (milling) sago palm pith and starch washing to separate starch from the pith fiber by repeated churning, washing and squeezing is tedious and inefficient. These repeated actions are aimed at releasing the starch granules from the pounded fibrous pith tissues to ensure the starch to pass freely through the sieves. Because starch granules are trapped in the fibrous pith tissues, plenty of water is required to wash off the starch and thus the washing, churning and squeezing has to be repeated a few times.

This process of starch and fiber separation can be done much faster and effortlessly in submerged condition. When the pounded pith is placed in water, the fiber is readily dispersed to release the trapped starch granules, allowing the starch granules to flow downwards through the sieves by gravity. Tedious churning, washing and squeezing actions can be simplified by light stirring of the milled pith particles in water above the sieves.

Starch settling and recovery using a dug-out canoe or large nylon bags are common and acceptable in the absence of better choices. The locals also placed a piece of plastic or woven nylon sheet at the base of the settling trough for ease of lifting out the settled starch.

On average 32 % of extractable wet sago starch was recovered from discarded pith residues indicating that pith chipping and pounding (traditional milling) for starch extraction using traditional tools and processing method is not efficient. For example, an average yield of sago palm pith is 600kg and 150kg of starch is recovered by traditional methods, the residual pith discarded is 450kg, the amount of starch discarded with the residue is 144kg (32%) or 49 % of the total starch. This indicate that traditional tools and methods used by locals on Manus Island is 50 % inefficient. Improved processing techniques are required for efficient sago starch extraction on Manus Island and maybe the same applies for rest of sago producing and consuming communities in PNG.

Market for sago starch on Manus Island is limited to consumers in Lorengau town. This study found that only small quantity (200 – 300kg) of sago starch (in wet form) is sold for cash per day. At average price of K2.25 per kg, the value of sago starch traded on Manus is Between K450.00 (USD128.00) to K673.00 (USD192.00) per day.

Market for sago starch on Manus Island and also for rest of PNG is still underdeveloped. Whilst demand by domestic and international consumers is increasing. Better understanding of the sago value chain is needed to develop the sago starch industry in PNG.

Sago is gluten-free, making it a suitable replacement for grain-based flour for people with celiac disease or those who are gluten intolerant requiring grain-free diets.

International consumers of sago starch are increasing. For instance, Japan has an increased demand for starch, which may open up markets for sago from PNG. However, the taste tendency of Japanese consumers is diversified to demand foods that are not only cheap, but safe, healthy, natural and low impact to environment in producing these foods.

Conclusion

Manus Island has abundant sago palm resource. The islanders have utilized these resources as staples for centuries employing traditional processing techniques. More efficient techniques are needed to increase their sago production and additional income from starch sale.

With improved processing techniques, sago has the potential to become an important economic crop for Manus, both for domestic consumption and export market by establishing a value chain that will have direct link between consumer and producers.

To produce better and more consistent starch quality, a good sieve (100-150 micron) is essential to the local community. A piece of nylon filtration screen (1 m x 1 m) will help the locals a long way.

With the current status of sago value chain, a more practical approach is needed to commercial sago starch production in Manus province. A community-based pilot sago starch value chain with a nucleus entrepreneur with marketing as a catalyst is recommended.

References

Bourke, R.M. and Harwood, T. (eds) 2009 Food and Agriculture in Papua New Guinea. ANU E Press, The Australian National University, Canberra.

National Statistical Office (NSO) [Papua New Guinea] and ICF. 2019 Papua New Guinea Demographic and Health Survey 2016-18. Port Moresby, Papua New Guinea, and Rockville, Maryland, USA: NSO and ICF.

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Comparison of Growth Characteristics and Yield Potential of Starch-accumulating Palms

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Abstract The growth characteristics and starch productivity of four starch-accumulating palm species in three genera, sugar palm (*Arenga pinnata* : Ap) , 'Sagu Baruk' (*A. microcarpa* : Am), clustered fishtail palm (*Caryota mitis* : Cm) and gebang palm (*Corypha utan* : Cu), growing in Indonesia, were compared at harvest stage with those of the sago palm (*Meteroxylon sagu*: Ms), including the oil palm (*Elaeis guineensis*: Eg) at the time of replantation. The plant length was around 20 m with the exception of Cm, and Ap, Am, and Cu showed a trend toward longer trunk length than Ms, but the trunk diameter was thinner in Ap and Am than in Ms, and thicker in Cu. These results indicated that trunk weight (volume) was Cu>> Ap≒ Ms> Eg> Am> Cm as well as the pith dry weight closely related to the starch content. Average starch percentage in pith (dry weight basis), another determinant of the starch content, was higher in the order of Ms (67)> Cu (58)≒ Am (54)> Cm (34)≒ Ap (30)> Eg (12%). The starch content of the surveyed individuals showed a range of 2 (Cm)-1394 kg (Cu), with significant differences. The average starch contents were Cu (963)>> Ms (356)>> Ap (140)> Am (71)> Eg (44)> Cm (3 kg), with 5 of the 10 surveyed individuals in Cu exceeding 1 ton, higher than the highest recorded for Ms (975 kg). These results indicate the importance of investigating and researching starch-accumulating palms besides sago palms.

Key words: Growth characteristics, Indonesia, Starch accumulating palm, Starch yield potential

Introduction

Palms in genera 8-14 (Ruddle et al., 1978; Ruddle, 1979; Nishikawa et al., 1979; Ehara, 2015) are known to accumulate starch in their trunks, however, with the exception of the sago palm (*Meteroxylon sagu*), researches on their growth characteristics and starch productivities are remarkably scarce. Against this background, we have studied on the starch-accumulating palms belonging to three genera and four species other than sago palm that grow in Indonesia [sugar palm: *Arenga pinnata* (Ap); 'Sagu Baruk': *A. microcarpa* (Am); clustered fishtail palm: *Caryota mitis* (Cm); gebang palm: *Corypha utan* (Cu)] (Yamamoto et al., 2021a; 2021b; 2021c; 2022). In this report, these starch-accumulating palms and oil palm [*Elaeis guineensis* (Eg)] at the time of replanting, are compared with sago palm (Ms) (Yamamoto et al., 2003a; 2003b; 2008; 2010; 2016; 2020a; 2020b; 2020c) for growth characteristics and starch productivity at the harvest stage. Eg is not recognized as a starch-accumulating palm species, but with the development of vast oil palm plantations in Indonesia and Malaysia, a large amount of waste wood is generated at the time of replanting (approximately 25 years after planting) and it has been reported that the waste wood contains a considerable amount of starch (Tomimura, 1992; Haska, 2001). Therefore, it was included in this report as a surveyed palm because it seems possible to harvest a large amount of starch per planted area.

Materials and Methods

Starch-accumulating palms of the above three genera and four species and Ms determined by local farmers to be suitable for harvesting, and oil palms at the time of replanting, were surveyed. The years, sites, and number of palms surveyed are shown in Table 1. Of the palms surveyed, Am and Cm are clustered palm species as well as Ms, while the other palms are solitary; propagation by sucker is common for the clustered palms, while the other palms are seed reproductive. Oil palms are pleonanthic, while other palms are hapaxanthic. Inflorescences are andromonoecium in Ms, monoecium in Ap, Am, and Eg, and hermaphrodite in Cm and Cu (Table 2). The surveyed sago palms include about 20 folk varieties. Table 3 shows the estimated number of years after seeding or suckering to harvesting as estimated by farmers in the research sites.

For these palms, after cutting with a chain saw, plant length and trunk length were measured from the trunk base to the tip of the uppermost leaf (all palms) and the lowest surviving leaf node (Ms, Cu, Eg) or uppermost surviving leaf node (Ap, Am), respectively. In Cm, trunk length was measured from the base of the trunk to the lowest inflorescence node. The trunk was cut into 2-8 equal parts in length according to the trunk length of the palm, and the diameters of each of the cut surfaces were measured. Disks approximately 2-3 cm thick were cut from the positions where the diameter was measured. Each disk was separated into bark and pith sections and weighed to calculate the pith weight ratio. For Am and Cm, trunk weights were measured directly by cutting the trunk into several pieces. For the other palms, logs 30-50 cm in length were cut from each point of trunk divided into 2-8 sections and the weights, lengths, and diameters of the logs were measured, and their densities (kg m^{-3}) were calculated. The trunk volume was then calculated from the length and average diameter of the trunk (averaged for all logs), and the trunk weight was calculated by multiplying this by the average density of each log. The pith of each disk was radially cut out and approximately 50-80g (0.1g unit) was sampled with a portable electric balance (HL-200, Kagaku Kyoeisha Co.). The collected pith samples were dried in a temporary dryer (75-80°C) for two days and in a ventilation dryer (65°C) for two days or more, and the dry weights were measured to calculate the dry matter percentages. The dried pith samples were crushed and ground to a fine powder of less than 100 mesh, and total sugar and starch were extracted by the method of Murayama et al. (1955) and measured by the Somogyi method (Somogyi, 1945) or the Anthrone method (Tamura, 1975). Starch content was calculated by multiplying the trunk weight by the pith weight ratio, the pith dry matter percentage, and the starch percentage (dry weight basis) in the pith.

Results

Plant lengths averaged around 20 m with no significant differences except for Cm (Table 3), with Cm being lower at around 10 m. Trunk lengths averaged around 15 m for Ap, Am, and Cu, tending to be longer than Ms (average 9.5 m), but trunk diameters tended to be thinner for Ap and Am than for Ms (average 48 cm), and thicker for Cu. As a result, trunk weights (volume) were Cu>> Ap≒ Ms> Eg> Am> Cm, with a more than 100-fold difference in average values. The differences in pith dry weights among the palms studied showed the same trend with those of the trunk weights. The ratio of pith weight to trunk weight was low in Cm and Am with the smaller-diameter, averaging 70 and 74%, respectively, and slightly lower in Cu, averaging 76%, due to the development of fibrous tissue in the lower trunk, but around 80% in the other palms.

Average starch percentage (per dry weight) in the pith was higher in the order of Ms (67)> Cu (58)≒ Am (54)> Cm (34) ≒ Ap (30)> Eg (12%), but the percentages of Cu and Am in the surveyed individuals were within the range of the Ms surveyed individuals. The variation in percentage was greater in Ap (8-50%). The starch content of the surveyed individuals ranged from 2 (Cm)- 1394 kg (Cu), showing significant inter-species and generic variation. The average starch content was higher in the order of Cu (963)>> Ms (356)>> Ap (140)> Am (71)> Eg (44)> Cm (3 kg), with 5 of the 10 surveyed individuals in Cu exceeding 1 ton, higher than the highest

Table 1. Surveyed years and sites of the starch-accumulating palms, oil palm and sago palm.

Palm name		Surveyed			
English	Scientific	year	site	country	No. of palms
Sago palm	*Metroxylon sagu*	1991	Batu Pahat	Malaysia	4
		1996-98	Mukah and Dalat	Malaysia	13
		1997/2008	Tebing Tinggi	Indonesia	16
		1998/1999/2006	Kendari	Indonesia	21
		1998/2007/2008	Ambon/Seram	Indonesia	24
		2007	Pontianak	Indonesia	7
		2003-2007	Jayapura	Indonesia	48
Sugar palm	*Arenga pinnata*	2008/2010	Muna	Indonesia	11
		2013	Tana Toraja	Indonesia	4
		2014	Tomohon	Indonesia	5
'Sagu Baruk'*	*Arenga microcarpa*	2008/2014	Sangihe	Indonesia	6
Clustered fishtail palm	*Caryota mitis*	2007	Pontianak/Sambas	Indonesia	5
Gebang palm	*Corypha utan*	2009/2015	Kupang	Indonesia	7
		2015	Muna	Indonesia	3
Oil palm	*Elaeis guineensis*	2009	Lebak	Indonesia	3

*Indonesian name.

Table 2. Botanical characteristics of the surveyed starch accumulating palms, oil palm and sago palm.

English name	Scientific name	Propagation	Growth habit	Inflorescence2)	Floweing habit
Sago palm	*Metroxylon sagu*	sucker	clustered	andromonoecism	hapaxanthic
Sugar palm	*Arenga pinnata*	seed	solitary	monoecism (M, F)	hapaxanthic
'Sagu Baruk'1)	*Arenga microcarpa*	sucker	clustered	monoecism (M, F)	hapaxanthic
Clustered fishtail palm	*Caryota mitis*	sucker/ seed	clustered	hermaphrodite	hapaxanthic
Gebang palm	*Corypha utan*	seed	solitary	hermaphrodite	hapaxanthic
Oil palm	*Elaeis guineensis*	seed	solitary	monoecism (M, F)	pleonanthic

1) Indonesian name. 2) M and F in monoecism indicate male and female inflorescence are formed separately.

Table 3. Comparisons of grwoth characteristics and starch content of starch accumulating palms and oil palm with sago palm..

Palm	Estimated plant	Plant	Trunk			Pith			Starch	Starch
	age (year)2)	lgth (m)	lgth. (m)	Diam. (cm)	Wt. (kg)	Wt. ratio (%)	DM (%)	Dry wt. (kg)	percentage3) (%)	content4) (kg)
Sago	10-29	13-28	4-16	31-68	418-3499	87-73*	27-52	162-1397	44-79	99-975
(Metroxylon sagu)	17.1±5.4	19.2±3.3	9.5±2.6	47.8±6.6	1507.4±671.2	81.3±3.5*	43.2±5.7	527.6±259.2	66.9±6.8	356.0±183.1
Sugar	9-25	15-27	10-21	26-40	682-3101	70-86	23-48	181-1017	8-50	26-288
(Arenga pinnata)	16.7±5.4	21.5±3.0	14.8±3.0	32.5±3.8	1545.9±592.5	78.9±4.9	35.8±7.6	449.0±227.0	30.3±11.5	139.8±84.5
'Sagu Baruk'1)	11-15	16-22	13-21	14-15	257-495	70-76	47-50	94-174	49-61	51-93
(Arenga microcarpa)	12.9±2.0	18.6±2.2	15.7±3.3	14.7±0.4	369.1±98.3	73.9±2.1	48.8±1.3	132.3±32.6	53.6±4.4	70.9±18.0
Clustered fishtail	-	8-12	3-7	10-13	20-53	68-72	29-38	5-14	26-43	2-5
(Caryota mitis)		11.0±1.7	4.3±1.6	10.7±1.5	36.6±11.6	70.4±1.9	33.6±4.1	8.7±3.4	33.8±6.6	3.0±1.5
Gebang	25-32	19-26	13-20	50-59	3233-5130	70-81	50-64	1291-2202	45-64	592-1394
(Corypha utan)	28.5±2.4	22.4±2.2	16.0±2.2	54.9±3.0	4039.9±528.3	75.6±3.9	55.1±4.2	1628.2±267.2	58.4±7.4	962.8±246.8
Oil	28	17-19	9-11	40-45	1128-1539	82-85	30-38	318-390	8-16	30-61
(Elaeis guineensis)	28.0±0.0	17.9±0.9	9.7±1.0	43.0±2.9	1293.0±217.3	83.8±1.4	33.9±4.3	364.4±40.7	12.2±4.1	44.2±15.9

Note) Upper: Range; Lower: Average ± standard deviation. 1) Indonesian name. 2) Estimated by the local farmers. 3) Pith dry weight basis. 4) Dry starch. * Values measured 14 plants.

recorded for Ms (975 kg). Comparisons among individuals with the highest content showed Cu (1394)>> Ms (975)>> Ap (288)>> Am (93)> Eg (61)> Cm (5 kg).

Discussion

The starch productivity of most of the starch-accumulating palms surveyed was inferior to that of sago palms, but the starch content of Cu was superior to that of sago palms, with 5 out of 10 individuals surveyed showing starch productivity of more than one ton (Yamamoto et al., 2021b). The reason for this was thought to be that Cu had superior trunk length and diameter and significantly higher trunk weight (pith weight) than Ms, although pith starch percentage was slightly lower than that of Ms. The highest starch content in sago palm was 975 kg by Yamamoto et al. (2020a), and the average value of Cu (963 kg) was comparable to this, with a maximum value of 1394 kg, 1.4 times higher than the highest value for Ms. The average annual starch productivity of Cu was 33.8 kg, compared to 20.8 kg for Ms, taking into account the difference in the number of years until harvest (Table 3), and again Cu was superior to Ms. The lower part of the Cu trunk was not harvested in the research site because the starch content of Cu decreases with age due to the development of hard pith fibers from the lower to the middle of the trunk, which further reduces the efficiency of extraction. Ecologically, Cu is more adapted to grow in arid regions than Ms (Goren et a., 1996; Nasution and Ong, 2003; Witono et al., 2018), and is expected to be used as a starch resource crop in relatively dry tropical regions where Ms is difficult to grow in the future.

On the other hand, starch productivity of all starch-accumulating palms other than Cu and Eg was significantly lower than that of Ms. The factors were based on both trunk (pith) weight and pith starch percentage (Cm), mainly due to the former (Am), and mainly due to the latter (Ap; Eg). Cm had a remarkably light trunk weight (36.6 kg) and low starch percentage (34%), but the starch percentage was lower in the lower part of the trunk and higher (60%) in the upper part near the nodes where inflorescences appeared. The diameter of the trunk was 10-13 cm, which was thin enough to allow a series of starch extraction operations to be carried out by women and children alone. In this study, starch productivity of Cm was measured from the base of the trunk to the lowest inflorescence node. Since 5-10 inflorescences appeared in the studied individuals and the starch percentage of inflorescence attachment sites was high, it was estimated that starch productivity would be much higher than the results of this study if the trunk (estimated at 2-3 m) at the site of these inflorescences was included.

Am, which had the second lightest trunk and pith weights after Cm, had a longer trunk length than Ms and a relatively high starch percentage of about 80% of Ms, with an average starch content of 70 kg per individual (Yamamoto et al., 2022). In addition, the thin trunk diameter (around 15 cm) facilitates a series of starch extraction operations from harvesting, and the high trunk length and thinness are estimated to allow dense planting, which is expected to result in starch productivity per area equal to or higher than Ms by adjusting planting density. In addition, the starch quality of this palm is superior to that of Ms in terms of whiteness, probably due to its low polyphenol content.

Ap is mainly grown in Indonesia for sap collection, but some starch is collected from Ap trunks and used to produce noodles. The pith weight ratio was inferior to that of Ms due to the development of tough fibrous tissue in the lower part of the trunk and the lower percentage of pith dry matter (Yamamoto et al., 2021a; 2021c). Although the maximum starch accumulation period is considered to be around the emergence of the first inflorescence (♀ inflorescence), in this report, the individuals with different growth and sap collection periods and sap collection intensity from just before the emergence of the first inflorescence to the end of collection were investigated, assuming that starch is collected even from individuals with various growing histories, and thus the variation in pith starch percentage (8-50%) was large. The average starch percentage was less than half that of Ms, and the maximum was 50%. The maximum starch percentage was found in individuals in dying-stage that had not undergone sap collection. The maximum starch content was 288 kg, which was higher than the average value (229 kg) for early maturing sago palm folk variety (less than 12 years old before harvest).

Eg was inferior to Ms in trunk weight and pith dry matter percentage, with pith dry weight about 70% of Ms. The pith starch percentage averaged 12%, significantly lower than Ms, and was also about 20% or more lower than other starch-accumulating palms. Starch content was second lowest to Cm at 30-60 kg. These values were consistent with the results reported by Tomimura (1992) and Haska (2001).The starch percentage on trunk location showed that it was low from the base to middle part of the trunk and relatively high above the middle part at around 20%. Therefore, it was estimated that efficient starch production from Eg waste wood should be targeted from the middle to top part of the trunk. According to FAOSTAT (2021), the harvested area of Eg in Indonesia is about 15 million hectares, and since the planting density per hectare is 125-143, the number of waste plants at the time of replanting about 25 years after planting would be enormous. Therefore, the starch productivity per area from Eg planting is estimated to be significantly higher.

For all starch-accumulating palms, starch content was more closely related to pith dry weight than to pith starch percentage, suggesting that starch content was more influenced by pith dry weight (trunk weight) in all palms. On the other hand, in Eg, starch content tended to be higher in individuals with higher pith starch percentage

Conclusions

The growth characteristics and starch productivity were investigated for three genera and four species of starch-accumulating palms other than sago palms growing in Indonesia and oil palms at the time of replantation. The results revealed the existence of starch-accumulating palms that are expected to have starch productivity higher than that of sago palms and starch productivity per area equal to or higher than that of sago palms with the ease of harvesting and extraction operations. Ecologically, the results also revealed the existence of starch-accumulating palms that are more adapted to arid lands than sago palms, indicating the potential use of starch-accumulating palms as resource crops under a wide range of environmental conditions in the tropics. These results indicate the importance of investigating and studying other starch-accumulating palms besides sago palms.

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References

Ehara, H. 2015 Taxonomy. In: The Sago Palm (The Society of Sago Palm Studies ed.) Kyoto University Press (Kyoto) pp. 1-16.

FAOSTAT 2021 Data (Production, Crops) https://www.fao.org/faostat/en/#home

Goren, L. E., J. S. Siemonsma, and P. C. M. Jansen 1996 Minor species. *Corypha* L. *In*: Plant Resources of South-East Asia 9. Plants yielding non-seed carbohydrates (Flach, M. and F. Rumawas eds.) Backhuys Publisher (Leiden) 169-170.

Haska, N. 2001 Comparison of productivity and properties of the starches from several tropical palms. *In*: Diversity and Optimum Utilization of Biological Resources in the Torrid and Subtropical Zones: Proceedings of the International Sago Symposium (in honor of Prof. Ayaaki Ishizaki's retirement. (Ogata, S., K. Furukawa, K. Sonomoto, and G. Kobayashi eds.) Kyushu University Press (Fukuoka) 13–16.

Murayama, N., M. Yoshino, M. Oshima, S. Tsukahara, and Y. Kawarazaki 1955 Studies on the accumulation process of carbobydrates associated with growth of rice plant. Bull. Natl. Inst. Agric. Sci. Jpn., Ser. B4: 123-166. (in Japanese with English summary)

Nasution, R. E. and H. C. Ong 2003 *Corypha utan* Lamk. *In*: Plant Resources of South-East Asia 17. Fiber plants. (Brink, M. and R.P. Escobin eds.) Backhuys Publisher (Leiden) 114-117.

Nishikawa, G., K. Oda and H. Suganuma 1979 Botanical description of sago palm. Japan. J. Trop. Agr. 23: 130-136. (in Japanese with English summary)

Ruddle, K., D. Johnson, P. Townsend, and J.D. Rees 1978 Palm Sago, A tropical starch from marginal lands. The University Press of Hawaii (Honolulu) pp. 207.

Ruddle, K. 1979 The geographical distribution of sago-producing palms. Bulletin of the National Museum Ethnology 3: 572-594.

Somogyi, M. 1945 A new reagent for the determination of sugars. J. Biol. Chem. 160: 61-68.

Tamura, T. 1975. Quantitative analysis method of total sugar (Anthorone sulfuric acid method). *In*: Analytical Measurement Method of Cultivated Plants (Study Group of Crop Analysis Method ed.) Yokendo (Tokyo) 289-290. (in Japanese)

Tomimura, Y. 1992 Chemical characteristics and utilization of oil palm trunks. JARQ 25: 283-288.

Witono, J. R., Y. W. C. Kusuma, and B. P. Naiola 2018 Traditional utilization and processing of gewang palm (*Corypha utan* Lam.) starch in Timor island, Indonesia. J. Biol. Res. 23: 95-100.

Yamamoto, Y., S. Kawamura, I. Yanagidate, T. Yoshida, T. Ichimaru, Y.B. Pasolon, F.S. Rembon, A.D. Pasulu, and A. Miyazaki 2021a Growth characteristics and starch productivity of sugar palms (*Arenga pinnata* Merr.) grown on Muna Island, Southeast Sulawesi, Indonesia. Trop. Agr. Develop. 65: 97-109.

Yamamoto, Y., S. Kawamura, H. Ishima, T. Yoshida, P. Hardaning, Y. S. A. Fauzan, N. Haska, F. S. Rembon, Namriah, A. Ochi, and A. Miyazaki 2021b Growth characteristics and starch productivity of gebang palms (*Corypha utan* Lamk.) grown in Kupang, Nusa Tenggara and on Muna Island, Southeast Sulawesi, Indonesia. Trop. Agr. Develop. 65: 153-162.

Yamamoto, Y., A. Ochi, I. Yanagidate, H. Ishima, T. Yoshida, F. S. Rembon, Y. B. Pasolon, E. Manaroisong, C. Sayangbati, R. B. Maliangkay, E. Tenda, and A. Miyazaki 2022 Growth characteristics and starch productivity of 'sagu baruk' (*Arenga microcarpa* Becc.) on Sangihe Island, North Sulawesi, Indonesia. Trop. Agr. Develop. 66: 12-20.

Yamamoto, Y., K. Omori, T. Yoshida, A. Miyazaki and F. S. Jong 2008 The annual production of sago (*Metroxylon sagu* Rottb.) starch per hectare. *In*: Sago: Its Potential in Food and Industry: Proceedings of the 9th International Sago Symposium. (Toyoda, Y., M. Okazaki, M. Quevedo, and J. Bacusmo eds.) TUAT Press (Tokyo) 95–101.

Yamamoto, Y., K. Omori, Y. Nitta, K. Kakuda, Y. B. Pasolon, F. S. Rembon, R. S. Gusty, A. A. Arsy, A. Miyazaki, and T. Yoshida 2016 Dry matter production and distribution after trunk formation in sago palm (*Metroxylon sagu* Rottb.). Trop. Agr. Develop. 60: 71-80.

Yamamoto, Y., F. S. Rembon. K. Omori, T. Yoshida, Y. Nitta, Y. B. Pasolon, and A. Miyazaki 2010 Growth characteristics and starch productivity of three varieties of sago palm (*Metroxylon sagu* Rottb.) in Southeast Sulawesi, Indonesia. Trop. Agr. Develop. 54: 1-8.

Yamamoto, Y., I. Yanagidate, A. Miyazaki, T. Yoshida, A. F. Irawan, Y. B. Pasolon, F. S. Jong, H. Matanubun, A. A. Arsy, and J. Limnongan 2020a Growth characteristics and starch productivity of folk varieties of sago palm around Lake Sentani near Jayapura, Papua State, Indonesia. Trop. Agr. Develop. 64: 23-33.

Yamamoto, Y., I. Yanagidate, T. Yoshida, H. Pranamuda, Y. S. A. Fauzan, U. E. Suryadi, Y. Indrayani, A. Miyazaki, and N. Haska 2020b Growth characteristics and starch productivity of sago palm (*Metroxylon sagu* Rottb.) grown in Pontianak, West Kalimantan, Indonesia. Sago Palm 28: 12-21.

Yamamoto, Y., T. Yoshida, Y. Goto, F. S. Jong, and L. B. Hilary 2003a Starch accumulation process in the pith of sago palm (*Metroxylon sagu* Rottb.). Jpn. J. Trop. Agr. 47: 124-131. (in Japanese with English abstract)

Yamamoto, Y., T. Yoshida, Y. Goto, Y. Nitta, K. Kakuda, F. S. Jong, L. B. Hilary, and H. Hassan 2003b Differences in growth and starch yield of sago palms (*Metroxylon sagu* Rottb.) among soil types in Sarawak, Malaysia. Jpn. J. Trop. Agr. 47: 250-259.

Yamamoto, Y., T. Yoshida, I. Yanagidate, F. J. Polonaya, W. A. Siahaya, F. S. Jong, Y. B. Pasolon, A. Miyazaki, T. Hamanishi, and K. Hirao 2020c Studies on growth characteristics and starch productivity of the sago palm (*Metroxylon sagu* Rottb.) folk varieties in Seram and Ambon Islands，Maluk, Indonesia. Trop. Agr. Develop. 64: 125-134.

Yamamoto, Y., T. Yoshida, H. Ishima, T. Yoshida, Manselinus, Y.B. Pasolon, F.S. Rembon, E. Manaroisong, C. Sayangbati, R. B. Maliangkay, E. Tenda, and A. Miyazaki 2021c Growth characteristics and starch productivity of sugar palms (*Arenga pinnata* Merr.) in Tana Toraja, South Sulawesi and Tomohon, North Sulawesi, Indonesia. Sago Palm 29: 25-38.

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Sago Production Potential in Several Regions in Indonesia

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Abstract Indonesia has vast natural sago forest areas, especially in the provinces of Papua, South Papua, Central Papua, West Papua, and Southwest Papua, as well as in the lowlands of the Papua Mountains. Apart from Papua, sago is also found in provinces on the islands of Sulawesi, Kalimantan, Sumatra, and Maluku. Sago in Indonesia covers an area of 5.5 million hectares. Sago productivity in Indonesia reaches up to 20-40 tons of dry starch per hectare. However, not much is known about the yield of dry sago starch per tree. In this research, we compare the yield of dry sago starch from each tree of sago palm-producing regions in Indonesia, namely South Papua, Papua, Central Papua, West Papua, South Sulawesi, Southeast Sulawesi, Central Sulawesi, West Sulawesi, South Kalimantan, West Sumatra, and the Riau Islands. Measurement of the dry sago starch yield was carried out by comparing the volume of the sago tree to the volume of the sample and then multiplying it with the weight of the dry starch sample. The result shows that the highest production in South Papua was found in the Mappi regency amounting to 1197 kg. The highest in Papua Province was 443 kg in Jayapura Regency, while in Jayapura City was 447 kg. In Central Papua Province, especially in Mimika Regency, the highest production was 402 kg in Central Mimika District. In West Papua Province, the highest production was 414 kg in South Sorong Regency, while in Southwest Papua Province, the highest production was 362 kg in Sorong City. In the Province of Southeast Sulawesi, the highest production was in South Konawe Regency, amounting to 445 kg. In South Sulawesi, the highest production was found in North Luwu Regency, amounting to 477 kg. In West Sulawesi, the highest production was found in Mamuju Regency amounting to 717 kg. In Central Sulawesi, it was found in Parigi Moutong Regency amounting to 429 kg. In South Kalimantan, it was found in Candi Laras District, Tapin Regency amounting to 178 kg. On the island of Sumatra, it was observed in West Sumatra, especially in the Mentawai Islands Regency, and in the Riau Islands Province, especially on Lingga Island. The highest production was found in the Mentawai Islands at 545 kg, while on Lingga Island was 288 kg.

Key words: Kalimantan, Maluku, Papua, Sulawesi, Sumatra

Introduction

Sago or *Metroxylon* spp. is a potential commodity as an alternative food because it has a productivity of 20-40 tonnes of dry starch/ha/year. Sago starch can also be used as industrial raw materials (glutamate, lactate, fructose) and fuel (methanol and ethanol) (Bintoro et al. 2010).

Sago is a natural resource originating from Indonesia. According to Djoefrie et al. (2014), Indonesia has 50% more sago potential in the world with an area of 5.5 million ha. The latest opinion according to Bintoro et al. (2021), the worldwide sago area is 6,279,637 million hectares and Indonesia has 85% of the world's sago area or around 5,337,691 million hectares. The largest distribution of sago in Indonesia is in the provinces of Papua, South Papua, Central Papua, West Papua, and Southwest Papua. The spread of sago in Indonesia is quite wide, sago also grows on the islands of Sulawesi, Sumatra, Kalimantan, Maluku, and Java.

In meeting the carbohydrate needs of Indonesia, its people rely heavily on the rice commodity. In the rice commodity, there are internal and external factors that make rice productivity difficult to increase to a level to meet carbohydrate needs in Indonesia (Ahmed 2017). The potential of sago should be further developed because sago can be used as a staple food reserve if rice supplies run low. Rapid population growth makes the world's food demand increase. Sago is one of the plants that needs to be developed to address the increasing need for food, besides that sago is very easy to process into various types of food so the potential for sago in Indonesia is very high (Mattori 2017). Research on sago production in Indonesia needs to be carried out.

Materials and Methods

Research activities were conducted in South Papua, Papua Province, Central Papua Province, West Papua Province, Southwest Papua Province, Southeast Sulawesi Province, South Sulawesi Province, West Sulawesi Province, Central Sulawesi Province, and South Kalimantan Province. The material used in this study was sago accession resulting from exploration. The tools used are cameras, Global Positioning System (GPS), tape measure, calipers, digital scales, plastic clips, measuring cups, filters, aluminum foil, basins, machetes, blenders, labels, sample rings, and supporting equipment.

Data Retrieval

Data Information on several types of sago was obtained from farmers who know the types of sago. Observations were made directly on selected sample plants. The sampling method was carried out by selective logging at each accession of sago plants that met the harvest criteria, namely when the sago plants were about to enter the generative phase (at the time of flower initiation).

Production character data is obtained from the processing of sago pith which is taken using a ring sample whose volume is known. The pith was collected at three points of the stem, namely the bottom, middle, and top. The observations made were on morphological, production, and genetic characteristics. There are two methods of observation in this study, namely qualitative and quantitative. The quantitative observation method is in the form of direct observation through measurement, while the qualitative method is in the form of interviews with farmers or people who have an understanding of the naming of sago, taking pictures of the stems and leaves of the plant, and the process of proximate analysis of sago starch.

Morphological Character

1. Stem

Stem observations consisted of length, diameter, circumference, color, and skin thickness. Stem length was measured in harvested trees. Measurement starts from the base of the stem at ground level to the tip of the stem (bottom leaf midrib). The diameter and thickness of the bark were measured at three points, namely the base, middle, and tip. Stem diameter was observed after the stem was felled.

2. Starch Production

Starch production was calculated using a volume ratio. Starch is obtained from the extraction of sago pith. The pith is taken from the stem using a ring sample of known volume. The pith on the sago stems was taken at the base, middle, and ends of the sago plant samples that had been cut down. The pith obtained was then crushed using a blender and squeezed three times with 200 ml of water. The juice is then settled for 12 hours to get wet starch. The starch is dried and weighed (dry starch). Starch production per tree is then calculated using the formula proposed by Bintoro et al., (2017) as follows:

$$\text{Starch production per stem} = \frac{\text{stem volume}}{\text{example volume}} \times \text{dry starch weight of sample}$$

Notes:

Stem volume = $\pi r 2$ x height, $\pi = 3.14$ and r = radius of sago stem
Dry starch weight is the average of the samples taken.

Starch yield is calculated using the formula proposed by Bintoro et al. (2017) as follows:

$$\text{Starch yield} = \frac{\text{dry starch weight}}{\text{pith weight}} \times 100\%$$

Results and Discussion

The types of sago found in Mappi Regency, South Papua consist of long thorn sago and smooth sago. The average production of sago-type dry starch in Mappi Regency was 477.44 kg stem^{-1} (Table 1). The highest amount of starch was found in heim sago with long thorns which was located in the Taragai village of 1,197.20 kg stem^{-1}. Production per tree in *katage* was 624.35 kg, *mani* was 718.15 kg, *wiyage* was 320.33 kg, and *arare* was 232.65 kg. Production in *katage* and *mani* is very high, while in *wiyage* and *arare* it is high. Production of sago starch in Assue District/District is high, namely 288.53 kg of dry starch/tree (*homang*) and 261.30 kg of dry starch from tree^{-1} (*sigare*).

Table 1. Production per village in Mappi Regency, South Papua (Tim IPB 2021a)

Accession	Yield (%)	Dry starch production (kg stick^{-1})
moor[1]	15.56	171.15
ghanu[2]	30.53	376.00
komru[2]	27.45	584.80
taragai[2]	27.52	1,197.20
wiyage[2]	30.94	320.35
katage[2]	39.01	624.25
mani[2]	32.32	718.15
arare[1]	34.81	232.65
sigare[2]	22.03	261.30
homang[2]	28.16	288.55
Average	28.83	477.44
Standard deviation	6.54	312.73
Coefficient of Variability (%)	22.70	65.50

Description: 1 = smooth sago, 2 = long thorny sago

There are several accessions of sago with high production in Jayapura City, Papua Province. One of them is the accession of *he bang* which is a type of non-thorny sago and is referred to as forest sago. The *he bang* accession has a dry starch weight of 447 kg stem^{-1}.

Sago in Central Papua Province, especially in Mimika Regency, has the highest production of 402 kg in Central Mimika Regency. The yield of sago starch in Mioko Village was between 14.54%-22.28% (Table 2). The yield of starch will have an impact on the production produced, the higher the yield the higher the production. Sago *omiya* accession 1 has a high starch yield and high yield potential.

Table 2. Production per village in Mimika Regency, Central Papua (Primary 2018)

Accession	Yield (%)	Dry starch Production (kg stick^{-1})
taina	22.28	250.57
oko	18.25	384.10
omiya 1	22.18	402.09
omiya 2	15.82	143.87
durumu	14.54	312.14
mbapare	18.73	239.18
omoroko	15.35	169.33
ikimina	19.76	220.49
Average	18.36	265.22
Standard deviation	2.93	94.02
Coefficient of Variability (%)	16.23	35.45

Sago in West Papua Province, South Sorong Regency has various accessions. *Fasai* accession (wild sago) has the lowest yield compared to other accessions, so it has the lowest starch production. Most of the sago accessions in this location are capable of producing more than 200 kg of dry starch per stem^{-1}. The average yield potential was 236.70 kg stem^{-1} dry starch. The accessions included *fafion, fakreit, falia, fanomic, fasampe, fasinan*, and *fosongka. phanomik* was the accession that produced the most starch, namely 414 kg stem^{-1} (Table 3).

Table 3. Production per village in South Sorong Regency, West Papua (Dewi et al. 2016)

Accession	Yield (%)	Dry starch production (kg stick^{-1})
fablen	15.64	169.81
fafion	18.31	310.00
failik	21.27	165.61
fakattao	20.60	185.29
fakreit	21.17	288.17
falia	20.52	259.06
fanke	17.46	129.65
fanomik	19.63	414.32
fasai	12.48	161.97
fasampe	17.97	244.53
fasinan	17.42	287.80
fasongka	15.90	224.15
Average	18.20	236.70
Standad deviation	2.65	80.97
Coefficient of Variability (%)	14.56	34.21

The highest production of sago is in Southwest Papua Province, namely 362 kg/stem in Sorong City. The yield of starch in all actions ranged from 25% to 50%. The lowest dry starch weight was in the *wawun* accession, namely 110.69 kg rod^{-1}, and the highest dry starch weight was in the *wasnan* accession, 361.51 kg rod^{-1} (Table 4). The higher the yield of sago starch, the potential for tree^{-1} dry starch will be higher.

Table 4. Production per village in Sorong City, Southwest Papua (Fathnoer 2018)

Accsession	Yield (%)	Dry starch Production (kg stick^{-1})
waruwo	40.53	289.21
wasulagi	43.80	248.54
wasnan	43.38	361.51
wayuluk	39.51	211.84
wagelik	25.52	215.72
wanegles	49.01	128.54
wawun	37.24	110.69
wafabala	41.29	149.30
Average	40.04	214.42
Standard deviation	6.83	85.17
Coefficient of Variability (%)	17.06	19.54

The highest production of sago in South Sulawesi is in North Luwu Regency, which is 477 kg/tree (Table 5). Accession factors had a very significant effect on stem height, starch production, and production potential. Yield and stem diameter had a significant effect, while the number of ripening trees was not significant. The average sago production potential varies from the six observed accessions. The accessions were not evenly distributed at each observation location. *Kapa* accession is not found in coastal areas, while *kiduri* accession and Ute accession have a relatively low distribution and number of clumps. *Ute* accessions grow with a relatively small number of tillers in a clump and are only found in certain spots.

Table 5. Production of each accession in North Luwu Regency, South Sulawesi (Masluki 2022)

Accsession	Yield (%)	Dry starch Production (kgstick^{-1})
kapa	22.22	477.00
kasimpo	18.45	359.61
ute	17.46	140.35
use	16.30	280.38
sabbe	21.02	221.78
kiduri	18.40	179.66
Average	19.31	276.40
Standard deviation	2.87	124.82
Coefficient of Variability (%)	14.85	45.16

Sago on the island of Sumatra is observed in West Sumatra, especially in the Mentawai Islands Regency. The starch yield of various sago accessions in Siberut National Park ranged from 19-32% with the *sakoat* accession having the lowest starch yield, namely 19.04%. The average potential for dry starch production is 312.68 kg stem^{-1}. According to Bintoro et al. (2010), sago plants have a production potential of 200-400 kg of dry starch stem^{-1}. All accessions had a production of over 200 kg of dry starch stem^{-1}, the highest production was 545 kg (Table 6).

Table 6. Production of each accession in Mentawai Islands Regency, Riau Archipelago (Firmansyah 2022)

Accsession	Yield (%)	Dry starch Production (kg stick^{-1})
saikoat	19.04	123.16
limu	24.93	216.48
betaet	31.55	383.87
ukra	32.24	544.37
sirilanggai	23.35	322.55
sibeotcun	24.27	285.62
Average	25.90	312.68
Standard deviation	5.08	144.74
Coefficient of Variability (%)	19.64	46.29

There are three types of sago accession in Mamuju Regency, West Sulawesi, namely *kasimpo*, *kapas*, and *ruwi*. All accessions were hepatic accessions or only experienced one generative (flowering) phase. The highest dry starch production was observed in the *kapas* accession, which was 436.61 kg stalk^{-1}, while the *kasimpo* accession was 243.14 kg stalk^{-1}. The lowest dry starch production was in the *ruwi* accession, which was 81.67 kg stem^{-1}. The average production of sago dry starch is 304.38 kg stem^{-1}. The *kapas* accession had the highest dry starch production which reached 717.90 kg stem^{-1} (Table 7).

The yield (%) per accession from lowest to highest, namely *ruwi* 11.05%, *kasimpo* 21.10%, and *kapas* 23.89%. Calculation of starch yield was used to determine dry starch production (kg stick^{-1}).

Table 7. Production per accession in Mamuju Regency, West Sulawesi (Abhal 2022)

Accsession	Sample	Yield (%)	Dry starch Production (kg stick^{-1})
kasimpo	1	18.80	183.64
	2	16.94	106.51
	3	20.44	144.68
	4	24.46	391.93
	5	25.80	388.93
Average		21.10	243.14
kapas	1	19.16	258.27
	2	24.61	425.76
	3	27.37	717.90
	4	24.41	344.52
Average		23.89	436.61
ruwi	1	11.05	81.670
Average		21.20	304.38
Standard deviation		4.920	192.39
Coefficient of Variability (%)		23.21	63.210

Sago of the Roe type found in Lameuru Village, South Konawe Regency, Southeast Sulawesi Province has the highest dry starch production of 445 kg (Table 8). Differences in the growing environment result in differences in the number of clumps and the state of the leaves which ultimately result in differences in the production and productivity of sago plants.

Table 8. Production of each accession in South Konawe Regency, Southeast Sulawesi (Tim IPB 2021b)

District	Height (m)	Dry starch production (kgstick^{-1})
Lameuru[1]	10.30	445.00
Arono[1]	7.25	314.36
Aopa[2]	8.00	237.86
Aopa[1]	8.40	236.54
Lamoen[1]	8.25	297.93
Lamoen[2]	5.95	228.19
Sandei[2]	9.60	280.59
Mataiwoi[1]	9.55	196.05
Mataiwoi[2]	6.35	243.24
Landabaru[2]	7.30	294.32
Landabaru[3]	7.70	261.06
Watundeho[1]	9.90	318.62
Unggulino[1]	13.88	432.46
Average	8.65	291.21
Standard deviation	2.07	74.71
Coefficient of Variability (%)	23.90	25.65

Sago in Central Sulawesi was found in Parigi Moutong Regency in Sigenti Village with the type of slippery sago, namely 429 kg/tree (Table 9). The lowest and highest yields per accession were South Sigenti at 8.13% and North Sigenti 1 at 25.24%.

Table 9. Production per accession in Parigi Moutong Regency, Central Sulawesi (Pembayun 2023)

Accession	Yield (%)	Dry starch production (kg stick^{-1})
tada timur 1[1]	19.02	386.10
sigenti[1]	20.80	429.19
tada timur 2[1]	15.29	329.33
khatulistiwa[1]	23.45	367.70
sigenti selatan 1[1]	8.13	68.07
sigenti selatan 2[2]	12.89	56.52
sigenti selatan 3[1]	18.08	320.05
sigenti selatan 4[1]	16.67	264.87
sigenti utara 1[2]	25.24	209.23
sigenti utara 2[2]	23.93	128.54
maninili utara[2]	23.31	122.99
maninili[1]	23.16	316.87
siaga[1]	8.37	112.75
sinei induk[1]	20.16	330.39
Average	18.46	245.90
Standard deviation	5.60	126.65
Coefficient of Variability (%)	30.34	51.51

Description: 1 = smooth sago, 2 = thorny sago

Sago in South Kalimantan, Candi Laras District, has five accessions. The *salak* accession had the lowest dry starch weight per stem, namely 91.04 kg stem^{-1}, while the accession that produced the highest starch was the *buntal* accession with a weight of 178 kg stem^{-1} (Table 10).

Table 10. Production per accession in South Kalimantan (Rahman 2021)

Accession	Yield (%)	Dry starch production (kg stick^{-1})_
mahang	22.31	102.11
buntal	24.56	178.00
salak	14.29	91.04
madang	18.38	157.84
gandut	19.13	127.82
Average	19.73	131.36
Standard deviation	3.93	36.64
Coefficient of Variability (%)	19.91	27.89

Sago in the Riau Archipelago Province, especially on Lingga Island, has several accessions including *nerekeh*, *pangga laut*, *musai*, *pekaka*, *keton*, and *teluk*.

Starch production is influenced by several factors, including height, diameter, moisture content, and yield of sago stems. Ehara (2009) states that sago starch production has a positive correlation with stem weight. Starch accumulation begins at the base of the lower stem and reaches a maximum in the middle to the upper two-thirds of the stem free of the midrib (Schuiling 2009). The highest sago starch production was in the Gulf accession, namely 288 kg stalk^{-1}, while the lowest sago starch production was in the *pangga laut* accession, namely 95.08 kg stalk^{-1} (Table 11).

Table 11. Production of each accession in the Riau Archipelago, Lingga Island (Manar 2023)

Accession	Yield (%)	Dry starch Production (kg stick^{-1})
nerekeh	15.99	156.68
panggak laut	14.81	95.08
musai	16.79	238.66
pekaka	22.10	210.38
keton	15.20	227.40
teluk	32.17	288.64
Average	19.51	202.81
Standard deviation	6.74	21.28
Coefficient of Variability (%)	34.57	53.87

Conclusion

Accession of sago spread across Indonesia has several types, including thorny sago and smooth sago. All sago accessions found in several provinces have many variations, from the lowest to the highest yield and from the lowest to the highest dry starch production. The highest production yield was identified in South Papua, Mappi Regency of 1197 kg stem^{-1}. High production yields are also discovered in Papua Province with the accession of *he bang* having a dry starch weight of 447 kg stem^{-1}.

Sago in Central Papua Province, especially in Mimika Regency, there is sago *omiya* 1 accession which has a high yield of starch and high yield potential, namely 402 kg stem^{-1}, while in West Papua Province, the highest production of *fanomic* accession is 414 kg stem^{-1} in South Sorong Regency.

Sago in the Province of Southwest Papua, Sorong City has *wasnan* accession with a weight of 361.51 kg stem^{-1}, while in the Province of Southeast Sulawesi sago of the *roe* type found in Lameuru Village, South Konawe Regency has the highest dry starch production of 445 kg.

The highest production of sago in West Sulawesi was in Mamuju Regency of 717 kg with *cotton* accession. Sago in Central Sulawesi was found in Parigi Moutong District, Sigenti Village of 429 kg. Sago in South Kalimantan was found in Candi Laras District, Tapin Regency of 178 kg with the addition of salak. On the island of Sumatra, it was observed in West Sumatra, especially in the Mentawai Islands Regency, and in the Riau Islands Province, especially on Lingga Island. The highest production was in the Mentawai Islands at 545 kg, while on Lingga Island it was 288 kg with the Gulf accession.

References

Abhal N.E.I. 2022. Identifikasi Berbagai Aksesi Sagu (*Metroxylon* Spp.) di Kecamatan Mamuju, Kabupaten Mamuju, Provinsi Sulawesi Barat. Graduation thesis. Institute Pertanian Bogor (Bogor).

Ahmad F. 2017. Identifikasi berbagai aksesi sagu (*Metroxylon* spp.) di Distrik Iwaka, Kabupaten Mimika, Papua. Master Thesis. Sekolah Pascasarjana, Institute Pertanian Bogor (Bogor).

Bintoro MH, Purwanto MYJ, Amarillis S. 2010. Sagu di Lahan Gambut. Bogor (ID): IPB Press (Bogor).

Bintoro, M.H., A.J. Pratama, F. Ahmad, M.I. Nurulhaq, M.L. Mulyanto and L. Ayulia 2017. Pemberdayaan dan Pembangunan Masyarakat Pinggiran melalui Sagu. Bogor. IPB Press (Bogor).

Bintoro M.H., Ehara H., Azhar A., Dewi R.K., Nurulhaq M.I., Ahyuni D. 2021. Ekofisiologi Sagu. Bogor (ID): IPB Press.(Bogor).

Dewi R.K., Bintoro M.H., Sudradjat 2016. Karakter Morfologi dan Potensi Produksi Beberapa Aksesi Sagu (*Metroxylon* spp.) di Kabupaten Sorong Selatan, Papua Barat. J. Agron. Indonesia. 44 (1) : 91-97.

Djoefri M.H.B, Herodian S, Ngadiono, Thoriq A, Amarilis S. 2014. Sagu untuk Kesejahteraan Masyarakat Papua. Unit Percepatan Pembangunan Papua dan Papua Barat. Jakarta.

Ehara H. 2009. Potency of sago palm as carbohydrate resource for strengthening food security program. Jurnal Agronomi Indonesia. 37(3):209-219. doi:10.24831/jai.v37i3.1255.

Fathnoer V. 2018. Karakterisasi Berbagai Aksesi Sagu (*Metroxylon* spp.) di Distrik Aimas, Kabupaten Sorong, Papua Barat. Master thesis. Sekolar Pascasarjana, Institut Pertanian Bogor (Bogor).

Firmansyah A.N.A. 2022. Identifikasi Berbagai Aksesi Sagu (*Metroxylon* Spp.) Di Taman Nasional Siberut, Kepulauan Mentawai, Sumatera Barat. Graduation thesis. Institut Pertanian Bogor (Bogor) .

Manar P.A. 2023. Potensi dan Bioprospeksi Sagu (*Metroxylon* Spp.) di Kabupaten Lingga, Provinsi Kepulauan Riau. Master thesis. Sekolar Pascasarjana, Institut Pertanian Bogor (Bogor) .

Masluki. 2022. Keragaman Morfologi, Produksi, Genetik dan Kimia Pati Sagu (*Metroxylon* Spp.) di Tana Luwu Provinsi Sulawesi Selatan. Ph.D. Dissertation. Sekolah Pascasarjana, Insitut Pertanian Bogor (Bogor).

Mattori V. 2017. Etnobotani sagu (*Metroxylon* sagu) di lahan basah situs air sugihan, Sumatera Selatan: warisan budaya masa Sriwiijaya. Kalpataru. 26(2):107–122.

Pembayun P. 2023. Identifikasi Berbagai Aksesi Sagu (*Metroxylon* spp.) di Kecamatan Tinombo Selatan Kabupaten Parigi, Moutong Provinsi, Sulawesi Tengah. Graduation thesis. Universitas Nusa Bangsa (Bogor) .

Pratama A.J. 2018. Keragaman Pertumbuhan dan Produksi Aksesi Sagu di Populasi Alam Distrik Mimika Tengah Provinsi Papua. Master thesis. Sekolah Pascasarjana, Institu Pertanian Bogor (Bogor) .

Rahman H.B.A. 2021. Sebaran dan Keragaman Beberapa Aksesi Sagu di Provinsi Kalimantan Selatan. Master thesis. Sekolah Pascasarjana, Institu Pertanian Bogor (Bogor) .

Schuiling D.L. 2009. Growth and development of true sago palm (*Metroxylon* sagu Rottboll) with special reference to accumulation of starch in the trunk: a study on morphology, genetic variation and ecophysiology, and their implications for cultivation. Ph.D. theisis. Wageningen University (Wageningen) pp. 259.

Tim IPB. 2021a. Kajian Kesesuaian Lahan Daerah di Kabupaten Mappi, Provinsi Papua. Kerjasama Badan Perencanaan Pembangunan Daerah Kabupaten Mappi dengan Institut Pertanian Bogor (IPB University). IPB University (Bogor).

Tim IPB. 2021b. Studi Kelayakan Pembangunan Industri Tepung Sagu atau Tapioka Konawe Raya, Sulawesi Tenggara. Kerjasama Perum BULOG dengan Institut Pertanian Bogor (IPB University). Bogor (ID)

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Regional Characteristics and Transformation of Sago Plam Utilization in Traditional Rural areas: From the cases of the three regions; West Papua-Indonesia, Southeast Sulawesi-Indonesia, Northeast Mindanao-Philippines

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Abstract The sago palm, which originated in New Guinea Island, spread to surrounding areas and has been used as a staple food and a material for daily life by the indigenous people. The form of sago palm utilization has developed its own method according to the local natural conditions and the way people use it in the areas where it was propagated/transmitted. People in the sago palm habitat are with the sago palm and make up the behavior of their lives from starch production to consumption. In particular, since the sago palm grows in marshy areas, it requires techniques to cut and process the palm, making use of the local natural conditions, unlike simple hunting and gathering. In particular, there are regional differences in palm pith rasping and starch extraction techniques. This sago palm processing technology was also inherited along with the propagation of the palms, forming a unique pattern. We discussed how sago palm will be used in the future by investigating the usage pattern of sago palm in the area with other cultivated crops propagated from the wild sago palm habitat.

Key words: Northeast Mindanao, Sago extraction, Sago utilization, Southeast Sulawesi, West Papua

Introduction

The sago palm, which originated on the island of New Guinea, is important to local residents as a palm that produces sago starch in tropical Southeast Asia and Oceania. The sago palm is positioned as an important and essential crop for the local people as a plant that exhibits dominant growth in barren marshes and areas where crops are difficult to grow. Especially in areas where sago starch is the staple food, people's lives are determined by the growth of sago palms. In this situation, the sago palm not only supplies starch but also uses the plant body, creating an environment where it is difficult to live without the sago palm.

On the other hand, since sago palm has various uses, it shows the usage pattern peculiar to the region. Naturally, it is also one of the elements that form the unique culture of the region. However, if other crops are cultivated in the sago palm habitat, the sago palm usage pattern will change.

Therefore, in this report, we analyze the conditions for regional application of the diversity and changes in the use of sago palm based on three regional cases regarding the use and positioning of sago palm, and discuss the direction of future sustainable use of sago palm. In addition, from the perspective of development, conservation and sustainability the future relationship between people (society) and sago palms will be considered.

Research Methods:

Selection of survey sites and actual conditions of sago palm

According to Nishimura (2015) and Ehara (2015), the sago palm originated on the island of New Guinea and genetically propagated to Southeast Asia and Pacific countries. Along with this, it is thought that the form of sago utilization also changed in the same direction.

Here, in order to investigate the transformation of sago palm, this paper took up three regions: i) origin of sago palm, ii) developed area of sago palm use, and iii) limited area of sago palm use. The actual situation of sago palm utilization in these areas was investigated (See Fig. 1 and Fig. 2).

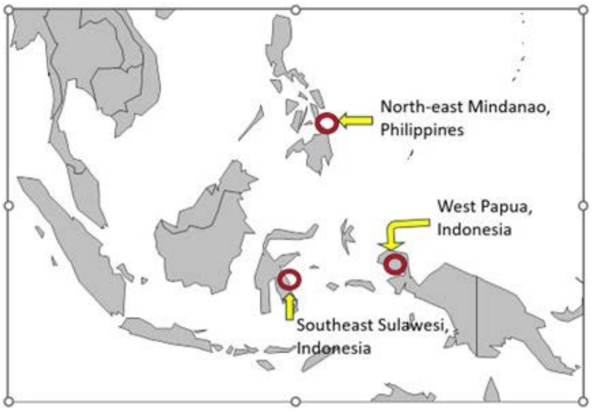

Fig. 1. Map of the survey areas

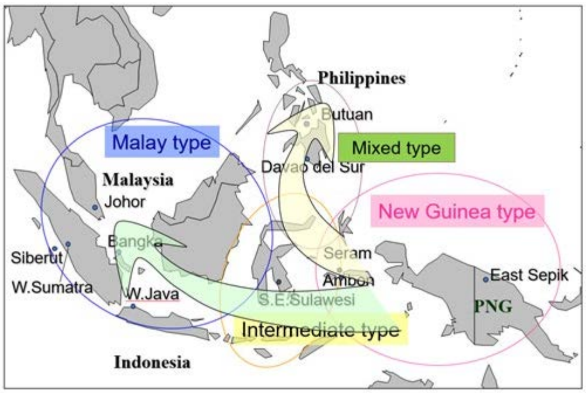

Fig. 2. Propagation of sago palm varieties and the diffusion of starch extraction technology (by Nishimura 2015)

1) Origin of sago palm: Village of wild sago palm forest in West Papua, Indonesia

Sago palm wild forest surveys were conducted in West

Papua Province, South Sorong District, Metamani Sub-district and Saga Village, Indonesia. Saga Village takes about 4 hours by high-speed boat from Teminabuan Town, which has the largest port in the area. It is a village of 80 households with a population of about 500, located on the bank of a remote area along the bay and upstream of the Metamani River. Therefore, it is far from the modern city, and it is an area underdeveloped.

Interviews were conducted with villagers in March 2013 using questionnaires to clarify the relationship between residents and sago palm wild forests. Based on this result, the overview of the village and life were summarized.

①Ownership of sago palm in Saga Village

Saga Village has 24 characters (Dusun), and the land has already been decided as privately owned land. The Iwaro tribe of Saga Village owns the land around Metamani District. Ownership of the sago palm belongs to the land owner Marga (big family).

② Village life

People eat three meals a day, and the staple food is sago starch, which is eaten as Papeda (porridge-like soup) or Sago-Bakar (sago wrapped in leaves and baked to solidify). In addition, rice, coconuts, bananas, potatoes, etc. are also eaten as staple foods from time to time occasionally.

As for his daily work, the man is extracting sago starch, but he also hunts and catches fish two to three days a week. They mainly hunt wild boars with traps (done at night). Other species such as deer, cassowary, and kangaroos can also be caught. Fishing is done by fishing and netting. Women are in charge of washing the sago starch extraction work. They also grow crops and vegetables. Each family has a boat that is rowed by hand and used on a daily basis. However, the number of people with outboard motors is limited.

③ Production and sales of sago starch

When villagers collect sago palm starch, they do so as a family unit. It is usually done by the couple, sometimes with the help of children. The men perform the labor-intensive felling, peeling of the trunk, and crushing of the pith, while the women extract the starch by soaking the pith waste (small pieces) in water. One or two sago palms are harvested for starch per week. This translates to about 500kg. 40% of the starch produced is for self-consumption and the remaining 60% is sold for markets.

④ Sago palm and people's livelihood

In addition to collecting starch for food, sago palms supply living materials such as mats made from woven small leaves for roofing and housing materials, petioles for pillars, and stem bark for fuel. The current wild sago palm forests provide a sufficient number of resources for their livelihood, so there is no problem with the sustainability of their current livelihood.

2) Developed area of sago palm utilization: Kendari, Southeast Sulawesi, Indonesia, where sago starch production shifts from staple food for self-consumption to sales

The Sulawesi Island, located in the center of Indonesia, has long been a midpoint between Southeast Asia and New Guinea. The sago palm, which originated in New Guinea, also propagated to the west of this landform, and joined the rice-growing area on Sulawesi Island.

The utilization of sago palm around Kendari city in Southeast Sulawesi was investigated from 1995 to 2000 in this report. The indigenous people of this area are the Tolaki people, and there is a history of immigration from surrounding ethnic groups such as the Buginese. Sago palm is one of the staple foods of the Tolakinese, but upland rice is also one of the staple foods. According to Nishimura (1995), rice, sago, maize, and cassava are the sub-staple foods (multiple answers allowed) in Kiaea village.

Kendari is located on a mountainous peninsula in the tropical monsoon region where wet and dry seasons occur. The sago palm forms forests mainly in river basins in mountainous areas. It also forms large vegetation areas in wetland around marshes. The Tolaki people used this sago palm, slash-and-burn farming, and hunting to secure food. Crops cultivated in the slash-and-burn farming include upland rice, maize, tubers, bananas, and vegetables. Upland rice, which is the main crop, has a growing season. From December to January, when the rainy season begins, upland rice is sown in slash-and-burn hills that have been cleared in advance. Harvesting takes place from May to June to secure a year's worth of rice. However, during the rainy season when upland rice is cultivated, rice storage becomes low, and during this time, starch is extracted from the sago palm and sago as a staple food is harvested. During this rainy period, it is possible to secure the water necessary for the sago starch extraction work, and there is an advantage that the extraction work can be done easily. In this way, the agricultural work of the Tolaki tribe has a variety of combinations of sago and slash-and-burn farming, which creates an annual work system considering the seasons and secures food.

3) Limited areas for sago palm use: Two villages in Mindanao, northeastern Philippines, where sago palm is used terminally

Bisaya and Bobon villages are located in the central part of the eastern side of Mindanao Island, and are part of the wetlands that extend along the basin of the Agusan River. Sago palms flourish in this wetland, forming many sago palm forests. This area is inhabited by the Cabanbanan ethnic people as the indigenous people of the Philippines.

One of the ethnics, Manobo people in Bisaya village were interviewed in 2008 to investigate sago palm forests and starch extraction practices. The land of the group is 3,166 ha, inherited from the ancestors. Of these, 300ha has sago palm forests. 150 ha of sago was planted by the Haribon Foundation, a World Bank (WB) project. The history of sago dates back to pre-Spanish rule in the 15th and 16th centuries. In this area, gold (*Bulawan*) has long been mined on the high ground on the prefectural border, and gold has become an important trade product. In addition, life in this area at that time consisted of hunting and slash-and-burn upland rice cultivation. Islamic trader came seeking this gold and exchanged it for gold on the condition that sago palms be planted in this area. Sago is said to have been introduced at this time (Nishimura, 2008).

Bobon Village is a village with 37 farms and a population of 175 people located near the coast. The current sago palm thriving situation in the village is not densely growing. Paddy fields have already spread around the village, and many useful crops such as coconut palms and fruit trees have been planted. The main agriculture in the village is paddy rice cultivation, which can be cultivated twice a year. Other sources of income include coconuts, bananas, firewood, and retail store management. Therefore, sago is not a staple food in this region, but is positioned as a food for use in confectionary. For that reason, it is often eaten at festivals or occasional times instead of being produced all the time. These are i) *Davao davao* (tempura-type fried dish), ii) *Balagsin* (steamed sweets wrapped in banana leaves), iii) *Kinable* (Sago Pearl) for sale.

In any case, confectionery is made using not only sago starch but also other ingredients. In addition, the leaves of sago palm are considered more important as a material for daily life than as a starch. Here, the leaves are woven and used as partitions or roofing material. And villagers say that sago palm leaves are important for roofing materials because they last 4-5 years longer than nipa palm leaves for 3 years. Therefore, the use of sago in this village is important as a material for daily life rather than as food. The sago owner has a 25% share and the worker a 75% share in the sago starch extraction operation. About 200 kg of starch can be harvested from one sago, and this starch can be sold at 20 pesos/kg.

・Sago starch extraction method:

First, cut the sago from the base, split the fallen stem in half, and extract the starch contained inside. The pith of the stem is pulverized with a hatchet (shaving ax). The crushed sago pieces are sprinkled with water to extract the starch. First, the device uses a dugout canoe as a container. Set the strainer on top of this. The device is a box made of a wooden frame placed on a woven bamboo plate (bamboo spread), and a filter net is spread on the bottom of this box, which serves as a filtering place. This device is called *Agahan*. The sago pith pieces are placed on the strainer and washed by hand with water, and the starch is collected in a boat-shaped vessel. This work revealed that the device was of the Malay type, but it turned out to be of the New Guinea type because the washing was done by hand. In other words, it was concluded that the two extraction methods were mixed.

Findings and Results

The sago palm, which originated in New Guinea, has created a culture of traditional sago palm use.

Table 1. Sago Palm Fact in 3 areas

Study area	farming condition	size of sago forestry	staple foods	sago starch use	palm use
Saga village (West Papua)	sago palm hunting-gathering	large, wider	sago starch	main staple foods surplus for sale	all parts
Kendari (S.E. Sulawesi)	sago slash-and-burn rice, maize, potato	middle, spotted	sago starch rice	staple food marketing	leaflet
Bisaya village (N.E. Mindanao)	paddy rice sago coconut palm	small	rice	confectionary	leaflet

In New Guinea, the place of origin of sago palm, a traditional system of utilization has been established by the indigenous people. As the sago palm spreads to various places, the usage of the sago palm changes to a form suitable for the growing areas (See Table 1).

The transformation of cultivars and the direction of the propagation of sago utilization patterns accompanying the spread of sago palms from New Guinea to the west show similar patterns (Nishimura, 2015).

・Coexistence with local agriculture associated with the spread of sago palms

Wild sago-growing areas are also isolated areas in humid areas. For this reason, other crops were unlikely to dominate in the sago palm forest, and people formed a lifestyle of gathering and hunting using the sago palm. The sago palm spreads and coexists with agriculture to cultivate crops in different environmental areas. The local people shared sago palms with rice, maize and tubers.

・Transition and transformation of starch extraction method

The traditional method of collecting sago starch is (1) cutting and dividing the sago palm into logs, (2) cutting the trunk pith into small pieces, (3) extracting starch by washing the small pieces of trunk pith with water, (4) draining the starch and packing it into containers, and (5) drying the wet sago into dry sago. Among these operations, the important works are the method of cutting/rasping with a piece of trunk pith and the method of washing and extracting this piece. These works have regional characteristics (See Table 2). Therefore, we considered a modification of this method. First, the pith piece work is a method of pulverizing the pith with a hatchet. There are standing and sitting methods of hand axing. In Papua and Mindanao, the standing method is seen, while in Kendari, the sitting method is seen. However, there are places where both methods are mixed. Also, in Papua they work in groups and in Kendari they work alone. This manual work has been mechanized and the introduction of crushers/rasper machine has become common. This made it more efficient.

Table 2. Patterns of sago pith crushing and starch extraction

Location	Sago pith crushing	Starch washing	Type
New Guinea	Chipping axe	Hands	New Guinea
Malaysia(Kalimantan)	Grater	Feet	Malay
Sulawesi Island	Chipping axe	Feet	Intermediate
Philippines(Mindanao)	Chipping axe	Hands	Mixed

Source: Nishimura and Laufa (2002)

There are two starch extraction methods which are hand rubbing and foot rubbing. In Papua and Mindanao, it is a hand rubbing, and Kendari is a foot rubbing. Foot rubbing is considered to be more efficient than hand rubbing. Therefore, it is considered to be a method implemented in areas where commerce is developed. However, recently, an efficient method of applying high water pressure by a pump has become widespread in both hand-rubbing and foot-rubbing methods. Therefore, as the traditional extraction method of Papua spread to the west, it became more and more important as a product, and it turned into an efficient work system. Therefore, as the traditional extraction method of Papua spread to the west, it turned into an efficient work system by increasing the weight of commercial product (Nishimura, 2018).

・Transformation of sago starch extraction (production)

In Saga village, the work of collecting/extracting sago starch is a self-sufficient type that is done by families. Men are in charge of cutting palms and making pith pieces, and women are in charge of extracting starch from the pieces. At Kendari, work is done in small groups. Also, sago starch is produced mainly for sale, although it is also self-consumed. The work is led by the leader of group. In the Bisaya villages, the groups work to extract starch, which is consumed in the village for festivals or occasion. This is done by working in groups.

In this way, as the village's economic activities progressed, the working systems are shifted from a family to a small group work, and a production system is developed more for sale.

・Transition and transformation as a staple food

Sago starch is an important staple food in production areas, but it is also eaten as a side dish or confectionery, however there are regional variations. In Papua, sago starch is the staple food, but in Kendari, it is one of the staple foods in combination with rice. However, it is no longer a staple food in Mindanao. Therefore, when a staple food other than sago becomes available, they tend to switch to it. In particular, the combination of sago and rice is not limited to Kendari, and this trend is gradually becoming in Saga of Papua.

・Changes in how starch is used

In addition to staple food, sago is also used as a side dish and confectionery, and in every region a wide variety of products are devised and made. As more ingredients for local cooking became available, the variety of sago dishes and confectionery to be made also increased, and they shifted to selling them for commercial use. In other words, there will be a shift from self-consumption to sales. However, in the course of this commercialization, it becomes necessary to process the form of sago starch from wet sago to dry sago. Transform into a form more suitable for sale. In Mindanao, sago starch is mainly eaten as a sweet for festivals.

・Use of plants

Sago palm uses not only starch production but also most of the plant body. In areas such as Papua that depend on sago palm, most parts such as leaflets, petioles, trunks and bark are used. It is often used as a construction material for houses. However, in areas such as Kendari and Mindanao, parts of the plant are collected for commercial use, subjected to simple care (processing), and sold. Since the leaves are used as materials for roofs and walls, they are woven and sold as sheets. In Mindanao, the use of sago palm for sale as leaflet mat is more important than the use of starch.

Discussion and future utilization in traditional rural areas

From this survey, we can say that the changes in the traditional use of sago palm in rural areas are as follows.

As a first step:

In traditional farming villages with wild sago forests, sago starch is the staple food, ensuring a stable life for the people. However, the situation changes greatly due to the economic transformation of the village. In particular, the value and position of sago change due to the development of distribution system and penetration of the money economy. This presents a choice between sago starch becoming a food product for subsistence consumption or transitioning to a starch intended for sale. The following selections will lead to the diversification of the village diet/meal by including staple foods other than sago starch. In other words, when the money economy permeates the village, it can be seen that the production system will shift to a production system that sells sago starch.

Therefore, the production method will also change to a more rational form. Examples of transformations for sales purposes are the introduction of rasper as a mechanization of sago palm-pith fragmentation and the introduction of a pump that uses water pressure for washing in starch extraction. As a result, the sago starch extraction work will be able to efficiently produce a large amount as a specialized business for sales.

In traditional villages, the use of sago changed from self-sufficiency to sales purposes. This transformation will lead to the modernization of the village.

As a second step

In villages where the staple food is not only sago starch but also rice, etc., sago starch is used not only as a staple food but also as a side dish and sweets. Confectionery is also produced in the first stage, which is mainly for the staple food of traditional villages, but the variety is limited. The reason is that there are few seasoning ingredients such as oil when making confectionery, and this is because the economy and logistics infrastructure are not advanced.

If a village has two staple foods, such as sago palm and other rice, the food valuation will increase and the opportunities for sago as a staple food will decrease. However, due to the influence of food diversification, the use weight of side dishes and confectionery using sago starch increased. Then, the production of confectioneries for sale became popular, and people and groups specialized in making confectioneries using sago starch appeared.

As a third step

As the use of sago expands, sago starch is consumed not as a staple food but as a side dish or confectionery due to the activation of economic activities in the village. Generally, the staple food is rice, other cereals and potatoes that can be produced in a short period of time. If there is a custom to eat sago starch in the area, it will be used as a meal for ceremonial occasions. As a result, the consumption of sago starch will decrease and rice and corn will dominate. Instead, the leaflets and other features of the sago palm are sold as durable construction materials.

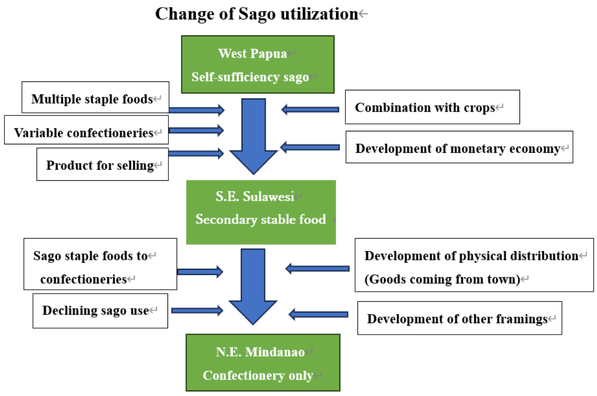

Fig. 3. Flow of sago utilization changes in the areas

As mentioned above, the traditional use of sago in farming villages will change along with the development of the local economy and society (See Fig. 3).

Conclusion

In the future, when the area around the sago palm forest is developed and the distribution of goods moves due to economic development, the position of sago will change. As a result, we believe that the direction of sago palm utilization will be concentrated in two directions. In other sago palm growing areas, the demand for sago palm is expected to decline. We consider this polarization to be as follows. So how are we going to deal with this in the future?

1) Production of starch that can compete with international prices.

It is thought that the industrialization of sago starch will progress in areas where sago palm forests are widely distributed. Since there are enough resources, the factory was designed to centralize starch extraction and improve processing efficiency by installing large-scale facilities. In particular, it must be of better quality than other starches, be cheaper, and be available in large quantities. In addition, easy access to production area and consumption areas is also required. However, in order to commercialize sago starch as starch, it must be cheaper than starches such as cassava, corn, and potato, and must be competitive. If it is found that sago starch has a unique effect/use, we believe that the form of industrialization will change greatly. In addition, if large-scale industrialization is to proceed, it will be necessary to adopt measures that enable sustainable management, such as planting trees, and to implement policies to compensate for the destruction of the environment that accompanies industrialization.

2) Maintaining of sago palm culture (sago palm farming and tourism) calling Sago-agritourism

This survey revealed that the need for sago will decrease in areas with sago palm forests as the economy develops and changes in people's diets occur. Therefore, it is necessary to carry out activities to maintain the sago palm culture considering the conservation of the sago palm and the connection between people. To this end, we propose Sago-agritourism. This plan considers sago palm as a comprehensive activity for regional development. A similar activity has already been carried out by Prof. Y.B. Pasolon's group in Kendari. This outline is shown in the figure (See Fig. 4). It is a comprehensive plan to ensure the diversity and sustainable use of sago palm, environmental conservation and economic activities. As mentioned above, it is considered to be aggregated into two ways.

Fig. 4. The model area of Sago agritourism in Kendari

Conclusive recommendation:
Future value and development of sago palm

This report clarified the relationship between sago palms and people in the future.

As globalization increases the movement of people, goods, and money, the area around sago palm forests will be developed, and the position of sago palms will change. Either the sago palm can take over the international starch industry, or other uses for the sago palm can be found. Therefore, we think that the direction of sago palm utilization will be concentrated in two directions. Other sago palm habitats are expected to fall victim to development and decline as the demand for sago palm decreases.

1) Business development of sago starch to a position of superiority in the international starch industry.
2) Local villagers will work on the use of sago palm in a way that integrates environmental issues, economic efficiency, and sustainability.

It is thought that sago palms will be decline in other sago palm habitats.

References

Ehara, H. 2015 Geographical origin, dispersal and distribution of the true sago palm. pp.17-22. *In*: The Society of Sago Palm Studies: The sago palm. Kyoto University Press. Kyoto.

Nishimura, Y. 1995[a] Agriculture in the villages of Southeast Sulawesi, Indonesia – Part1: The Inter-village variations in food production and consumption. Sago Palm 3:55-61. (Japanese)

Nishimura, Y. 1995[b] Agriculture in the villages of Southeast Sulawesi, Indonesia – Part2: The role of sago exploitation in household and village economy. Sago Palm 3:62-71. (Japanese)

Nishimura, Y. and T. M. Laufa 2002 A study of traditional used for sago starch extraction in Asia and the Pacific. pp.211-218. *In*: Kainuma, K., M. Okazaki, Y. Toyoda an J.E. Cecil(eds.), New Frontiers of Sago Palm Studies: Proceeding of the International Symposium on SAGO. Universal Academy Press, Tokyo.

Nishimura, Y. 2008 Present sago palm situation in Mindanao, Philippines. Proceeding of the Conference of the Society of Sago Palm Studies,31-36. (Japanese)

Nishimura, Y. 2015 Starch extraction and production: Traditional extension methods pp235-242. *In*: The Society of Sago Palm Studies: The sago palm. Kyoto University Press. Kyoto.

Nishimura, Y. 2018 Sago starch: Transformation of extraction and consumption processes in traditional Indonesian Societies. pp221-229. *In*: Ehara, H., Y., Toyoda and D.V., Johnson, Sago Palm: Multiple contributions to food security and sustainable livelihoods. Springer open.

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Possibility of Up-scaling Sago Production in Sepik Area, Papua New Guinea

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Abstract
The Food and Agriculture Organization of the United Nations (FAO) and four members of Society of Sago Palm Studies (SSPS) joined a technical cooperation project (TCP) titled, 'Enhancing food security and combating climate change through scaling-up sago production', and conducted researches in Papua New Guinea in collaboration with FAO Papua New Guinea Office. Among several suggested sites, two sites near Wewak, the capital city of East Sepik Province, have been chosen for the project. Preliminary research was conducted by three research members in August 2022, and they decided to carry out two things for up-scaling sago production; 1) to establish nurseries and to apply seed propagation method in order to increase the rate of germinating, 2) to introduce rasping machines for grinding sago pith tissues into small pieces in order to increase starch extraction efficiency. In November 2022, three members visited the research sites, and they gave the villagers instructions for making nurseries and seed propagation method. In addition to this, the research team organized a workshop titled 'Sago Planting Materials' in Wewak city, gave instructions for growing sago to local people. After that, the people in one of the research sites, following the advice from the research team, finished making a nursery in their village, which would be the first sago palm nursery in Papua New Guinea. They began to grow sago seeds with seedling bags in the nursery for seed propagation. A rasping machine was introduced in May, 2023. In this project, the authors found a possibility of up-scaling sago production in this area, while they found some social and cultural aspects they have to consider in carrying out the project.

Key words: Nursery, Papua New Guinea, Seed Propagation, Social aspects

Introduction

Papua New Guinea (PNG) has a large resource base of sago with over 1 million ha, and almost 30 % of its total population consider sago as staple food. The rate of sago as the major food staples is around 10 %, although it is gradually decreasing. Traditionally sago making has been the mainstay of low and wetland communities of PNG, and played a significant cultural role as a commodity of trade or were used in barter exchanges for other foods or goods (Temu and Saweri 2001). Almost all sago starch in PNG is produced on a subsistence level, and commercial cultivation is virtually nonexistent (Pue 2018). Compared with the situation in Indonesia and Malaysia, it is not yet widely commercialized.

FAO, who acknowledges food security and climate change are urgent issues, considers that sago (*Metroxylon sagu* Rottb.) is an underutilized indigenous crop that is well adapted to PNG conditions, and that it has great potential in addressing the food insecurity status of the country. Therefore, FAO considers that scaling up sago production would be one of the effective ways to combat climate change and tries to find ways of upscaling sago production. The PNG office of FAO asked the Society of Sago Palm Studies (SSPS) to provide technical assistance that could enhance the production of sago, training and post-harvest management, processing and value adding technologies.

It is reported that the total annual amount of sago in PNG is estimated to be around 100,000 mt (Gibson 2001). Considering the total space of growing area is around 1 million ha, however, there is scope for more sago production. If the area has 20 stands of sago per ha, and if we expect 50 kg per stand, then 1 mt per ha is possible, which leads to the total amount of 1,000,000 mt (Pue 2018).

After the PNG office of FAO and SSPS consulted the possibility of technical cooperation project, it was decided that four members of SSPS, who have an experience of research on sago in PNG, would join the project. The members are, Ehara, Toyoda, Naito and Mishima. The title of the project was 'Enhancing food security and combating climate change through scaling-up sago production'. The objective of this project is to provide technical assistance to enhance the production of commercially viable sago palm nurseries to cater to large-scale plantings, training the sago-dependent communities on nursery development and management, harvest and post-harvest management, processing, and value addition technologies.

Due to the administrative affairs, the partner of the agreement was made not with SSPS, but with Tokai National Higher Education and Research System (TNHERS), which includes Nagoya University, to which the leader of the project, Ehara, belongs. The project is supposed to be conducted from August 2022 to August 2023 in collaboration with FAO Papua New Guinea Office.

This paper is a report of the activities of the current project and the authors discuss the social and cultural issues they face with, when conducting the project.

Methodology

One of the authors, Toyoda, has been conducting anthropological research on sago in Papua New Guinea for some 30 years, and the contents of this paper is partly based on this experience. In that sense, the research of this paper was conducted with anthropological fieldwork. Also, interview with those local people who are involved with sago growing was conducted with semi-structural method.

Another methodology was the Rapid Rural Appraisal (RRA), which was used while staying in the field area, in order to assess the utilization of sago in Sepik area and the potential for commercial utilization of sago starch, based on interviews with many local people.

Purpose of the Project

After discussion between FAO PNG Office and the research members, the purpose of the project has been decided. The letter of Agreement was exchanged between FAO PNG Office and TNHER, and it says the purpose of the project as follows;

Outcome

The Services will contribute to the following outcome:

Increased sago production through improvement of cropping, management, and value addition practices in the three targeted locations.

Outputs

The Service Provider (TNHERS) will produce, achieve or deliver the following outputs:

1) Implement an improved sago cultivation system in the selected locations in the provinces;
2) Increase sago production (sago palm production) through community-based cropping, management, and value addition practices in the targeted locations;
3) Improved post-harvest management practices and value addition methods introduced to the farmers in the targeted provinces;
4) And develop sago palm cropping and management capacities of farmers and technical staff in the targeted provinces at the national, provincial and community level.

Activities

The Service Provider (TNHERS) will undertake the following activities:

1) Conduct survey and assessment of cropping and or production system in targeted provinces;
2) Set about the work for establishing sago palm nursery in the targeted provinces;
3) Set about the works for establishing 2-3 community-sago based household food security and income generation program
4) Conduct capacity training on cropping and management of sago palm for increased sago yield;
5) Conduct capacity training on mechanized improved harvesting practices and post-harvest management practices; and
6) Conduct capacity training on downstream processing of sago starch.

Research Site

To complete the project, the authors decided to arrange 4 trips to the research areas. In August 2022, they had a first visit to PNG, and they decided to conduct preliminary research during the 1st visit. First, the authors had a meeting with the landowners of the areas, and explained the objectives of the projects to them beforehand, and got a permission from them to conduct the project.

Among several suggested sites, two sites near Wewak, the capital city of East Sepik Province, have been chosen for the project. Later it was found that one of these two sites were to be considered as 2 villages, and 3 villages have become project candidates. Preliminary research was conducted by three research members in August 2022.

Activities of the Project

The authors planned to upscale the sago production through their technical assistance, based on their experience of previous research in Papua New Guinea. For the project, some provinces are planned as candidate sites from the office of FAO PNG Office, and among these provinces, the authors have chosen East Sepik Province, where sago is the staple food, and the authors can expect that the result of the project will contribute directly to the people's life in this province. Later, Manus Province was added to the project site, and additional activities were conducted in August 2023.

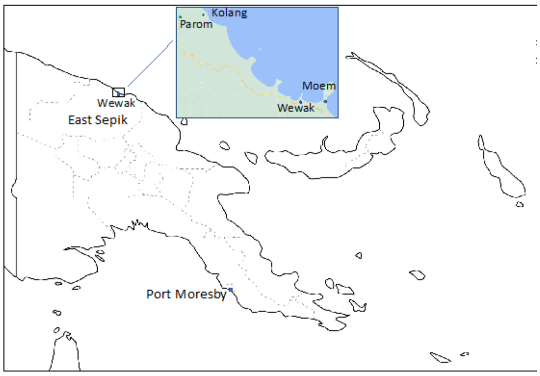

Fig. 1. Map of research sites in East Sepik

During the 1st visit, the authors had a look on some of the candidate sites, and finally, they have chosen 2 villages for the research sites, which were Moem and Parom (Fig 1). The authors had a talk with local people, and they decided to carry out two things for up-scaling sago production; These are , 1) to establish nurseries and to apply seed propagation method rather than vegetative one for efficient propagation of planting materials. 2) to introduce rasping machines for grinding sago pith tissues into small pieces in order to increase starch extraction efficiency.

In order to increase sago production, first, the authors planned to establish nurseries and to apply seed propagation, not vegetative propagation, which is through using suckers. It is reported that the rate of growing through seed propagation is better than using suckers (Ehara (2006), Ehara et al. (1998, 2001, 2006), Naito et al. (2006), Takagi et al. (2019). Therefore, the authors expected that they can expect more efficient sago growing with this approach.

As for the rasping machines, they are widely used in Malaysia and Indonesia for small-scale farmers. But in PNG, they have never been used so far. The people in PNG get sago starch mostly by scrapping by hands, mixing with water. Therefore, by introducing rasping machines, the authors expected that the procedures of grinding sago pith will be easier, and also more efficient, since the rate of starch extraction through rasping machines is better than the one through scrapping by hands. In order to introduce a rasping machine, the authors arranged importing one from Indonesia.

Before finishing the 1st visit, the authors suggested the villagers of Moem to build a nursery, and gave them a blueprint, specification, and some constructing materials. After the 1st visit, the authors received a report saying that the villagers of Moem people began to build a nursery for sago growing. Before the authors' second visit, they had almost completed the nursery.

In November 2022, three members conducted a 2nd visit to the research sites. During the 2nd visit, the authors conducted the following things;

1) To give instructions for seed propagation method to the villagers
2) To organize a workshop to give instruction to the villagers how to scale up sago production

As for the instructions for seed propagation, the authors showed the ways of seed propagation as follows;

1) Preparing clean seed after removal of seed coat tissues, pericarp (exocarp and mesocarp) and sarcotesta, from the fruit. To minimize practical work and save time, cutting of

husk of fruit (top part of husk above embryo) will be acceptable
2) Soaking the clean seed in enough amount of water (one seed/100 mL water) for a few days with frequent renewal of water (To save time or in case of husk cut fruit, the soaking process will be skipped.)
3) Planting the seed/husk cut fruit one each in a pot (seedling bag) filled with soil at an angle of embryo by 90 degrees to the soil surface
4) Covering the seed /husk cut fruit with soil up to the seed/fruit
5) Supplying water well every morning and/or evening considering atmosphere
6) Recording the growth (appearance of each organ) especially the number of leaves to consider preferable timing for transplanting (As basic information, leaflets will appear from the third leaf stage)

The authors also organized a workshop titled 'Sago Planting Materials' in Wewak city, and gave instructions for growing sago to local people. In the workshop, 21 local people from the province joined in the discussion. In the Q&A session, a lively discussion was held between the participants and the team members.

After the 2nd visit, the people in Moem village finished making a nursery in their village, which was the first sago palm nursery in Papua New Guinea, and began to grow sago seeds with seedling bags in the nursery for seed propagation.

The rasping machines were introduced in May, 2023. It was used just for demonstration to show its possibility to the local people and is not yet used regularly. The effect of the introduction of rasping machine is, therefore, not yet evaluated at the time of July, 2023.

Fig. 2 Sago Nursery and Seedling of Sago in Moem

When the authors had a 3rd visit in May 2023, they did not have enough time because of the delays of air flights and they had only a ceremony of opening a sago nursery, and also a demonstration of using a rasping machine (Fig. 3) to the villagers.

Fig. 3 Rasping machine of sago introduced in Moem Village

Conclusions

As the result of the authors' activities,
1) The people of Moem village have constructed a sago nursery as a community.
2) They learned a way of seed propagation of sago and began to grow sago seeds in a nursery.
3) The people of other areas in East Sepik Province got interested in constructing sago nurseries and a landowner of Sepik River area began to construct one.
4) Not only Moem people but also the people of surrounding area joined a workshop and got lectures of growing sago efficiently.
5) The Moem people got a rasping machine and they are ready to use it.

Therefore, the authors found a certain amount to possibility of up-scaling sago production in East Sepik Province, Papua New Guinea.

Discussion

As the activities of the project shows, the authors found a possibility of up-scaling sago production in this area in that showing the ways of seed propagation and introducing a rasping machine. But at the same time, some social and cultural aspects to be considered were found when the authors are carrying out the project as follows;

1) Issues of management

To keep the project going, the people have to manage common properties, such as nurseries and rasping machines, and other equipment. But they have little experience of managing these things. The issues are: who will hold these properties, and, if someone wants to use them, who will handle the procedures. Also, to maintain these facilities, they need some cash for repairing and fuels, and the problem is who will pay for that.

2) To keep the people motivated to continue the project is not easy

The authors introduced these two approaches, seed propagation and introducing rasping machines. The efficiency of rasping machine is easy to understand, but the results of new propagation method is not easy to understand. The timing of getting starch is some 10 years after they plant seeds, and far ahead. Therefore, it will not be easy to keep the people to continue the project. In order to keep people motivated, continuous guidance might be necessary.

3) Financial problems

When the authors start the project and also keep the project going, they need some funds for that. With this current project, the authors provided the local people building materials for constructing nursery, and also a rasping machine. But when the authors leave the project, the local people have to manage with their own funds for that. Not so many people have such enough funds to keep the project going.

Therefore, the authors found that there is a possibility of up-scaling sago production, but at the same time they are facing these social and cultural problems.

References

Bourke and Harwood 2009 Agricultural Systems of Papua New Guinea, National Statistics Office, Port Moresby.

Food and Agriculture Organization of the United Nations, Climate change and food security: risks and responses, 2015.

Gibson 200, In Bourke R.M., Allen M.G., Salisbury J.G. (eds) Food security for Papua New Guinea. Proceedings of the Papua New Guinea food and nutrition 2000 conference. PNG University of Technology, Lae, PNG, 26–30 June

2000. Australian Centre for International Agricultural Research (ACIAR), Canberra, pp 395–406.
King, D. and S. Ranck (eds.) 1982 Papua New Guinea atlas. A nation in transition. Papua New Guinea: Robert Brown Assoc.
Temu P.I., Saweri W., 2001 Nutrition in transition. In: Bourke R.M., Allen M.G., Salisbury J.G. (eds) Food security for Papua New Guinea. Proceedings of the Papua New Guinea food and nutrition 2000 conference. PNG University of Technology, Lae, PNG, 26–30 June 2000. Australian Centre for International Agricultural Research (ACIAR), Canberra, pp 395–406.
The Society of Sago Palm Studies, 2015 The sago palm—the food and environmental Challenges of the 21st century, Kyoto Univ. Press.
Toyoda, Y., R. Todo, & H. Toyohara, 2005 Sago as Food in the Sepik Area, Papua New Guinea, SAGO PALM Vol.12(2), 2005:1-11.
Toyoda, Y. 2008 Anthropological Studies of Sago Palm in Papua New Guinea. Rikkyo University Centre for Asian Area Studies, Occasional Paper No. 13.
Pue, J., M. T. Fletcher, B. Blaney, A. R. Greenhill, J. M. Warner, A. Latifa, and J. C. Ng, 2018 Addressing Food Security in Papua New Guinea Through Food Safety and Sago Cropping. In Ehara, H., Toyoda, Y. and D. V. Johnson (eds.), Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods, Springer.

Potential Study of Sago Dregs Waste as Renewable Energy: Quality and Economic Value of Sago Dregs Briquette Production

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Abstract Currently, the world's energy consumption tends to depend on fossil fuels. Renewable energy is still underdeveloped. Indonesia has the potential to develop renewable energy, especially from the field of biomass. One of the Biomass is sago dregs waste (*repu*) which can be processed into briquettes. Sago dregs briquettes can be used as an alternative fuel that can be a solution to the energy crisis. Economically, sago dregs briquettes can be a very potential business. Making sago dregs briquettes can be done with the simplest technique. For this reason, it is necessary to carry out a calculation of economic value of sago dregs briquettes. This research was conducted using sago starch waste adhesive with a weight percentage of 5 % of the weight of sago dregs briquettes. The results of this study were that sago dregs briquettes had a moisture content of 9.74 %, ash content of 11.44 %, volatile matter content of 15.89 %, and calorific value of 4,598 kcal/kg. When compared with the quality of Indonesian national standard (SNI) 01-6235-2000 briquettes, sago dregs briquettes have not reached the specified quality standards. The results of calculating the economic value of production in local micro, small, and medium enterprises (MSME's) to produce sago dregs briquettes with a capacity of 1,350 kg, total income per month is IDR.5,461,865 with a net profit is IDR 243,000. The cost of goods sold sago dregs briquettes is IDR 4,045/kg and the new selling price that can be offered to consumers is IDR 4,225/kg. In this calculation, the break-even point (BEP) value per unit of sago dregs briquettes in one month is 1,255 kg while the payback period is 22 days.
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Keywords: Economic value, Renewable energy, Sago dregs briquette

Introduction

Indonesia is a country facing serious energy problems because of its high dependency on fossil fuels. Despite paying little attention to alternative energy development, Indonesia has considerable potential to develop renewable energy. For example, by utilizing sago waste as bioenergy. Sago (*Metroxylon sagu* Rottb.) is a monocot plant from the *Palmae* family, genus *Metroxylon,* and order *Spadiciflorae*, including carbohydrate-producing plants that are useful in supporting food security programs in Indonesia (Tarigans, 2001). Sago plants ranging from leaves to stems can be used, the leaves can be used as roofs, the midrib can be made into handicrafts and the stems can be processed into sago starch. Utilization of sago at this time can be processed into food additives, animal feed, industry, fertilizers, pharmaceuticals, and sources of raw materials in product innovation to address environmental problems (Murod, 2018).

The area of sago plantations in Indonesia is one of the largest in the world, more than 50 % of the world's sago area is in Indonesia with production in 2021 will reach 381,065 t (Badan Pusat Statistik, 2021). Riau Province is the largest contributor to sago starch production in Indonesia reaching 274,807 tons in 2021, of which more than 85 % of the supply comes from Kepulauan Meranti Regency with a record production of 243,708 tons. The prospect of developing the sago business in Kepulauan Meranti Regency has a great opportunity to increase food security and the national economy. Viewed from a geographical aspect.

Kepulauan Meranti Regency is very strategic, because it is close to neighboring countries, namely Malaysia and Singapore as the country's export destinations. Until now, it has been recorded that 95 sago refineries have been established in legal companies, which has resulted in the addition of new jobs in Kepulauan Meranti Regency. This sago dregs briquette industry was developed by a research team of sago dregs briquettes, Environmental Engineering Study Program, Riau University. Good quality briquettes have a calorific value of 20,055 J/kg while poor quality briquettes have a calorific value of 12,293 J/kg (Supriyatno and Merry Chrishna, 2010). Syamsiro et al. (2020) said, from an economic analysis, that making briquettes from sago dregs is a very potential business. This is because sago waste is currently the main contributor to pollution in the sago processing industry. Today's society really wants stable fuel prices and supplies. So, it is necessary to carry out a calculation of economic value for the process of producing sago dregs briquettes, so that it is suitable for use by the community as an alternative fuel to replace fuel oil.

Research Methods

The implementation of this research consists of 2 stages:

1) Making briquettes and analyzing the quality of briquettes (proximate analysis).
2) Calculation of cost of sales, break-even point, and cost analysis (economic aspect).

a. Briquette Making Process

The raw material to be prepared is sago dregs resulting from industrial processing of sago starch (Sentra IKM Sagu) location in Sungai Tohor, Kepulauan Meranti Regency which is collected and cleaned of impurities. continued through the carbonization process in a furnace burning sago waste waste into charcoal, which is indicated by the appearance of white smoke from the top of the can. Then reducing the size of the material is done by using stone collisions. The results of the reduced material are sifted with a 50 mesh. The selection of the sieve size for each of these materials is based on the statement Pancapalaga (2008), sifted dry sago dregs with a pass size of 50 mesh. The filtered ingredients are then mixed with an adhesive treatment with sago starch binder.

The binders contain sago starch are mixed with as much as 30 % of the weight briquette dough (sago dregs) to form a rather dry dough. The briquette mixture that has been mixed with the binder is put into a cylindrical mold with a diameter of 2.8 cm and a height of 4 cm. Molding process using machine pressure based on Kurniawan (2017) with a pressing force of

100 kg/cm^2.

The next step is to dry briquettes with sunlight for 6 days, the aim is to reduce the water content in the briquettes. So that the briquettes burn quickly and do not smoke. Briquettes are not dried in an oven because temperatures that are too high can cause the concrete to crack.

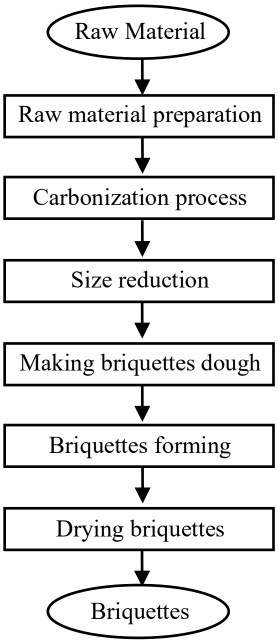

Fig. 1. Sago dregs briquettes production flowchart

b. Process testing and analysis briquettes

The briquette testing stage is the stage of testing the characteristics of the briquettes to find out whether the resulting briquettes are of good quality according to SNI, the test steps (proximate analysis) carried out include moisture content, ash content, carbon content, volatile matter content, and calorific value. The stages involved in research, concept development, or case resolution are written in the methodology section.

Results and Discussion

1. Quality of sago dregs briquette

Briquettes are a material in the form of powder or small pieces compacted using a press machine with mixed adhesive thus producing a shape compact (Faijah et al., 2020). Sago dregs briquettes that have been made based on the treatment adhesive formulation from sago starch are then carried out a proximate analysis to determine the quality of the briquettes produced.

Table 1. Results of briquette analysis and comparison briquette quality based on SNI 01-6235-2000.

Parameter	SNI (01-6235-2000)	Adhesive (Sago starch)	Information
Moisture content (%)	Max 8	9,74	Not eligible
Ash content (%)	Max 8	11,44	Not eligible
Volatile Matter content (%)	Max 15	15,89	Not eligible
Calorific value (cal/g)	Min 5,000	4,598	Not eligible

1.1 Moisture content

Moisture contained in the sago dregs briquettes is 9.74%. Based on the results of the moisture content test and the calculations that have been carried out is not eligible. show that the moisture content of the briquettes using sago starch adhesive has a fairly large water content exceeding the applicable standards set out in SNI 01-6235-2000 where the maximum moisture content is 8 %. Pancapalaga (2008) said the high water in sago binders is because sago has many pores and still contains chemical constituents such as cellulose, lignin, and hemicellulose.

Moisture content in briquettes is very influential on the calorific value and the process of lighting a fuel briquette. The moisture content affects the quality of the briquettes resulting from. The lower the moisture content, the higher the calorific value (Nurmalasari and Afiah, 2017). Lestasi et al. (2015) explain, on the other hand, the higher the water content, the decrease in calorific value.

1.2 Ash content

Ash is the residue from combustion, in this case, ash from burning briquettes. One of the ash components is silica which adversely affects the calorific value of the resulting charcoal briquettes. The ash value of sago dregs briquettes is 11.44% (not eligible). The high ash content is caused by the carbonization process which tends to be weak and uneven because the water content in the waste waste is quite high. The high ash content makes the ignition process difficult.

This ash can reduce the calorific value and cause scale on the equipment so the permissible percentage of ash is not can be too big. The higher the level of ash, causing lower the briquette quality so that the resulting calorific value decreases. An increase in ash content can be affected by the increase in the concentration of the adhesive and the type of adhesive used This statement is supported by Faijah et al. (2020) said the best briquette formulations with low ash content were made using adhesive based on sago starch with the lowest concentration.

1.3 Volatile matter content

Meanwhile, the volatile matter content obtained from the sago dregs briquette test was 15.89%. Based on SNI 01-6235-2000, the value of volatile matter content in sago briquettes is still quite high and is not eligible. Volatile matter in a briquette is a substance that can be vaporized as the decomposition of remaining compounds contained in charcoal besides water, carbon bonds, and ashes.

Research results put forward by Purnomo et al. (2015) explain starch contains a lot of organic matter such as carbohydrates which improves the content of volatile substances such as CO, CO_2, H_2, CH_4, and H_2O in briquettes because ingredients containing carbohydrates are not caught fire in the process burning. Different types of adhesives affect the amount of volatile matter in briquettes. Volatile matter in making briquettes is expected as low as possible so that the smoke produces briquettes at the timeless burning.

1.4 Calorific value

The calorific value greatly affects the quality of the briquettes. The higher the calorific value, the higher the quality of the briquettes produced. The lowest calorific value was obtained when the briquettes were given a sago binder of 4,598 cal/g (not eligible). Briquettes with sago binder had a higher calorific value due to higher water content and ash content. This is the same as Nurhayati (1974) in Masturin (2002), where the calorific value is affected by the moisture content and ash content of the briquettes.

Anizar et al. (2020) said calorific value is the most important parameter in the manufacture of fuel. The calorific value can determine the quality of briquettes. Calorific value is a very decisive quality of the briquettes produced. The higher the calorific value, the higher the quality of the briquettes resulting from. Necessary calorific value is analyzed to find out the value of possible combustion heat produced by briquettes as an ingredient burn (Nurmalasari and Afiah, 2017).

2. Calculation of economic value

Calculation of economic value is very important in supporting the continuity of production. Hamid (2023) explained prospects for the briquette business in efforts to assist and empower the community towards a circular economy indicating that the opportunities and prospects for the existing briquette business can have a significant circular economic impact on society to improve family welfare.

Fig. 2. Local MSME's sago dregs briquette production

From an aspect Economically, briquette processing is relatively simple and is carried out by small and medium-scale businesses. Machmud (2011) said, financial limitations, access to information limited market and market uptake as well as quality that does not meet requirements, are constraints and problems in developing a briquette production industry. So, we need a clear and correct analysis of economic calculations.

2.1 Cost of goods sold

The cost of goods sold is obtained by adding up all costs incurred by the local MSME group for one month. The daily production capacity is 45 kg and the annual production capacity is 1,350 kg/month. The following data to determine the cost of goods sold can be seen in Table 2.

Table 2. Calculation of the cost of goods sold sago dregs briquettes 1,350 kg/month in May 2023.

Cost Description	Cost Per Month (IDR)
Fixed cost:	
• Building & land tax 100 m^2	32,865
• Fix 2 employee salary	4,000,000
• Electrical energy 1,300 VA	500,000
• Insurance 2 employee	77,000
Variable cost:	
• Raw material	400,000
• Daily worker wages	150,000
• Equipment Depreciation	200,000
• Distribution product	100,000
Total	**5,461,865**
Cost of sales	**4,045**

Table 3. Calculation profit sago dregs briquettes per month (capacity 1,350 kg if market price IDR 4,300/kg)

Cost description	Value per month (IDR)
Total income	5,805,000
Total cost	5,461,865
Gross profit from revenue	343,135
Marketing cost	(100,000)
Net profit per kilograms	**180**

Based on Table 3, the market price of the briquettes is IDR.4,300 referred to Mulyati (2016). The new price for sago dregs briquettes is the cost of sales + net profit per kg = 4,045 + 180 = IDR.4,225/kg. This price is still below the market price, so there is a great opportunity to improve quality at a more affordable price.

2.3 Break-even point

The break-even point (BEP) is a situation where in the company's operations, the company does not make a profit and does not suffer a loss. Known that the fixed cost value is IDR.4,609,865 and the variable cost per unit is IDR 629. The break-even point for sago dregs briquettes per month is:

$$\text{BEP (Kg)} = \frac{\text{Fixed Cost}}{\text{Price – Variable cost per unit}}$$

$$= \frac{4{,}609{,}865}{4{,}300 - 629} = \mathbf{1{,}255\ kg/month}$$

2.4 Payback Period

The Payback Period in one month for investment in the business of making sago dregs briquettes is:

$$\text{Payback period} = \frac{\text{Investment}}{\text{Net profit}} = \frac{5{,}461{,}865}{243{,}000} = \mathbf{22\ days}$$

2.1 Cost analysis

Production costs indicate that briquettes from sago dregs are relatively cheap. This is because the selling price of briquettes per kg may still be affordable in general. The price of sago dregs briquettes can compete with the prices of other fuels, namely kerosene and gas. This shows that comparison briquettes made from sago dregs and other fuels can be seen in Table 4.

Table 4. Comparison of fuel consumption and costs of several types of household energy sources per month

Item	Kerosene (Oil)	LPG (Gas)	Sago dregs briquette
Price (kg or L)	11,000*	6,000*	4,225
Total Calories (Kcal/kg)	10,478	11,254	4,598
Energy demand (Kcal/kg)	44,000	44,000	44,000
Household demand (kg or L)	4.1	3.9	9.5
Total costs consumption (IDR)	**45,100**	**23,400**	**40,137**

Source: *Ministry of Energy and Mineral Resources Republic of Indonesia (2023)

If a household needs 4.1 L of kerosene per month, the calorific value of kerosene is 10,478 kcal, and the energy needed by this household is 44,000 kcal/kg per month. If the current price of kerosene is IDR 11,000 then the family needs energy costs of IDR 45,100 per month. The value of the energy requirement of kerosene is used as a basis for comparing calorie requirements of two different fuels: LPG and sago dregs briquettes. To meet the household's energy needs of 44,000 kcal/kg per month using LPG, the cost of energy consumption is IDR 23,400. By using briquettes from sago dregs, the energy consumption cost is only IDR 40,137 to meet the household energy needs of 44,000 kcal/kg. From the results of this comparison of energy consumption costs, using briquettes from sago dregs can be an alternative energy combined for other household activities, such as cooking food by burning, baking, or grilling process.

In addition to reducing dependence on non-renewable and unsustainable fossil fuels, the use of briquettes made from sago dregs production by local MSME group is a cost-effective energy source, especially for the lower-middle class economy. Mulyati (2016) Explained the development of alternative energy in this case is carried out to avoid an energy crisis happening with the supply of materials non-renewable fossil fuels running low and the price getting more expensive

Conclusions

From the results of the research conducted, it can be concluded that the ratio of starch adhesive with a concentration of 30% by weight of sago dregs waste briquette can be produced, but it still does not meet the standard quality requirements in SNI 01-6235-2000. Quality of sago dregs waste briquettes with sago starch binders was carried out by analyzing the moisture content of 9.74 %, ash content of 11.44 %, volatile matter value of 15.89 %, and calorific value of 4,598 kcal/kg. Calculation of economic value resulted has a very promising economic potential. The price sago dregs briquettes produced by local MSMEs is IDR.4,225 when production reaches 1,350 kg/month in a cost of production IDR 5,461,865 with a net profit is IDR 243,000. The break-even point (BEP) per unit in one month is 1,255 kg while the payback period is 22 days.

Suggestion

This research is basic research regarding the calculated economic value of briquettes production from sago dregs waste. There are still weaknesses and shortcomings in this study, so it is hoped that future researchers will be able to complete and perfect this research on briquettes from sago dregs waste. The availability of abundant, renewable, and sustainable raw materials is a huge capital for developing briquettes from sago waste as an alternative fuel to replace fossil fuels.

References

Anizar, H., E. Sribudiani and S. Somadona 2020 The effect of tapioca adhesive and sago adhesive on the quality of charcoal briquette from rind of Nipah. Perennial 16:11–17. (in Indonesian)

Badan Pusat Statistik. 2021. Sago production by province in Indonesia 2017-2021. Indonesian Statistics Center. pp. 3. (in Indonesian)

Faijah., R. Fadilah and Nurmila 2020 Comparison of tapioca and sago in the manufacture of Nipah rind (*Nypafruticans*) briquettes. Jurnal Pendidikan dan Teknologi Pertanian. 6:201-210. (in Indonesian)

Hamid, A 2023 Experimental Studies and Economic Analysis of Biomass-Based Briquettes. Journal of Energy and Technology Innovation (ENOTEK) 2:59–63.

Kurniawan, A 2017 Effect of Pressing Variation on Character Characteristic of Coconut Shell Charcoal. Thesis UNNES University pp. 37. (in Indonesian)

Lestari, L., V. I. Variani., I. N. Sudiana., D. P. Sari., W. O. S. Ilmawati and E. S. Hasan 2015 Characterization of briquette from the corncob charcoal and sago stem alloys. The 5th International Conference on Theoretical and Applied Physics 846:1–6.

Masturin, A 2022 Physical and chemical properties of charcoal briquettes from waste charcoal mixture. Thesis IPB University pp. 30. (in Indonesian)

Ministry of Energy and Mineral Resources Republic of Indonesia 2023 Conversion of Kerosene to Gas. Directorate General of Oil and Gas Republic of Indonesia. (in Indonesian)

Mulyati, M 2016 Techno-economic analysis of charcoal briquettes from dried leaf waste. Teknoin 22:505–513. (in Indonesian)

Murod, M., C. Kusmana., M. H. Bintoro., N. Widiatmaka and E. Hilmi 2018 Structure analysis of the contstraint sago sustainable management in Kepulauan Meranti Regency, Riau Province. Buletin palma 19: 101-116. (in Indonesian)

Nurmalasari and N. Afiah 2017 Sago bark briquettes (*Metroxylon sagu*) using tapioca starch adhesive and kapuk leaf extract (*Ceiba pentandra*). Jurnal Dinamika 8: 1-10. (in Indonesian)

Pancapalaga and Wehandako 2008 Evaluation of cow manure and agricultural waste (kosap plus) as alternative fuels. Thesis University of Muhammadiyah Malang. Pp. 43. (in Indonesian)

Purnomo, R. H., H. Hower and I. R. Padya 2015 Utilization of biomass waste for briquettes as alternative energy. Proceedings of the FKPT-TPI Agro-industry Seminar and National Workshop. B:54-67. (in Indonesian)

Supriyatno and M Chrishna 2010 Case study of alternative energy for environmental waste briquettes in campus POLBAN Bandung. National Proceedings Seminar "Kejuangan". Yogyakarta. (in Indonesian)

Syamsiro, M., M. N. Aridito and S. Maarif 2020 Potential application of sago briquette for electricity generation using gasification technology in Papua Province, Indonesia. Key Engineering Materials 849:20-26.

Tarigans, D. D. 2001. Sago strengthens self-sufficiency in food. Warta Penelitian dan Pengembangan Pertanian 23:1–3. (in Indonesian)

Triono, A 2006 Characteristics of charcoal briquettes from a mixture of African Sawdust (*Maesopsis eminii* Engl.) and Sengon (*Parasenrianthes falcataria* L. Nielsen) with the addition of coconut shell (*Cocos mucifera* L). Thesis IPB University pp. 30. (in Indonesian)

Widarti, Sarwono, R. Hartono 2007 Experimental study of organic briquettes with raw materials from PPL Seloliman. Thesis ITS University pp. 54. (in Indonesian)

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Impact of Ultrasonication Treatment on Resistant Starch (RS) Content and Characteristics of Sago Starch

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Abstract. Ultrasonication is a nonthermal technique widely used in food science and technology. Sago starch of three different varieties (*iwamuluk*, *iwayuluk*, and *iwasnan*) were subjected to ultrasonication (US) of 42 kHz at 30°C and 50°C for 15 and 45 min. The US untreated and treated samples were analyzed for resistant starch (RS) content, chemical component, and pasting properties. Starch granules were characterized by light microscopy and scanning electron microscopy. The results indicated that under US treatment, the RS content significantly increased from 1.08-1.56% (db) to 17.66–31.96%(db). *Iwayuluk* consistently produces high content of RS compared to the varieties of *iwamuluk* and *iwasnan*. Ultrasonic treatment induced cracks and pores in starch granules with small loose of maltese cross properties. The pasting properties of US treated were comparable with those of US untreated sago starch. This study provides insights into the future direction on the benefit of ultrasonication treatment for the modification of sago starch functional properties.

Key words: Resistant starch, Sago, Ultrasonication

Introduction

Sonication is a technique that apply the ultrasonic wave, covering the frequency range of low-energy (high frequency) diagnostic ultrasound (10 to 1 MHz), extended range ultrasound (1 MHz – 100 kHz), and power ultrasound (100–16 kHz) (Bonto et al. 2021). Sonication techniques offer wide applications on starch modification. It can be applied on either native starch granules suspended in solution (Rahaman et al. 2021; Sujka and Jamroz 2013; Zhang, Li, and Zhu 2018) or on starch after gelatinization (Liu et al. 2023). It was reported that in starch-water system, the physical effects (such as hole effect, mechanical effect, etc.) generated by ultrasonic treatment will produce strong shear force, high temperature and free radicals in the local area, which will change the multi-scale structure of starch, including formation of resistant starch/RS (B. Wang et al. 2023). The advantages of ultrasonication are higher selectivity and quality, less chemical usage, and processing period. Ultrasonication is also one of the advance technologies that are environmentally friendly, efficient, and usable in food (Bhargava et al. 2021). Ultra sonic (US) treatment can affect the physicochemical and functional properties of starch derived from different botanical origins as reported by several studies (Bonto et al. 2021; Rahaman et al. 2021).

Sago starch is produced from sago palm (*Metroxylon sagu*) trunk which is origin to Southeast Asia. Mostly, sago palm field was found in Malaysia, Indonesia, and Papua New Guinea (Ehara, Toyoda, and Johnson 2018). The tree is very immune to extreme conditions such as drought, flood, strong wind, and fire (Ehara, Toyoda, and Johnson 2018). Currently, sago starch has received more attention because of the sustainability of the crop (Karim et al. 2008). It also absorbs a large amount of CO2, mitigating the climate change and global warming (Singhal et al. 2008). Therefore, it plays a significant role in food security.

Unfortunately, sago starch is still considered as an underutilized starch due to its low functionality, especially as an ingredient for food products. Starch with high content of resistant starches (RS) can be considered to have a functional food property. RS provide several benefits due to the contribution on intestinal and colonic health, glycemic and lipid management (Bojarczuk et al. 2022; Purwani, Iskandriati, and Suhartono 2012; Purwani, Purwadaria, and Suhartono 2012). The RS can be developed by physical treatment of ultrasonication (US) as described by earlier researchers (Bonto et al. 2021; Liu et al. 2023; Noor et al. 2021). Limited published report was available on sago starch. Based on the above-mentioned condition, the study was carried out to examine the impact of high-power ultrasound of 42 kHz frequency on the formation of RS, morphological and physicochemical properties of sago starch.

Materials and Methods

The sago starch of three (*iwasnan*, *iwamuluk*, and *iwayuluk*) different accession was obtained from sago field at Sorong, West Papua Province, Indonesia. *Iwasnan* and *iwayuluk* were identified as spiny type with high yield productivity, while *iwamuluk* was not well identified yet. Sago was stored at room temperature, and it had moisture content of less than 10 %. The starch had amylose content of approximately 29.96% (*iwaluyuk*), 32.70% (*iwasnan*), and 33.42% (*iwamuluk*) respectively.

Ultrasound treatment

The ultrasonic treatment of sago starch granules was carried out by the ultrasonicator bath BRANSONIC 3510. Approximately 12 g of sago starch was mixed in 28 mL distilled water in a beaker. The treatment was carried out with frequency 42 kHz at temperature of 30°C for 15 min, 30°C for 45 min, 50°C for 15 min, 50°C for 45 min.

After the treatment, the solutions were cooled (4-5°C) in a refrigerator for 24 hrs and it was then decanted followed by drying in a oven dryer at 50°C for 1 hr and stored for further analysis. The samples were assigned as Ultrasonic (US)-untreated, US 30:15 (Ultrasonic treatment at 30°C for 15 min), US 30:45 (Ultrasonic treatment at 30°C for 45 min), US 50:15 (Ultrasonic treatment at 50°C for 15 min) and US 50:45

(Ultrasonic treatment at 50°C for 45 min).

Resistant starch analysis and proximate analysis

Resistant starch (RS) content was analyzed according to the method described by Goñi et al. (1996). Briefly, the procedure was described as following: sample, approximately 50 mg was mixed in 5 mL of KCl-HCl solution pH 1.5. The mixture was incubated with 4400 units of pepsin solution at 40°C for 60 min with constant shaking to remove the proteinous substances. Tris maleate buffer 0.1 M, pH 6.9 (4.5 mL) was added to the sample mixture and furthur incubated with 100 unit of amylase at 37°C for 16 h with constant shaking to hydrolyze the digestible starch, then centrifuged (1000 g for 15 min) twice, to discard the supernatant. The residue was moistened with 1.5 mL of distilled water and solubilized with 1.5 mL of KOH 4 M. RS solution was mixed with HCl 2 M and Na-acetate 0.4 M buffer, pH 4.75, then incubated with 100 unit of amyloglucosidase solution at 55°C for 45 min. Glucose formed in the supernatant (collected after centrifugation at 1000 g for 15 min), was determined using phenol-sulfuric acid method. RS content was calculated as glucose (g) 0.9 and was expressed as percent of RS in sample analysis.

Chemical component (moisture content, ash, proteins, and fat) was analysed according to the standard method of (AOAC 2019).

Scanning electron microscopy (SEM)

Sago sample of US untreated and treated were sprinkled thinly onto the specimen holder which had been coated with carbon tape and given a gold coating using the Sputter Coater (Quorum Q150R ES, Germany). Gold plating was carried out with a voltage setting of 20 mA for 60 seconds. The gold-coated sample was then mounted in a stage holder for analysis using a Scanning Electron Microscope (SEM) (ZEISS EVOIMA10, England). A series of pictures were taken using SEM at a shooting point of 8 – 9 mm and an EHT of 16 kV. 2.6.

Polarized light microscopy.

Polarized light microscopy was applied to examine the birefringes of the starch sample. Sago sample of US untreated and treated were taken using a spatula/spatula then dispersed on a glass object with 1 drop of distilled water then the sample was flattened until no water bubbles were visible on the object glass. The object glass is then placed on the preparation table/object table and the light is adjusted on the microscope until the sample of starch granule was clearly visible.

The pasting properties determination

Pasting properties of samples were analyzed using a Rapid Visco Analyzer (RVA). The sample (approximately 43%, db) was dispersed in distilled water and stirred in an RVA canister at 960 rpm for 10 seconds. The rotation speed was then lowered to 160 rpm until the end of the test. The test lasted for 20 min. The temperature used was 15°C at the beginning of the test until minute 2, then it was raised to a temperature of 95°C in minute 7 past 43 seconds and was held (at 95°C/constant temperature) until minute 10. After that, the temperature was then slowly lowered to 25°C in the minute 15 and was stable at that temperature until the end of the test in the minute 20.

Data analysis

The data were descriptively analyzed and reported as averages of triplicate observations. An analysis of variance with a significance level of 5% was established and Duncan's test applied to determine differences between means using the commercial statistical package (SPSS 16.0).

Results

Resistant Starch (RS) Content and Chemical Component

Table 1 showed the resistant starch (RS) content of US untreated and treated sago starch, while Table 2 presented the chemical component of US untreated and treated sago starch.

Table 1. Resistant starch content of ultrasonication untreated and treated sago starch.

Treatment	RS (%, db)		
	iwamuluk	*iwayuluk*	*iwasnan*
US-untreated	1.56 ± 0.39^a	1.08 ± 0.04^a	1.36 ± 0.01^a
US 30°C/15min	6.60 ± 0.42^b	7.02 ± 0.84^a	7.21 ± 0.01^b
US 30°C/45min	10.18 ± 2.24^c	17.06 ± 0.35^b	11.14 ± 0.11^c
US 50°C/15min	13.88 ± 0.45^d	29.46 ± 0.00^c	12.38 ± 1.03^c
US 50°C/45min	27.41 ± 1.23^e	31.96 ± 5.73^c	17.66 ± 1.87^d

Each value is expressed as the means ± SD (n = 3). Different letters in the same column showed significant differences (p=0.05).

Table 2. The chemical composition of US untreated and US treated sago starch at 50°C for 45 min

Composition	US untreated			US treated		
	iwamuluk	*iwayuluk*	*iwasnan*	*iwamuluk*	*iwayuluk*	*iwasnan*
Moisture (%)	9.52	9.56	9.49	9.92	10.02	11.82
Ash (% db)	0.18	0.23	0.21	0.22	0.19	0.19
Fat (% db)	0.24	0.18	0.05	0.07	0.01	0.03
Protein (% db)	0.68	0.76	0.71	0.61	0.72	0.23
Carbohydrate (% db), by different	98.90	98.83	99.03	99.19	99.17	99.60

Morphological properties

The surface morphology of RS and US-treated samples was analysed using scanning electron microscopy (SEM). Starch granule surface having holes/pores and fissures was noticed on US untreated and US treated sample. More pores was found on US treated sample than those of US untreated samples (Fig. 1). The pore was clearly observed when the SEM imaging was magnified at 2000 times. Pore formation was occurred consistently on all three-sago accession.

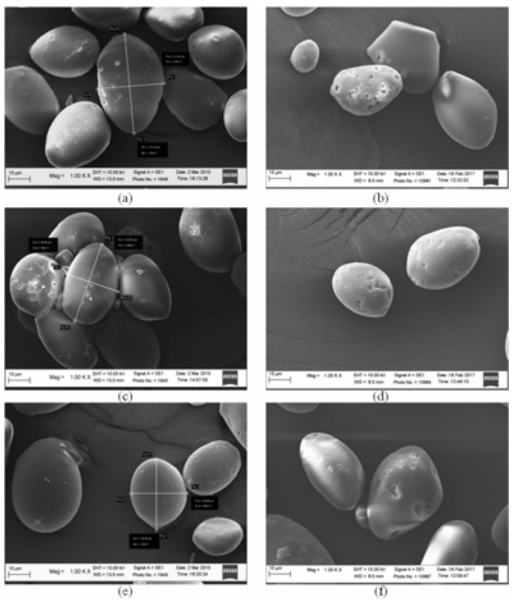

Fig. 1. Scanning electron microscopy micrographs of US untreated (left) and US treated sago: (a,b) *iwamuluk*, (c.d) *iwasnan*, (e,f) *iwaluyuk*.

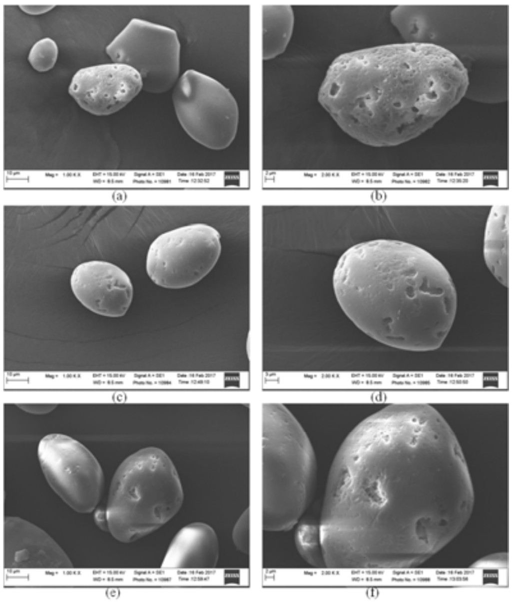

Fig. 2. Scanning electron microscopy micrographs of US treated at magnification of 1000 times (left) and 2000 times: (a,b) *iwamuluk*, (c.d) *iwasnan*, (e,f) *iwaluyuk*.

Under polarized light microscopy, sago starch of US untreated and US treated showed birefringence, with strong patterns at the granule centre's known as Maltese crosses. Native starch granules have a semi-crystalline structure, and the crystalline structure and the amorphous structure exhibited anisotropy in density and refractive index under a polarizing microscope, resulting in birefringence and exhibiting a unique characteristic of the Maltese cross (Xie et al. 2013). The appearance changes of the Maltese cross reflected the change in the crystal structure of the internal particles (Ji 2018).

This study showed that sonication treatment resulted in a small change toward the birefringence of the starch granule. Weak birefringence and fade luminance was observed on US treated sago starch especially on *iwayuluk* variety/accession, as shown in Fig. 3.

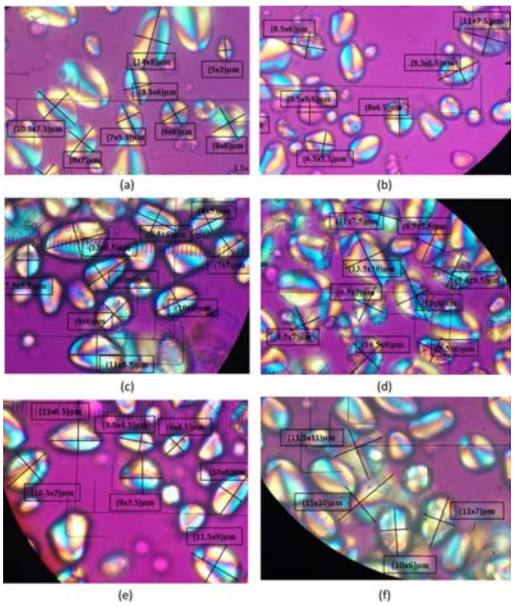

Fig. 3. Polarized light microscopy micrographs of US untreated (left) and US treated (right) at magnification of 400 times: (a,b) *iwamuluk*, (c.d) *iwasnan*, (e,f) *iwaluyuk*.

Pasting properties

Viscoamylogram US untreated and US treated sago starch was similar (Figure 4), indicating that there was no significant impact of ultrasonication on the starch pasting properties, compatible with the studies of by Bian and Chung (2016); Yang et al. (2019).

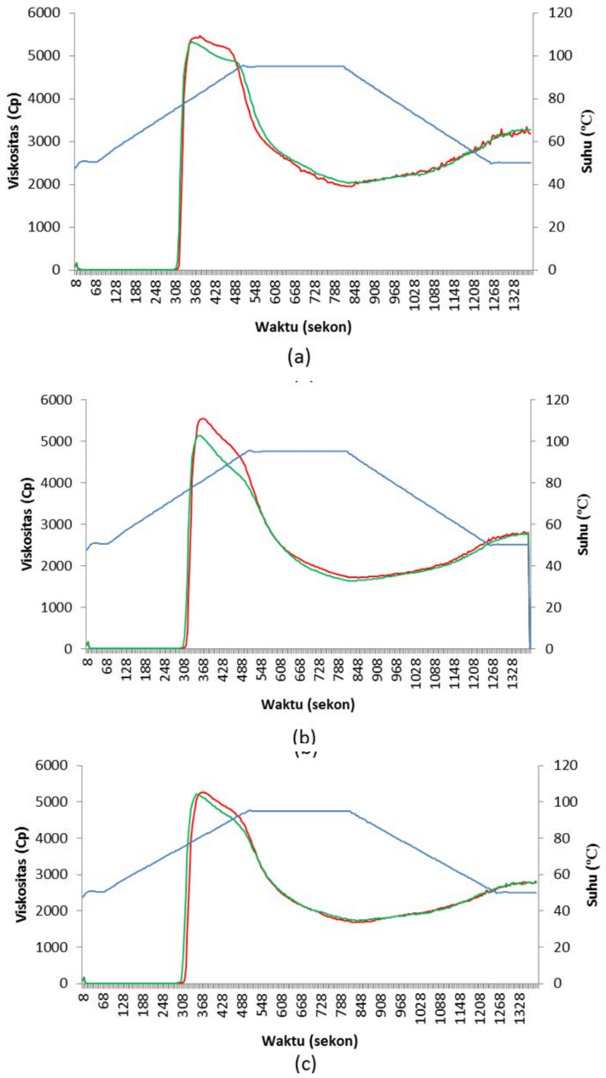

Fig. 4. Viscoamylogram of US untreated (red) and US treated (green) sago starch: (a) *iwamuluk*, (b) *iwayuluk*, (c) *iwasnan*

Discussion

Sonication treatment significantly increased resistant starch. RS content significantly increased with increasing of temperature and time sonication at 42 kHz. Under US treatment, the RS content significantly increased from 1.08-1.56% (db) to 17.66–31.96% (db). US treatment was noticed to be effective in increasing the RS content. Amylose content of *iwayuluk* was lower (29.96%) than those of *iwasnan* (32.70%) or *iwamuluk* (33.42%). However, RS content of *iwayuluk* was higher than those of *iwamuluk* and Iswanan as shown in Table 1. The result of this study agreed with previous study reported by several researchers. Type 3 resistant starch (RS3) was prepared from native potato starch using an ultrasonic method combined with autoclave gelatinization. Under the optimal treatment conditions, the RS3 content increased from 7.5% to 15.9% (Liu et al. 2023). Lotus starch subjected to ultrasonication contained RS of more than 90% (Noor et al. 2021). The formation of RS might be contribution of the cleavage of long chain amylose and depolymerization of amylopectin resulted from the effect of cavitation during US treatment. Thus, the molecule formed the alignment or aggregation which leads to an enhanced yield of RS (Yang et al. 2019). In this study, the sample of US treated at 50°C for 45 min was selected for further analysis, due to the high RS content. A slight change in the chemical component was found due to US treatment as shown in Table 2.

According to (Bonto et al. 2021), formation of fissures and pores, as well as the degradation of the starch granule under ultrasonic conditions, were induced by the shear forces and micro-jets of the collapsing bubble during cavitation. It was reported that the magnitude of ultrasonic power is an essential parameter of the mechanical effect in distorting the starch granules. The appearance of pores/holes and fissures on the surface of starch particles induces changes in the morphology/ultrastructure of polymers (Yang et al. 2019), thus changing the structure and properties of starch (Zhu 2015). Because of its capacity to produce fissures and pores, US treated sago starch also has potential as a carrier of active compound for specific uses of sago starch.

Several reports demonstrated that ultrasonication causes depolymerized starch through hydrolysis of glycosidic bonds in starch granules, which tends to produce lower starch viscosity because of starch molecular weight loss [20,24,25]. Ultrasonication changes the pasting properties, especially by decreasing the peak viscosity (Herceg, Jambrak, and Šubarić 2010; Satmalawati et al. 2020). The differences in US treated pasting properties can be attributed to several factors such as frequency, power, and temperature of applied ultrasonic parameters and also differences in botanical sources of starch.
L. Wang and Wang (2004b, 2004a) observed no damage on UT starch even with the application of ultrasonic frequency (20 kHz, 750 W) arguing that only non-covalent bonding between the starch and protein was most likely affected by ultrasonication.

Conclusions

US treatment of sago starch 42 kHz at 50°C for 15 and 45 min induces the RS formation. The treatment dominantly modified the morphological properties rather than fine structure such as pasting properties, providing additional information for its application.

References

AOAC 2019 Official Methods of Analysis of AOAC International. 21st ed. ed. George W. Latimer. Maryland: AOAC International.

Bhargava, Nitya, Rahul S Mor, Kshitiz Kumar, and Vijay Singh Sharanagat 2021 Ultrasonics - Sonochemistry Advances in Application of Ultrasound in Food Processing : A Review. Ultrasonics - Sonochemistry 70(July 2020): 105293. https://doi.org/10.1016/j.ultsonch.2020.105293.

Bian, Linlin, and Hyun Jung Chung 2016 Molecular Structure and Physicochemical Properties of Starch Isolated from Hydrothermally Treated Brown Rice Flour. Food Hydrocolloids 60: 345–52. http://dx.doi.org/10.1016/j.foodhyd.2016.04.008.

Bojarczuk, Adrianna, Sylwia Skąpska, Amin Mousavi Khaneghah, and Krystian Marszałek 2022 Health Benefits of Resistant Starch: A Review of the Literature. Journal of Functional Foods 93(April).

Bonto, Aldrin P., Rhowell N. Tiozon, Nese Sreenivasulu, and Drexel H. Camacho 2021 Impact of Ultrasonic Treatment on Rice Starch and Grain Functional Properties: A Review. Ultrasonics Sonochemistry 71: 105383. https://doi.org/10.1016/j.ultsonch.2020.105383.

Ehara, Hiroshi, Yukio Toyoda, and Dennis V. Johnson 2018 Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods.

Goñi, I., L. García-Diz, E. Mañas, and F. Saura-Calixto 1996 Analysis of Resistant Starch: A Method for Foods and Food Products. Food Chemistry 56(4): 445–49.

Herceg, Ivana Ljubić, Anet Režek Jambrak, and Drago Šubarić 2010 Texture and Pasting Properties of Ultrasonically Treated Corn Starch. Czech Journal of Food Sciences 28(2): 83–93. https://doi.org/10.17221/50/2009-CJFS.

Ji, Ying 2018 In Vitro Digestion and Physicochemical Characteristics of Corn Starch Mixed with Amino Acid Modified by Low Pressure Treatment. Food Chemistry 242: 421–26. http://dx.doi.org/10.1016/j.foodchem.2017.09.073.

Karim, A A, A Pei-lang Tie, D M A Manan, and I S M Zaidul 2008 Starch from the Sago (Metroxylon Sagu) Palm Tree—Properties, Prospects, and Challenges as a New Industrial Source for Food and Other Use. 7(1977).

Liu, Xiangyun et al. 2023 Preparation and Characterization of Type 3 Resistant Starch by Ultrasound-Assisted Autoclave Gelatinization and Its Effect on Steamed Bread Quality. Ultrasonics Sonochemistry 92(October 2022): 106248. https://doi.org/10.1016/j.ultsonch.2022.106248.

Noor, Nairah et al. 2021 Resistant Starch Type 2 from Lotus Stem: Ultrasonic Effect on Physical and Nutraceutical Properties. Ultrasonics Sonochemistry 76: 105655. https://doi.org/10.1016/j.ultsonch.2021.105655.

Purwani, Endang Yuli, Diah Iskandriati, and Maggy Thenawidjaja Suhartono 2012 Fermentation Product of RS3 Inhibited Proliferation and Induced Apoptosis in Colon Cancer Cell HCT-116. Advances in Bioscience and Biotechnology 03(08): 1189–98.

Purwani, Endang Yuli, Tresnawati Purwadaria, and Maggy Thenawidjaja Suhartono 2012 Fermentation RS3 Derived from Sago and Rice Starch with Clostridium Butyricum BCC B2571 or Eubacterium Rectale DSM 17629. Anaerobe 18(1): 55–61. http://dx.doi.org/10.1016/j.anaerobe.2011.09.007.

Rahaman, Abdul et al. 2021 Ultrasound Based Modification and Structural-Functional Analysis of Corn and Cassava Starch. Ultrasonics Sonochemistry 80(August): 105795. https://doi.org/10.1016/j.ultsonch.2021.105795.

Satmalawati, E. M., Y. Pranoto, D. W. Marseno, and Y. Marsono 2020 The Physicochemical Characteristics of Cassava Starch Modified by Ultrasonication. IOP Conference Series: Materials Science and Engineering 980(1).

Singhal, Rekha S. et al. 2008 Industrial Production, Processing, and Utilization of Sago Palm-Derived Products. Carbohydrate Polymers 72(1): 1–20.

Sujka, Monika, and Jerzy Jamroz 2013 Ultrasound-Treated Starch: SEM and TEM Imaging, and Functional Behaviour. Food Hydrocolloids 31(2): 413–19. http://dx.doi.org/10.1016/j.foodhyd.2012.11.027.

Wang, Baoshi et al. 2023 Recent Progress of Starch Modification Assisted by Ultrasonic Wave. Food Science and Technology (Brazil) 43: 1–6.

Wang, Linfeng, and Ya Jane Wang 2004a Application of High-Intensity Ultrasound and Surfactants in Rice Starch Isolation. Cereal Chemistry 81(1): 140–44.

——— 2004b Rice Starch Isolation by Neutral Protease and High-Intensity Ultrasound. Journal of Cereal Science 39(2): 291–96.

Xie, Yanli et al. 2013 Effect of Microwave Treatment on the

Physicochemical Properties of Potato Starch Granules. Chemistry Central Journal 7(1): 1–7.
Yang, Qing Yu et al. 2019 Fine Structure, Crystalline and Physicochemical Properties of Waxy Corn Starch Treated by Ultrasound Irradiation. Ultrasonics Sonochemistry 51(August 2018): 350–58. https://doi.org/10.1016/j.ultsonch.2018.09.001.
Zhang, Hao, Mei Li, and Chuanhe Zhu 2018 Effect of Ultrasound Pretreatment on Physicochemical Properties of Corn Starch. 164(Icmse): 572–76.
Zhu, Fan 2015 Impact of Ultrasound on Structure, Physicochemical Properties, Modifications, and Applications of Starch. Trends in Food Science & Technology. http://dx.doi.org/10.1016/j.tifs.2014.12.008.

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AB: providing sago
NS: validation, review and editing draft
DRY: technical laboratory analysis
ABA: conceptualization, methodology, data curation and validation

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Maltodextrin from Sago Starch at Different Hydrolysis Times

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Abstract Maltodextrin is widely used in the food and beverage industries causing the need for maltodextrin to increase every year, then it is necessary to conduct this study. This study aimed to determine the characteristics of maltodextrin from spineless sago starch type at different hydrolysis times. The study was designed using a completely randomized design. The main raw material in this study was spineless sago starch. The enzymes used were Liquozyme Supra 4.5X with different hydrolysis times, that was A = 15 minutes; B = 25 minutes; C = 35 minutes with the concentration of enzyme being 0,015 µl/g dry starch. Each treatment was repeated 2 times. The sago starch suspension of 20% was prepared in 200 ppm $CaCl_2$ solution and adjusted to pH 6. Hydrolysis was carried out at 80°C and stirred at 950 rpm. After that, the slurry was dried in a cabinet dryer at 50°C for 2 days (± 5% of water content). The size uniformity of dry maltodextrin was carried out using a 100 mesh sieve. The results showed that the brightness level of the maltodextrin color for the three treatments ranged from 79.86-80.66. Slight roughness on the starch granule's surface was found at all treatments, but X-ray diffraction patterns did not change from the native sago starch pattern. The viscosity ranged from 3826.0-5294.0, the breakdown ranged from 774.0-1839.0, set back ranged from 401.0-1844.0, the pasting temperature ranged from 76.15-76.50, and equivalent dextrose ranged from 2.14-3.13. The DE value in this study was very small, which may be due to low enzyme concentration.

Keywords: Hydrolysis time, Maltodextrin, Ssago starch

Introduction

Sago has an important role as a potential raw material for food and non-food products, cause they have high production per land area compared with other starch source plants; sago is a clumping plant so it doesn't need to be replanted; there are no serious diseases and predators, and sago can adapted to extreme growing conditions; and sago can be used to produce many foods (noodles, bread, vermicelli) and also used as a thickener in the production of soup and baby food as well as an additive in various food products; and for non-food products, such as bioethanol.

The total sago population in Indonesia is around 5.5 Mha, and around 4.7 Mha (85.5 %) grows in Papua (Bintoro, 2018). Productivity of sago starch in Indonesia averages 30 t of dry starch/ha/year (Bintoro, 2011), while cassava around 1.5 t/ha/year, potatoes around 2.5 t/ha/year, wheat around 5.0 t/ha/year, corn around 5.5 t/ha/year, and rice 6.0 t/ha/year (Ishizaki, 1998). Based on the sago population, it can be predicted that the total sago starch production in Papua is around 141 Mt/year. However, the utilization of sago starch in Papua is only around 5 %. Therefore, it is necessary to develop various products made from sago starch to increase sago starch utilization.

Sago starch content is around 96 % with amylose composition ranging from 33.61 % -38.47 % and amylopectin ranging from 61.54 % -66.40 % (Santoso et al., 2021), which can be used to manufacture maltodextrin. The need for maltodextrin in the world continues to increase because it is used as a raw material in the food and beverage industries. Based on data, the Global Maltodextrin Market Size Reached USD 2154.2 Million in 2022, and it is expected to grow around 8.2 % per year (https://www.marketwatch.com/press-release/global-maltodextrin-market-2023-2030-booming-industry-expected-to-surpass-37055-2023-05-16).

Maltodextrin is produced from incomplete hydrolysis (Pycia et al., 2016). Factors that influence the manufacture of maltodextrin are the type of raw material, enzyme or acid concentration, temperature, and speed of stirring during the hydrolysis process. Hydrolysis time is one of the important factors for the interaction of starch with the catalyst. Meriatna (2013) found that the best conditions for the manufacture of maltodextrin from sago starch at 80 °C within 130 min of hydrolysis using hydrochloric acid. Meanwhile Haryani et al (2022), hydrolysis of sorghum starch with α-amylase 0.2 % v/v for 10 minutes at 75°C and 9 % of starch concentration produced good maltodextrin with a DE value of 16.99. Therefore, the characteristics of maltodextrin from sago starch that hydrolyzed using Liquozyme Supra 4.5X at various hydrolysis times will be studied.

Materials and Methods

Materials

The main raw material used in this study was starch from spineless sago. The hydrolysis process of sago starch used Liquozyme Supra 4.5X. Other materials were aquadest, 2N NaOH, 0.1 M HCl, and 200 ppm $CaCl_2$.

Hydrolysis process

The study was designed using a Completely Randomized Design. The sago starch suspension of 20 % was prepared in 200 ppm $CaCl_2$ solution and adjusted to pH 6. Hydrolysis was carried out at 80 °C and stirred at 950 rpm. Hydrolysis time was 15 min (A); 25 min (B); and 35 min (C) with the enzyme concentration of 0.015 µL/g dry starch, and each treatment was repeated 2 times. After the hydrolysis was complete, the suspension and its container were immersed in cold water, and 0.1 M HCl was added to a pH of around 3 to inactivate the enzyme. The suspension cooling process continues until the temperature drops to 300 °C and then maintained for 30 min. After that, the suspension was neutralized using 2N NaOH to pH 7. The suspension was centrifuged at 250 rpm for 10 min to separate the water. Then the slurry was dried in a cabinet dryer at 50 °C for 2 days (± 5 % of water content). The dry maltodextrin was sieved using 100 mesh and packed in a plastic bottle.

Analysis of maltodextrin

Color

Color analysis was performed using a Minolta CR 300 Chromameter (Japan). Tests were performed with the Hunter L*, a*, b* color system. Before measurement, the chromameter was calibrated with the white standard contained in the tool.

Scanning Electron Microscopy

The microscopic structure of maltodextrin was performed using scanning electron microscopy (SEM) XRD-7000 Shimadzu, which operated at an accelerating voltage of 20 kV. The samples were spread thinly and evenly on circular metal stubs using double-sided adhesive tape.

Xray-Diffraction

X-ray diffraction of maltodextrin was obtained using a Philips *diffractometer* using cobalt monochromatic radiation, 31 kV, 26 mA. Diffractogram recorded at $2\theta = 4°$ to $35°$ with rate of scan 1°/minute.

Viscosity

The viscosity of maltodextrin was conducted using Rapid Visco Analyser (RVA) (Model RVA-4SA, Newport Scientific Pty Ltd. Warriewood, Australia). Maltodextin (about 3 g) was dispersed in distilled water (25 mL) and stirred in an RVA canister at 960 rpm for 10 seconds, and then the speed was adjusted to 160 rpm until the end of the test. Measurements were made within 13 min. The temperature and time used is 50 °C for 1 min then the temperature is raised to 95 °C in 3 min 45 sec then maintained at 95 °C for 2 min 30 sec and followed by cooling to 50 °C in 3 min 45 sec, then maintained at 50 °C for 2 min.

Dextrose equivalent

The dextrose equivalent was analyzed following the method of Miller (1959). The sample of maltodextrin (1000 ppm) was taken as much as 1.5 mL and then put into a test tube containing 1.5 mL of the DNS reagent. Then, the solution was shaken with a vortex for 10 sec and heated in boiling water for 10 min. The equivalent Dextrose was calculated by using the equation: $DE = (Reduced\ sugar\ content\ /\ Sugar\ (carbohydrate)\ total) \times 100$.

Results and Discussion

Color of maltodextrin

Observation of maltodextrin color using Chromameter has three values, namely L*, a*, and b*. The L* value indicates the brightness level, where the greater the L value shows the brighter the sample color, and conversely. The a* value indicates the level of redness, and the b* value indicates the level of yellowness (Pardede et al., 2017). Based on data (Table 1), showed that the brightness level of the maltodextrin for the three treatments ranged from 79.86 to 80.66, which was lower than the native sago starch (87.56). This fact indicates that occurs the process of non-enzymatic browning reactions, especially the Maillard reaction during the hydrolysis. Maillard is a complex reaction, in which the formation of characteristic flavors, aromas, and colors (browning) in foods prepared by heating can occur due to the reaction between reducing sugars and amino acids (Verma et al., 2019).

Table 1. Color parameters of maltodextrin from sago starch

Treatments	L*	a*	b*
A	79.86	7.92	9.83
B	80.66	7.64	9.43
C	80.45	7.65	9.57
NSS*	87.56	9.54	4.96

A: 15 min, B: 25 min, C: 35 min, NSS: Native sago starch) = Santoso et al. (2021).

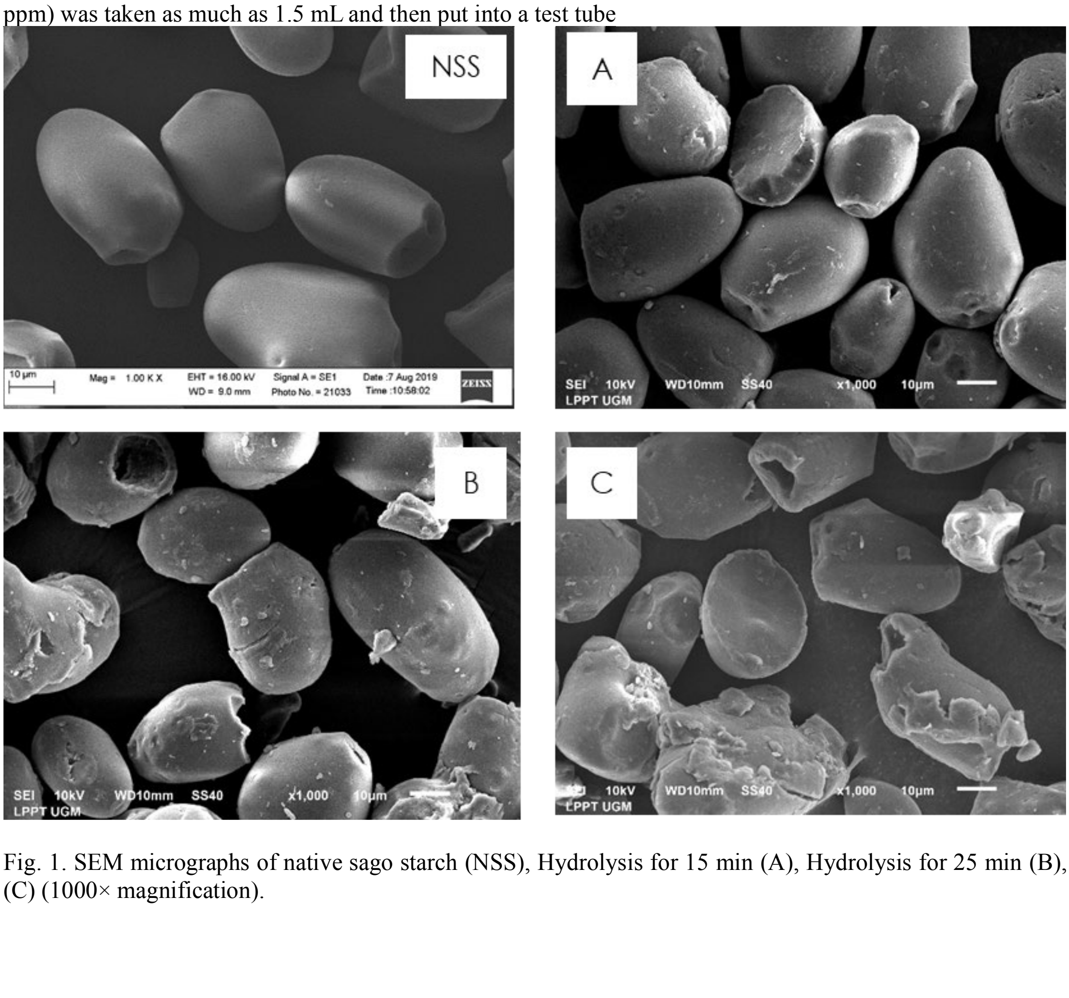

Fig. 1. SEM micrographs of native sago starch (NSS), Hydrolysis for 15 min (A), Hydrolysis for 25 min (B), Hydrolysis for 35 min (C) (1000× magnification).

Scanning electron microscopy (SEM)

The results of observations under SEM (Fig. 1) showed that the sago starch granules remained intact the same as the granules of native sago starch. This is because the hydrolysis process in the manufacture of maltodextrin is partial hydrolysis which only reaches the liquefaction stage. During the liquefaction stage is only occur the breakdown of α-1,4 glycosidic bonds by α-amylase enzymes randomly on the polysaccharide chain to produce glucose, maltose, maltodextrin, and α-limit dextrin. While, the surface of starch granules treated with the Liquozyme Supra 4.5X had roughness and pores compared to the native sago starch (smooth without any pores and fissures), which the severity of starch surface was increasing with increasing hydrolysis time caused by enzyme degradation.

X-ray diffraction

The native sago starch has C type pattern, with peaks at 2θ of 5° to 15°, 17°, 18°, and 23°, and a small peak at $2\theta = 5°$ (Santoso et al., 2015). Observations under an X-ray diffractometer showed that partial hydrolysis of sago starch using Liquozyme Supra 4.5X enzyme with a concentration of 0.015 µL/g dry starch for 15 to 35 min did not change the diffraction pattern (Fig. 2). This showed that enzymatic erosion preferentially occurred in amorphous areas of the granules. This study is in line with a previous study by Shariffa et al. (2009) on enzymatic hydrolysis in cassava and sweet potato starches, in which the amylolysis primarily occurs in the amorphous regions of the starch granules.

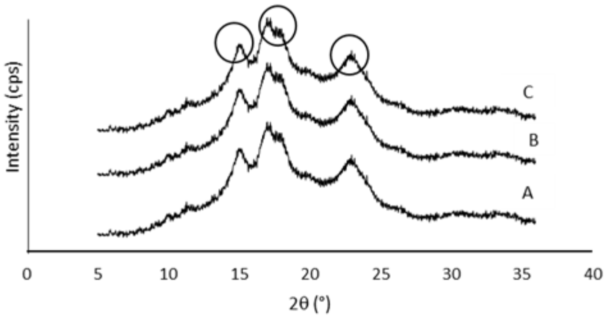

Fig. 2. X-ray diffraction patterns of maltodextrins from sago starch

Viscosity

Hydrolysis of sago starch using the Liquozyme Supra 4.5X enzyme at a concentration of 0.015 µL/g dry starch for 15 to 35 min did not affect the pasting temperature, but the viscosity was decreased compared to native sago starch (Table 2). From the data can also be seen that the viscosity of maltodextrin tends to decrease with increasing hydrolysis time. This may be the enzymatic erosion, especially in amorphous areas, causes some amylose and amylopectin chains to break down shorter, and the granules become fragile due to the effects of heating (Perez and Gonzales, 1997). Amylose degradation occurs randomly into maltose and maltotriose which then causes a decrease in viscosity.

Table 2. Pasting temperature, viscosity, and dextrose equivalent of maltodextrin from sago starch

Treatments	Pasting temp. (°C)	Peak viscosity (cP)
A	76.50	5294.0
B	76.15	3826.0
C	76.45	3970.0
NSS*	74.65	7571.0

Santoso et al. (2021)

Dextrose equivalent

The dextrose equivalent in this study ranged from 2.14 to 3.13 (Table 2). The DE value in this study was very small, which may be due to the non-optimal work of the enzyme. Maltodextrin produced from the hydrolysis of sago starch by the α- amylase enzyme with a hydrolysis time of up to 120 min can produce maltodextrin from sago starch with a DE value of 12 (Arfah et al., 2018). According to Hidayat et al., (2003), the DE value of 2 to 5 can be used as a substitute for milk fat in desserts mouth, yogurt, bakery products, and ice cream, because they are readily soluble and dispersible in water. Maltodextrin with a DE value of 3 to 9 can be used as a source of carbohydrates in isotonic sports drinks. Meanwhile, maltodextrin with a DE value of 15-20 is used as a high-calorie food product (Anwar et al., 2009; Takelti et al., 2010).

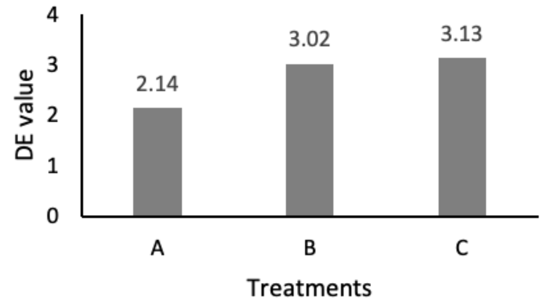

Fig 3. Dextrose equivalen of maltodetrin from sago starch Hydrolysis for 15 min (A), Hydrolysis for 25 min (B), Hydrolysis for 35 min (C)

Conclusions

The color of maltodextrin was slightly brownish compared to the color of native sago starch due to the Maillard reaction during the hydrolysis process. However, the hydrolysis process does not change the diffraction profile and the pasting temperature. The viscosity of maltodextrin was lower than that of native sago starch, and the DE of maltodextrin ranged from 2.14 to 3.13.

References

Anwar E., Joshita D., Yanuar A., Baktiar A., 2009 Utilization of Wheat Flour Maltodextrin as Essipien in Tablet and Niosomian Tablet Formulations. Pharmaceutical Science Magazine 1(1): 34-36.

Bintoro, M.H. 2011 Progress of sago research in Indonesia. *In:* Proc. 10th Int.Sago Symposium: Sago for food security, Bio-energy, and Industry from Research to Market, Bogor, 29-31 October. p.16- 34.

Bintoro, M.H., M.I. Nurulhaq, A.J. Pratama, F. Ahmad, dan L. Ayulia. 2018 Growing area of sago palm and its environment. *In*: sago palm: multiple contribution to food security and sustainable livelihoods (Eds: Ehara, H., Y. Toyoda and D.V. Johnson). Springer. Singapore.

Haryani, K., D.S. Retnowati, N.A. Handayani, W.M. Dewi, S.A. Pamularsih. 2022 Enzymatic Modification of Sorghum Starch into Maltodextrin Using Alpha Amylase and Gluco Amylase Enzymes. Jurnal Teknologi Pangan 6(1), p. 8–12.

Hidayat, B., Ahza, A B., and Sugiyono, 2003 Characterization of Maltodextrin DP 3-9 and Study of Potential of Use as Source of Carbohydrate at Sports Drink. Journal. Teknol. And Food Industry, XIV (1): 51-58

Ishizaki, A. 1998 Concluding remark. In: Jose, C., Rasyad, A., editors. Proceedings of the 6th International Sago Symposium. Pekanbaru, Riau, Indonesia.

Matos M.E. & Pérez E, 2003 Characterization of native and modified cassava starches I. Ultrastructural study by scanning electron microscopy and X-ray diffraction techniques. Cereal Food World, 48, 78-81.

Meriatna. 2013 Hydrolysis of Sago Flour to Maltodextrin Using Hydrochloric Acid**.** Jurnal Teknologi Kimia Unimal 1 (2), p. 38-48.

Miller, G.L., 1959 Use of Dinitrosalicylic Acid Reagent for Determination of Reducing Sugar. Anal Chem., **31** (3): 426-28.

Santoso B, Sakakura K, Naito H, Ohmi M, Nishimura Y, Uchiyama T, Itaya A, Hisamatsu M, Ehara H, Mishima T. 2015 Effects of micro powder milling on physicochemical properties of sago starch. J Appl Glycosci 62 (2): 73-80.

Santoso, B., Z.L., Sarungallo, A.M.P., Dewi. 2021 Physico-chemical and functional properties of spineless, short-spines and long-spines sago starch. Journal of Biodiversitas**,** Vol. 22 (1), p. 137-143. DOI: 10.13057/biodiv/d220119.

Shariffa, Y.N., A.A. Karim, A. Fazilah, I.S.M. Zaidul. 2009 Enzymatic hydrolysis of granular native and mildly heat-treated tapioca and sweet potato starches at sub-gelatinization temperature. Food Hydrocolloids 23, p. 434– 440. DOI: 10.1016/j.foodhyd.2008.03.009

Takelti, C. Y., Kiecbusch, T. G., and Collares-Queiroz, F. P., 2010 Morphological and Physicochemical Characterization of Commercial Maltodextrins with Different Degrees of Equivalent Dextrose. Journal of Food Properties, (13): 411-25.

Perez, E. dan Z. Gonzales 1997 Functional properties of cassava (Manihot esculenta Crantz) starch modified by physical methods. Starch: 49-53.

Pycia, K., L. Juszczak, D. Gałkowska, M. Witczak, and Grażyna 2016 Maltodextrins from chemically modified starches. Carbohydrate Polymer. Accepted Manuscript. Maret.

Verma, V., Z. S. and N. Yadav. 2019 Maillard Reaction and Effect of Various Factor on the Formation of Maillard Products: and Its Impact on Processed Food Products. Book Chapter: Research Trends in Food Technology and Nutrition. Published by: AkiNik Publications, p. 146.

Zobel, H., 1988 Molecules to granules: A compressive starch review. Starch/Starke, 40, 44-50.

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Diversity of Medicinal Plants in the Sago area of Siberut National Park, West Sumatra

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Abstract Medicinal plants can be found in various types of habitats including in sago stands in Siberut National Park. The purpose of this research is to identify and describe the diversity of plant species in sago stands and their use by the Mentawai indigenous people. Research activities were carried out from January to March 2022 in Siberut National Park using the methods of vegetation analysis, interviews, and field observations. The results showed that there were 193 plant species from 64 families found under sago stands. The composition of plant species under sago stands in Sakaladhat sub-village consists of 107 plant species from 51 families with an H' of 3.05. In the sago stands in Ukra sub-village, 140 species from 55 families were found with an H' of 3.14. The Community Similarity Index between sago stands in Sakaladhat sub-village and Ukra sub-village is 43.72%. As many as 60 species from 31 families have been used by the community as medicine for 13 groups of diseases. The most widely used plant species came from the Cyperaceae family (11.66%), herb habitus (63%), leaf parts (68.97%), internal use (50%), digestive tract disease group (26.67%), processed by grating then brewing (60.37%), as a single drug (84%), and used only when sick (97.30%). Knowledge about the use of medicinal plants is obtained by the community through dreams and passed down from generation to generation.

Key words: Diversity, Local Knowledge, Medicinal Plants, Sago Stands

Introduction

Medicinal plants are plant species, both cultivated and uncultivated, which are believed or known to have medicinal properties that can be used as raw materials in the manufacture of modern or traditional medicines (Abdiyani, 2008). The use of traditional medicinal plants is part of the cultural system of the local community. One of these community groups is the Mentawai indigenous people in Siberut National Park (Zai, 2018) whose implementation is carried out by *sikerei*. *Sikerei* is a shaman who provides treatment and is believed to have good knowledge about the use of medicinal plants.

Siberut Island, one of the islands inhabited by the Mentawai indigenous people, has the potential for a sizeable sago area, which is 1,295 ha of the total area of Siberut Island (387,790 ha) (BPS, 2022). Aside from being the main food source, sago is also used as a building material and is part of traditional rituals (Zamzami, 2014). Based on this, it can be said that the community has a close relationship with sago in meeting their daily needs. The use of sago and medicinal plants under sago stands by the Mentawai indigenous people has become part of their daily life, but there is no complete information regarding the variety of medicinal plants that grow under sago stands. Studies on the diversity and use of medicinal plants in sago stands have never been carried out. This study will be useful for the added value of managing and cultivating sago stands. There is a need for research related to this matter to map the potential utilization of medicinal plant species in sago stands. The results of research on the diversity of medicinal plants under sago stands and their use by the community are expected to become a community asset in achieving health independence.

Materials and Methods

Research activities were carried out from January to March 2022 in Sakaladhat sub-village, Simalegi Village, West Siberut District, and Ukra sub-village, Malancan Village, North Siberut District, Mentawai Islands Regency. The tools and materials used in the research were vegetation analysis equipment, interview equipment, and herbarium-making equipment. The research object is the vegetation on sago stands.

The research was conducted using several data collection methods, namely vegetation analysis, interviews, and field observations. Vegetation analysis was carried out by observing all growth rates in a 50 m × 50 m observation plot. The plots observed at each research location were five plots. Interviews were conducted with eight informants who were believed to have high knowledge regarding the use of medicinal plants. Field observation activities were carried out to find out how to use medicinal plants to maintain health.

The data obtained through vegetation analysis was analyzed by calculating the Importance Value Index (INP) to see the composition of the vegetation. The Important Value Index (INP) is the sum of the Relative Density (KR) and Relative Frequency (FR) at the growth rate of saplings, seedlings, and undergrowth. The Important Value Index (INP) at the growth rate of trees and poles is the sum of the Relative Density (KR), Relative Frequency (FR), and Relative Dominance (DR). The data was also analyzed by calculating the Species Diversity Index (H') and Community Similarity Index (IS) to compare species diversity and species similarity in the two communities studied. The following is the Shannon Index of General Diversity formula,

$$H' = -\sum_{i=1}^{n}\left[\frac{ni}{N}\ \ln\frac{ni}{N}\right]$$

Information:
H' = Shannon Index
ni = I-species INP
N = Total IVI

while the Index of Similarity formula is,

$$IS = \frac{2w}{a+b} \times 100\%$$

Information:
IS = Community Similarity Index
w = Same number of species between the two communities (a and b)
a = Number of species found in community a
b = Number of species found in the community b

Data and information obtained through interviews were analyzed qualitatively and quantitatively to provide an overview and explanation of the data that has been collected. The data analyzed included species used as medicine, parts of plants used, types of diseases that can be treated, processing methods, methods of use, and intensity of use.

Results

Species Diversity of Plants under Sago Stands

In general, the diversity of plant species found in sago stands in Sakaladhat and Ukra sub-village is quite different. The composition of plant species in the sago stands in Sakaladhat sub-village consisted of 107 plant species from 51 families with an H' of 3.05. In the sago stands in Ukra sub-village there were 140 species from 55 families with an H' of 3.14. The Community Similarity Index between sago stands in Sakaladhat and Ukra sub-village is 43.72%. A Community Similarity Index value of less than 75% indicates that the species composition of the sago stands in Sakaladhat and Ukra sub-village is relatively different.

Species that dominate a community are species with a high level of adaptation because they can utilize the environment more efficiently. The dominant species is the species that has the highest Importance Value Index. The most dominating species for all growth stages were areca nut (Areca catechu) with a total IVI of 250.93% under sago stands in Sakaladhat sub-village and langsat (Lansium domesticum) with a total IVI of 141.43% under sago stands in Ukra sub-village. Plant species found under sago stands in Sakaladhat sub-village, namely harendong (Melastoma malabathricum), bandotan (Ageratum conyzoides), knob grass (Cyperus kyllingia), taro (Colocasia sp.1), taro (C. sp.2), and arum lily (Calla palustris). The plant species found under the sago stands in Ukra sub-village are banana (Musa sp.), fresh pacing (Cheilocostus speciosus), and manggar (Merremia peltata).

Species Diversity of Medicinal Plants under Sago Stands

The diversity of medicinal plant species found will be grouped based on plant family and habitus. The medicinal plants found were from 31 families. The Cyperaceae family ranks highest with a total of 11.66% of all existing families (Table 1). Species from the Cyperaceae family are known as weeds, but species from this family also have some benefits for humans. The benefit is that it can be used as a raw material for medicines for digestive disorders, bronchitis, blood disorders, menstrual irregularities, and inflammation (Taheri et al., 2021). Species of the Cyperaceae family are used as remedies for sea sickness, fever, and trance.

Table 1. Diversity of medicinal plant species under sago stands by family

No	Families	Species Name	Percentage (%)
1	Cyperaceae	*Cyperus cyperoides, C. mindorensis, C. rotundus, C. sphacelatus, C. strigosus, C. kyllingia dan Scleria sp.*	11.66
2	Asteraceae	*Acmella caulirhiza, A. paniculata, Ageratum conyzoides, Struchium sparganophorum dan Vernonia cinerea*	8.32
3	Moraceae	*Artocarpus heterophyllus, A. sp., Ficus hispida dan F. sp.*	6.66
4	Rubiaceae	*Hamelia patens, Ophiorrhiza mungos, Spermacoce remota dan S. sp.*	6.66
5	Convolvulaceae	*Ipomoea asarifolia, I. carnea dan I. pes-carpe*	5.00
6	Zingiberaceae	*Alpinia uraiensis, Curcuma longa dan Etlingera elatior*	5.00
7	Araceae	*Aglaonema modestum* dan *Calla palustris*	3.33
8	Arecaceae	*Areca catechu* dan *Cocos nucifera*	3.33
9	Euphorbiaceae	*Codieaum variegatum* dan *Manihot esculentas*	3.33
10	Fabaceae	*Chamaecrista fallacina* dan *Milletia*	3.33
11	Phyllanthaceae	*Phyllanthus niruri* dan *P. urinaria*	3.33
12	Poaceae	*Eragrotis amabilis* dan *Milium effusum*	3.33
13	Verbenaceae	*Stachytarpheta jamaicensis* dan *Verbena urticifolia*	3.33
14	Vitaceae	*Leea indica* dan *Tetrastigma* sp.	3.33
15	Malvaceae	*Hibiscus tiliaceus* dan *Durio* sp.	3.33
16	Acanthaceae	*Justicia gendarussa*	1.67
17	Campanulaceae	*Hippobroma longiflora*	1.67
18	Commelinaceae	*Commelina* sp.	1.67
19	Costaceae	*Cheilocostus speciosus*	1.67
20	Dilleniaceae	*Tetracera* sp.	1.67
21	Dipterocarpaceae	*Dipetrocarpus* sp.	1.67
22	Flagellariaceae	*Flagellaria indica*	1.67
23	Lamiaceae	*Lycopus uniflorus*	1.67
24	Linderniaceae	*Lindernia crustacean*	1,67
25	Melastomataceae	*Melastoma malabathricum*	1,67
26	Musaceae	*Musa* sp.	1,67
27	Myrtaceae	*Syzygium malaccense*	1,67
28	Onagraceae	*Ludwigia erecta*	1,67
29	Piperaceae	*Piper sp.*1	1,67
30	Rutaceae	*Citrus* sp.	1,67
31	Selaginellaceae	*Sellaginella* sp.1	1,67
Total			**100.00**

Based on plant habitus (stature), the most commonly found were herbs with 37 species (63%), while the least found were lianas with four species (7%) each habitus (Figure 1).

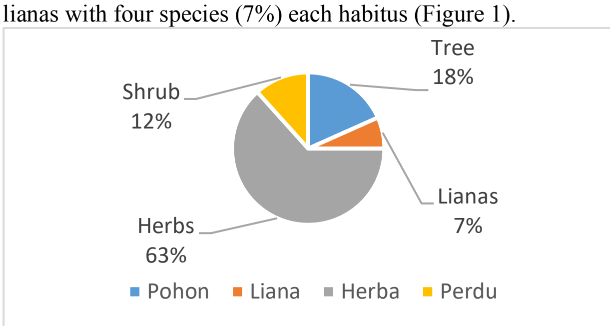

Figure 1. Diversity of medicinal plants based on habitus

Several species with herbaceous habitus found in the study area were freshwater pacing (Cheilocostus speciosus), Ophiorrhiza mungos, and kecombrang (Eltingera elatior). According to Diana et al. (2021), many herbaceous habitual plants are found in shaded places except in very dark places and are plants in watery areas.

Utilization of Medicinal Plants by the Community

The Mentawai indigenous people know plants that can be used as medicinal ingredients. The knowledge possessed by the *sikerei* and *siagai laggek* comes from dreams and is passed down from generation to generation. The forms of utilization of medicinal plants also vary according to individual knowledge and skills. *Sikerei* is an individual who focuses on treating serious illnesses that come from disturbances by evil spirits using rituals ending with dance, while *siagai laggek* is more focused on treating minor illnesses by concocting herbs into medicine.

The results of interviews with five informants showed that 60 species of medicinal plants under sago stands were used by *sikerei* and *siagai laggek* to treat thirteen groups of diseases/uses in Sakaladhat sub-village, Simalegi Village, West Siberut District, Mentawai Islands Regency. The highest number of plant species used is to treat digestive tract diseases, namely 16 species. This species is used to treat several types of diseases including diarrhea, stomach pain, intestinal worms, ulcers, vomiting, and heartburn. The minimum number of plant species used is to treat several groups of diseases, including circulatory disorders, antidotes, and malaria. For example, the species used by *sikerei* and standby *laggek* to treat diarrhea are banana (Musa sp.), Malay apple (Syzygium malaccense), Artocarpus sp., and luwingan (Ficus hispida).

Sikerei and *siagai laggek* in the Ukra sub-village, Malancan Village, North Siberut District utilize medicinal plants based on their expertise. Based on the results of interviews with key persons, there are nine *siagai laggek* officers with various expertise including treating wounds, bone diseases, pregnancy and childbirth care, eye diseases, headaches and fever, antidotes for poisons, gastrointestinal diseases, and non-physical diseases related to interference spirits (trance). As many as three out of nine standby *laggek* were willing to be interviewed about the medicinal plants used. Other informants were reluctant to be interviewed for fear that documentation and dissemination of information related to the ingredients used would have an impact on reducing income economically. According to the beliefs of the Mentawai indigenous people, medicinal methods obtained through dreams may not be disseminated and used by other individuals without the permission of the dream owner. This is believed to have an impact on the healing properties of the concoctions that are concocted.

Table 2. Diversity of traditional herbs and diseases that can be treated based on *siagai laggek* knowledge in Ukra Sub-village

No.	Disease group/ function	Type of Disease/Uses	Potion Name
1	Wound Treatment	Wound	*Agot assak lorang obe*
2	Others	Disturbance of Spirits	*Sodjokjok ka sapeu, sadjokjok, sodjokjok ka talaganbaga*
		Possessed	*Agot gilo*
		Disturbed Psyche	*Agot jomang*
		Diseases of Children	*Origin katippuk*
3	Headache and Fever	Migraine	*Agot ute*
		Headache	*Besit ute belaelu*
4	Gastrointestinal Diseases	Stomach ache	*Geleng-geleng sioikateinung*
		Sore Throat	*Kalokkan*

Sago (*Metroxylon sagu*) is also used as medicine. Sago root is used as a medicine for toothache by crushing it and then boiling it in bamboo and drinking it warm. Sago root is also used as medicine in Papua and Kalimantan. Sago root is used in Papua as an antimalarial drug (Budiarti et al., 2020), while in Kalimantan it is used as a medicine for diarrhea (Bakhriansyah et al., 2011).

The Mentawai indigenous people have used various parts of plants such as leaves, fruit, stems, flowers, buds, roots, bark, rhizomes, and tubers, to all parts of the plant. The diversity of the use of plant parts is related to the different active ingredients in each part of the plant so the efficacy also varies (Pei et al., 2009). The part that is used most is the leaves (68.97%), while the parts with a low percentage of use are bark (0.86%), rhizomes (0.86%), and tubers (0.86%).

There are 19 ways of processing plants that are commonly done in Dusun Sakaladhat. The most common processing method was grated and then brewed (60.36%). Processing of plants by grating is a characteristic of the processing of medicinal plants by *sikerei* and *siagai laggek*. This can be seen in the form of processing plants with various grated methods. As much as 11.71% of the medicinal plants were processed by simply grating them while 68.47% of the other herbs were grated and further processed in various ways such as boiling, baking, mixing with coconut, and soaking in water. Processed by simply grating it is usually served wrapped in Calla palustris leaves (Figure 2).

Figure 2. Processing of medicinal plants (a) grated medicinal ingredients and (b) the grated product wrapped in Calla palustris leaves and (c) Calla palustris leaves

The use of medicinal plants is divided into three categories of use, namely internal use, external use, and external and internal use (Figure 3). According to Wahyono et al. (2017), internal use is a method of taking drugs by mouth and then swallowing or drinking while external use is a method of using drugs outside the body, for example when used on the skin by smearing or dripping into the nostrils/eyes/ears.

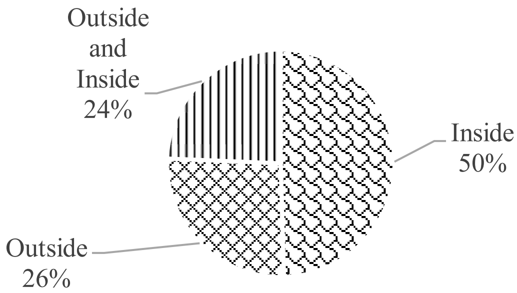

Figure 3. Diversity of medicinal plants by category of use

Sikerei and *siagai laggek* in Sakaladhat sub-village use medicinal plants for internal use more than for external use. Medicinal plants with internal use are more dominant because the existing diseases are dominated by internal medicine. The diversity of ways of using medicinal plants by *sikerei* and *siagai laggek* in Sakaladhat sub-village consists of 17 ways. The most used form of medicinal plants was by drinking (48.65%). This is because the processing of medicinal plants that are mostly done is grated and then brewed. The use of medicinal plants by drinking and eating aims to treat various diseases originating from within the body (Hutagalung, 2016).

Based on their composition, the use of plants by *sikerei* and *siagai laggek* in Sakaladhat sub-village can be grouped into two, namely single ingredients (one plant species) and ingredients (a mixture of several plant species) (Figure 4).

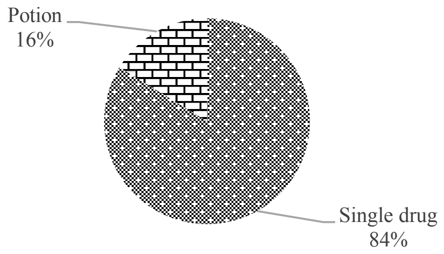

Figure 4. Diversity of medicinal plants based on the composition of the ingredients

The grouping results showed that *sikerei* and *siagi laggek* in the Sakaladhat sub-village used a single medicinal ingredient more often than using ingredients. As much as 16% of medicinal plants are used as ingredients to treat fever, diarrhea, snake bites, disturbances of spirits, cold sweats, heartburn, seasickness, sore eyes, and sore throat. According to the sources, the time to use the drug is adjusted to the diagnosis of the disease. There are four categories of time for the use of medicinal plants that are prevalent in society, namely when sick, after being sick, every bath time, and every day. The dosage or dose for the use of medicinal plants commonly used by the Mentawai people is based on the number of relative doses such as leaf blades and handheld. This is also in line with Elenora and Ristiawati (2019) who state that compounding medicinal plants traditionally uses doses that are difficult to determine precisely, such as a strecth, a handful, or a pinch.

Conclusions

The plant species found under the sago stands in Sakaldhat and Ukra sub-villages are quite diverse with relatively different community compositions. The variety of plants under sago stands shows that sago can grow and be developed together with other plants. The various forms of utilization of medicinal plants show that the community has knowledge and awareness about how to use existing resources. Utilization is carried out traditionally using simple equipment. This is influenced by the limitations and exclusivity of knowledge that comes from dreams and hereditary heritage.

References

Abdiyani, S. 2008 Keanekaragaman jenis tumbuhan bawah berkhasiat obat di Dataran Tinggi Dieng. Jurnal Penelitian Hutan dan Konservasi Alam, 5(1), 79–92. https://doi.org/10.20886/jphka.2008.5.1.79-92

Bakhriansyah, M., Febria, A., dan Rahmah, D. D. 2011 Efek antibakteri in vitro dan antidiare in vivo infus akar sagu (*Metroxylon sagu*). Majalah Farmasi Indonesia, 22(223), 158–165.

BPS. 2022 Kepulauan Mentawai dalam Angka 2022. BPS Kabupaten Kepulauan Mentawai, Kepulauan Mentawai.

Budiarti, M., Maruzy, A., Mujahid, R., Sari, A. N., Jokopriyambodo, W., Widayat, T., dan Wahyono, S. 2020 The use of antimalarial plants as traditional treatment in Papua Island, Indonesia. Heliyon, 6(12), 1-10. e05562. https://doi.org/10.1016/j.heliyon.2020.e05562

Diana, R., Mercury, Y. H., dan Nurhidayah 2021 Ekologi Tumbuhan Herba dan Liana. CV. Pustaka Learning Center, Malang.

Elenora, R., dan Ristiawati, N. 2019 Ketepatan penggunaan obat tradisional serta pengalaman penyuluhan di lingkungan RW 02 dan RW 03, Kelurahan Jatipadang, Jakarta Selatan. Bulletin Dharmesti Niramaya Jurnal Pengabdian Masyarakat, 1(1), 10–13.

Hutagalung, M. R. 2016 Pemanfaatan tumbuhan obat pada masyarakat Suku Batak Toba di Kampung Pagaran Lambung Kabupaten Tapanuli Utara, Sumatera Utara. Skripsi. Fakultas Kehutanan dan Lingkungan Institut Petanian Bogor. Bogor.

Pei, S., Zhang, G., dan Huai, H. 2009 Application of traditional knowledge in forest management: ethnobotanical indicators of sustainable forest use. Forest Ecology and Management, 257(10), 2017–2021. https://doi.org/10.1016/j.foreco.2009.01.003

Taheri, Y., Herrera-Bravo, J., Huala, L., Salazar, L. A., Sharifi-Rad, J., Akram, M., Shahzad, K., Melgar-Lalanne, G., Baghalpour, N., Tamimi, K., Mahroo-Bakhtiyari, J., Kregiel, D., Dey, A., Kumar, M., Suleria, H. A. R., Cruz-Martins, N., dan Cho, W. C. 2021 Cyperus spp.: a review on phytochemical composition, biological activity, and health-promoting effects. Oxidative Medicine and Cellular Longevity, 2021, 1–17. https://doi.org/10.1155/2021/4014867

Wahyono, S., Mustofa, F. I., Rahmawati, N., dan Novita, A. 2017 Pedoman Pengumpulan Data (L. Handayani, W. Budiarto, H. S. A. Putra, A. Isnawati, R. S. Handayani, dan U. Siswanto (eds.)). Kementerian Kesehatan RI, Jakarta.

Zai, Y. 2018 Bioprospeksi keanekaragaman spesies tumbuhan obat di Taman Nasional Siberut, Mentawai Sumatera Barat. Skripsi. Fakultas Kehutanan dan Lingkungan Institut Petanian Bogor. Bogor.

Zamzami, L. 2014 Sekerei Mentawai: keseharian dan tradisi pengetahuan lokal yang digerus oleh zaman. Antropologi Indonesia, 34(1), 1–17. https://doi.org/10.7454/ai.v34i1.3195

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Genetic Diversity of Sago (*Metroxylon* spp.) in Lingga District, Kepulauan Riau, Indonesia

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Abstract Indonesia has not been able to meet the food needs of its people. This can be seen from the import activity of several food commodities such as wheat, sugar, and rice. Sago starch can be used as a substitute for wheat flour for making bread and biscuits and can be used as a substitute for cane sugar. Sago (*Metroxylon* spp.) is a potential commodity as an alternative food with high productivity, which is around 20-40 tons of dry starch/ha per year. Food security based on the strength of local resources will reduce dependence on imported commodities or products to create food self-sufficiency. The sago area in the world is 6,279,637 million hectares and Indonesia has 85% of the world's sago area or around 5,579,637 million hectares. This study aims to obtain information on the diversity of sago species through genetic analysis of various sago accessions in Lingga District. The genetic analysis method used is RAPD (Random Amplified Polymorphic DNA) analysis. Based on the results of the dendrogram analysis, sago samples can be grouped into three major groups at a similarity coefficient value of 54%. Group I consisted of 4 samples and 2 large groups at a similarity coefficient value of 45%. Group II consisted of 10 samples and 1 large group at a similarity coefficient value of 70%. In Group III, 10 samples have a similarity coefficient value above 70%. In these groups, there is visible genetic variation in sago palm in Lingga District which comes from differences in the growing environment, cross-pollination, and crosses between close relatives and different types of sago.

Key words: Genetic resemblance, Indonesia, RAPD

Introduction

A strategic geographical location with extensive and fertile agricultural land and good natural carrying capacity is Indonesia's main strength in intensify the national food security strategy (Miyasto 2014). Based on the 2020 population census, Indonesia's population has reached 270 million. This makes Indonesia the fourth most populous country in the world. This number has increased by 1.25% compared to the population in 2010 (BPS 2021a). It requires the state to be able to guarantee the availability of food for the community.

Currently, Indonesia has not been able to meet the food needs of its people. This can be seen from the import activity of several food commodities such as wheat, sugar, and rice. Indonesia is the second country with the highest total wheat imports in the world after Egypt. Indonesia's total wheat imports in 2020 reached 10.29 million tons (BPS 2021b). This number increases to 11.2 million tons in 2022 (FAO 2022; USDA-FAS 2023). The number of wheat imports continues to increase in line with the increasing public interest in processed wheat products such as bread, biscuits, and cereals. Indonesia's wheat consumption in 2022 will reach 10.5 million tons (FAO 2022; USDA-FAS 2023). Wheat plants can only grow in subtropical regions (Riska 2018). Until now, Indonesia has not been able to produce its wheat.

Sago starch can be used as a substitute for wheat flour for making bread and biscuits and can be used as a substitute for cane sugar. Bintoro et al. (2010) stated that 30% substitution of sago starch did not affect the quality of the product produced. Based on research conducted by Ramadhani and Mulyani (2018), the preferred cake product is a substitute product of 50% wheat flour with 50% sago starch. Substitution of wheat flour with sago starch can reduce Indonesia's dependence on wheat imports. Sago starch can also be used as a raw material for making liquid sugar or powdered sugar through an enzymatic reaction and can be used as a raw material for making fuel (methanol and ethanol) (Bintoro et al. 2010).

Sago palm (*Metroxylon* spp.) is a potential commodity as an alternative food with high productivity, which is around 20-40 tons of dry starch/ha per year. Food security based on the strength of local resources will reduce dependence on imported commodities or products thereby creating food self-sufficiency (Kusumawaty et al. 2018). Bintoro et al. (2021) says one individual sago palm can produce as much as 200-400 kg of dry starch. The total area of sago fields in the world is 6,279,637 million hectares and Indonesia has 85% of the world's sago area or around 5,579,637 million hectares. According to Pranata et al. (2018) the vast land is still not properly utilized. The potential utilization of sago palm is still low, estimated at only around 15-20%. Many sago palm that has entered the harvest period is not harvested and is eventually damaged. One of the ways to determine sago palm accession is through the analysis of sago palm genetic diversity.

More than 50% of sago palm in Indonesia is in Papua (Bintoro 2008). Abbas et al. (2009) stated that Papua is the center of origin of the sago palm species. In a study conducted by Dewi (2015) in Sayal Village, Saifi District, South Sorong District, West Papua, 11 sago palm accession groups had quite a genetic relationship. Previous research by Abbas et al. (2009) stated that Papua has the highest sago palm genetic diversity as indicated by haplotype diversity and the percentage of polymorphism haplotypes.

This study aims to obtain information on the diversity of sago palm species through genetic analysis of various sago accessions in Lingga District, Kepulauan Riau. The hypothesis used as a reference for this research is that there are differences in genetic diversity of various accessions of sago palm (*Metroxylon* spp.) in Lingga District, Kepulauan Riau.

Materials and Methods (or Research Methods)

The research was conducted from October 2022 – February 2023. The locations for taking leaf samples for RAPD (Random Amplified Polymorphic DNA) analysis were in 6 villages in Lingga District, which are Teluk Village, Musai Village, Keton Village, Pekaka Village, Nerekeh Village, and Panggak Laut Village.

The materials used in this study consisted of 24 samples from 6 villages in Lingga District (Table 1). Other materials used were CTAB buffer, CIA (Chloroform isoamyl alcohol), Aquades, TAE buffer, Ethidium Bromide (EtBr), 10 mM agarose gel, 2x MyTaq HS Red Mix, DNA Ladder (VC 100bp Plus), and DNA Primer P01, P04, P06, P17, PA4, PAA17, PAB4, PAB18, and PG2. The tools used are a microtube, PCR tube, mortar and pestle, micropipette, centrifuge, spectrophotometer, electrophoresis chamber, thermal cycler, hot plate, pipette tip, vortex, spatula, beaker glass, Erlenmeyer, and computer.

Table 1. Sample data of sago palm accessions in Lingga District

No	Village	Spine/Spineless
1	Keton	Spine
2	Keton	Spine
3	Panggak Laut	Spine
4	Panggak Laut	Spine
5	Pekaka	Spine
6	Pekaka	Spine
7	Musai	Spine
8	Musai	Spine
9	Nerekeh	Spine
10	Nerekeh	Spine
11	Nerekeh	Spine
12	Nerekeh	Spine
13	Teluk	Spineless
14	Teluk	Spine
15	Teluk	Spineless
16	Teluk	Spine
17	Musai	Spineless
18	Musai	Spineless
19	Nerekeh	Spineless
20	Nerekeh	Spineless
21	Nerekeh	Spineless
22	Nerekeh	Spineless
23	Panggak Laut	Spineless
24	Panggak Laut	Spineless

Genetic characters were observed in the DNA of each sago palm accession using the RAPD (Random Amplified Polymorphic DNA) method. DNA samples were taken from the shoots of sago palm leaves during the tillering phase, then the collected leaves were stored in a plastic clip (zip lock) and stored in a cool box to keep the leaves fresh when in the field. Leaf samples were then taken 2 cm^2 and put in 700 µl of CTAB buffer solution until ready to be extracted in the laboratory. The stages of DNA extraction and RAPD analysis are as follows:

a. DNA extraction

The leaf samples were crushed using a mortar and pestle. The sample was then transferred into a 1.5 ml microtube and immersed in a water bath at 65°C for 30 minutes. Then the samples were incubated for 10 minutes at room temperature. Each sample was added with 700 µL of CIA (Chloroform Isoamyl Alcohol) solution and slowly inverted.

The sample is then centrifuged so that the solution is mixed until homogeneous, at a rate of 10 000 - 15 000 rpm for 5 minutes. The DNA solution will separate from the chloroform solution. The upper phase is taken and inserted into a new microtube. Absolute ethanol is added 2 times the sample volume. The sample is then incubated at room temperature for 10 minutes. Next centrifuged in 11,500 rpm for 5 minutes.

The supernatant solution resulting from centrifugation will be discarded leaving a DNA precipitate at the bottom of the microtube. The DNA precipitate will be dried using a vacuum for 45 minutes. The dried DNA was then dissolved using 50 µL of distilled water and tapped to dissolve the DNA (stock solution). The DNA stock solution was then stored at -20°C. The working solution for DNA samples was prepared by mixing 2 µL stock solution of DNA to be dissolved in 200 µL of distilled water.

b. PCR (Polymeration Chain Reaction) amplification for RAPD

The RAPD primers used in the experiment were 9 types of primers that had been selected by Ehara et al. (2003) as follows:

1) P01 (5' GCGGCTGGAG 3')
2) P04 (5' CGTCTGCCCG 3')
3) P06 (5' TTCCGCGGGC 3')
4) P17 (5' ATGACGACGG 3')
5) OPA04 (5' AATCGGGCTG 3')
6) OPAA17 (5' GAGCCCGACT 3')
7) OPAB04 (5' GGCACGCGTT 3')
8) OPAB18 (5' CTGGCGTGTC 3')
9) OPG02 (5' GGCATCGAGG 3')

PCR components were added to each microtube, namely 2x MyTaq HS Red Mix (50 µL), DNA working solution (25 µL), and primer (25 µL). Each of these components is attached to a different side of the microtube wall. Furthermore, the entire microtube is centrifuged to collect these solutions at the bottom of the microtube. Microtubes that have been centrifuged are then put into the Thermal cycler for 2 hours and 55 minutes.

c. DNA electrophoresis

1) Preparation of agarose gel

0.6 g agarose powder and TAE buffer were put into the Erlenmeyer and stirred into a solution. The agarose solution is heated using a hot plate until it is homogeneous. The homogeneous solution is poured into a mold equipped with a comb to make wells. This solution was left for 45 minutes until it solidified and after that, the comb was removed from the mold. The next step is to put the TAE solution into the mold until it covers the agarose gel.

2) Loading DNA and ladders

The PCR result solution (DNA) was put into the well as much as 2.5 µL. In the first and last wells, 5 µL of DNA ladder was added. The next step is the electrophoresis chamber is turned on at a voltage of 90V for 85 minutes. The electrophoretic agarose gel was then stained by immersion in ethidium bromide solution for 15 seconds. The gel was rinsed using distilled water by soaking it for 15 minutes. The DNA bands were observed using UV light.

The electrophoretic PCR results were then photographed and analyzed by scoring. The DNA band profile from the RAPD analysis was scored based on the presence or absence of amplification results in the polymorphic DNA bands. The genotype will be given a value of 1 if there is a band and given a value of zero if there is no band.

The accession genetic relationship can be identified from the number of polymorphic bands in the plant's DNA. These polymorphic bands will be converted into binary data by comparing the presence of polymorphic bands in selected samples from sago palm accessions. There are certain base pairs (bp) in the DNA band. Each band is considered a homologous locus. The locus is then converted into binary data by giving a value of one for the locus that has polymorphic bands and a value of zero if the locus does not have polymorphic bands. The scoring table is used in the analysis of similarity and clustering analysis. The data in the table will be analyzed using the Numerical Taxonomy and Multivariate Analysis System (NTSYS-pc version 2.02) program (Rohlf 2009). The data will be processed using the Simqual (Similarity of Qualitative) procedure to obtain similarities. The next step is to perform a clustering analysis using the UPGMA (Unweighted Pair-Group Method Arithmetic) method to create a dendrogram.

Results and Discussion

a. General condition of Lingga District

Lingga District has a space of 45,456.72 km^2. 95% of the area is an ocean and only 5% is land area. Lingga District is located between 0° 20' North Latitude - 0° 40' South Latitude, and 104° 30' - 105°00' East Longitude. The land area of Lingga District is dominated by hilly areas with slope levels which are divided into six classes, namely 0 – 2%, 2 – 8%, 8 – 15%, 15 – 25%, 25 – 40%, and >40%. Soil types in Lingga District are litosol, red-yellow podzolic, and organosol. The soil layers in this area have a crumb-to-lumpy structure with a clay-enveloped and firm bottom layer (BPS Kabupaten Lingga 2019).

The land area of Lingga District is dominated by hilly areas with slope levels which are divided into six classes, namely 0 – 2%, 2 – 8%, 8 – 15%, 15 – 25%, 25 – 40%, and >40%. As much as 77% of the Lingga District area has a slope of > 15%. Generally, the soil types in Lingga District are litosol, red-yellow podzolic, and organosol. The soil layers in this area have a crumb-to-lumpy structure with a tough, clay-enveloped underlayer. The rivers in Lingga District in flat areas have depths ranging from 2-3 meters from the water surface. In hilly areas, the rivers in Lingga District have depths ranging from 3-7 meters (BPS Kabupaten Lingga 2019).

Lingga District has a tropical and wet climate (BPS Kabupaten Lingga 2019). The average rainfall in this area in 2022 is 879 mm3. The highest rainfall occurred in May of 1786.4 mm3 and the lowest in September at 308.5 mm3. The average temperature in Lingga District in 2022 is 27 °C with a minimum temperature of 22 °C and a maximum temperature of 33 °C. The highest average humidity occurs in June 2022, which is 90.4%, while the lowest humidity occurs in January, which is 84.9% (BMKG 2022).

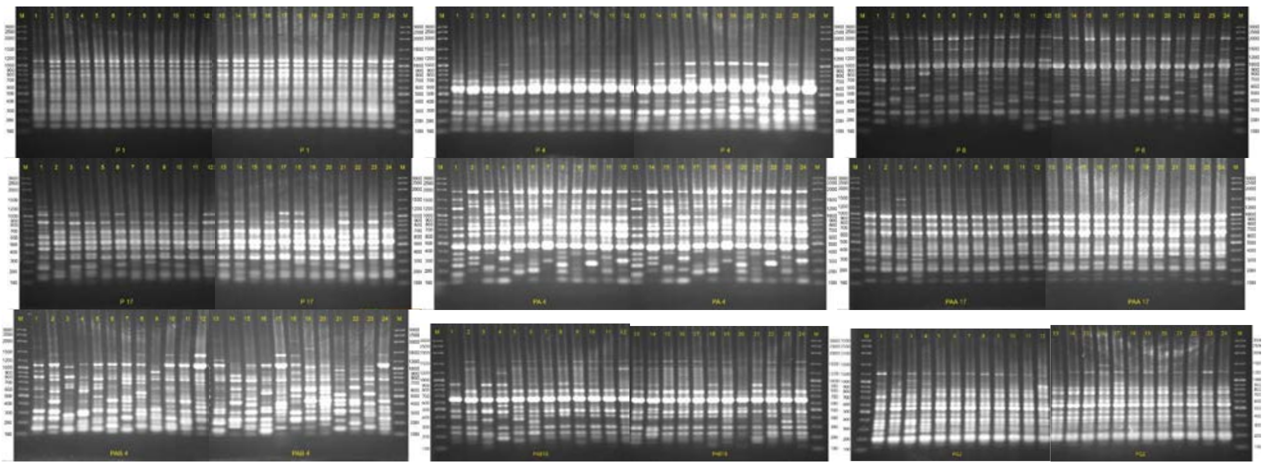
b. DNA isolation

The isolation of sago palm DNA was given out using the DNA isolation method combined with CTAB (Abhal 2022). P06 primer was adopted to test the quality of the DNA. Based on the events of the electropherogram (Fig 1) of 24 samples of sago palm leaves from 7 villages in Lingga District, DNA isolation can be said to have been successfully carried out. This was identified by the presence of DNA fragments which could be seen in the agarose gel being analyzed. The results of DNA isolation can be used for RAPD analysis because the DNA fragments on the electropherogram are not damaged and can be seen even though there are still smears or DNA bands that are elongated in the form of elongated stains on some DNA bands. According to Hikmatyar et al. (2015), DNA bands that shine firmly and clearly on agarose gel when exposed to ultraviolet light are well-isolated DNA.

Smear on the isolated DNA occurs because the DNA that comes out due to the lysis process is cut by the endonuclease enzyme during the extraction process in the CTAB buffer during the DNA isolation process (Mulyani et al. 2011). According to Iqbal et al. (2016), smears on DNA electrophoresis results are caused by contaminants such as protein and residual solution in the DNA isolation process. According to Husniyati (2012), smears can form during the DNA isolation process due to centrifugation, temperature treatment, and the remaining solutions used. The smear will affect the quality of the DNA that will be used.

c. DNA Amplification

DNA amplification was carried out on 24 sago palm accession samples from 7 villages in Lingga District with two types of sago palm, namely thorny sago and non-thorny sago. The primers used were P01, P04, P06, P17, OPA04, OPAA17, OPAB4, OPAB18, and OPG02. The sequence of bases and the number of DNA fragments obtained from the amplification results are shown in Table 7. The amplification results produced between 7 – 22 fragments from each primer used. The sizes of DNA fragments ranging from 100 bp – 2600 bp. In Firmansyah's research (2022), from 24 sago palm accession samples in Siberut National Park, a total of 158 DNA fragments were obtained.



Picture. 1. Results of DNA amplification based on genetic characters (RAPD) of various sago accessions in Lingga District

The results of the DNA amplification showed that there was polymorphism in the pattern of the DNA fragments (Fig. 1). The number of DNA fragments produced is different for each primer. The DNA fragment in the OPAB04 primer yielded 22 fragments with sizes between 100 bp – 1700 bp. This amount is the most compared to other primers. P01 primers produced the least number of fragments, namely 7 DNA fragments ranging in size from 375 bp to 2500 bp. The difference in the size of the DNA fragments (polymorphism) in the amplification results is caused by the distribution of nucleotide base locations in the genome which are the sites of primary attachment. RAPD results from polymorphism come from deletions, mutations, and insertions. The success of genomic DNA amplification in RAPD analysis is determined by the sequence of primers used, quantity (Susantidiana et al. 2009), and suitability of PCR conditions such as primer annealing temperature and extension (Gusmiaty et al. 2012).

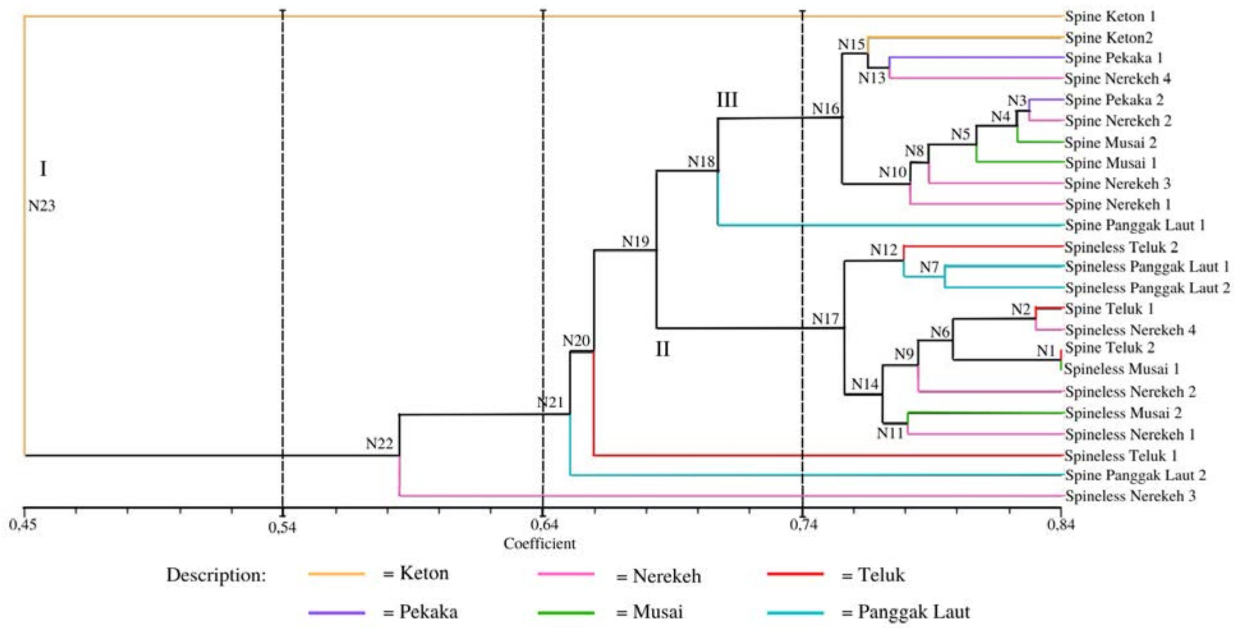


Figure 2. Dendrogram of 24 sago samples in Lingga District

d. Genetic Resemblance

RAPD analysis results on 24 samples taken from 6 villages in Lingga District showed that there was a genetic resemblance between individuals. This is indicated by the value of the similarity coefficient in the dendrogram which ranges from 45% to 84% (Fig. 2). Based on the dendrogram results, the sago samples can be grouped into three major groups at a similarity coefficient value of 54%. Group I consisted of 4 samplings and two large groups at a similarity coefficient value of 45%. Group II consisted of 10 samples and one large group at a similarity coefficient value of 70%. Group III consisted of 10 samplings with similarity coefficient values above 70%.

Group I is the sample group with the largest range of similarity coefficient values, which ranges from 45% - 66%, and nodes N20 - N23. The samples in group I sampled from several villages with spine and spineless sago palm, namely Keton 1 spine, Nerekeh 3 spineless, Pangga Laut 2 spine, and Teluk 1 spineless. The Keton 1 sample in group I has a relationship with 23 other samples at a similarity coefficient value of 45% and node N23 which is the smallest similarity coefficient value. Genetically, the Ketone 1 spine sample has many differences from the other 23 samples, so the Keton 1 spine sample has the most distant genetic resemblance from the other 23 samples. The Keton 1 spine sample is the first repeat spine sago palm sample taken from Keton Village. When compared with the Keton 2 spine sample which is the second repeat sample from the same village, the genetic resemblance values of the two are very far apart. The difference in the results of the amplification of the DNA fragments in each sample underlies the differences in the genetic resemblance between individuals. Nodes N20 – N22 have similarity coefficient values ranging from 58% - 66%.

Group II is found in similarity coefficient values between 68% - 84% and node N19. Eight samples in this group came from spineless sago palm species from different villages while two samplings came from spine sago palm species from the same suburb. Panggak Laut 2 spine and Musai 1 spineless samples have a similarity coefficient value of 84%. This value is the largest similarity coefficient value based on the RAPD results. This shows that the Teluk 2 spine and Musai 1 spineless sample have the closest genetic resemblance among the other samples. The Teluk 1 spine and Teluk 2 spine samples still have a fairly large similarity coefficient value, which is 80%.

Group III is at a similarity coefficient value between 70% - 82.5% and node N18. All samples in this group are spine sago palm. The 1st spiked sea arch sample is the one that has the lowest similarity coefficient value in group III, which is 70%. Spine sago palm from Keton Village, Nerekeh Village, Pekaka Village, and Musai Village has a fairly close genetic resemblance compared to spine sago palm from Teluk Village and Panggak Laut Village.

Data for groups II and III show that spine sago palm from different villages in Lingga District still has a moderately close genetic resemblance. This is the same as spineless sago palm from a different village in Lingga District. The type of spineless sago palm has a similarity coefficient value of 68% with spine sago palm at node N19. The results of the analysis of genetic resemblance in Lingga District showed that ten samples with similarity coefficient values above 70% were samples of spine sago palm, and eight samples had similarity coefficient values ranging from 68% - 84% of spineless sago palm. There were two samples with a similarity coefficient value of 84% which came from spine and spineless plants. This shows that the genetic characteristics of sago palm can affect its morphological characteristics. Morphological characters can also be different due to the influence of environmental factors.

The results of the RAPD analysis show that there is a genetic resemblance between the sago palm. Based on the results of the analysis, the similarity coefficient values can be divided into four parts, namely 45% – 54%, 54% – 64%, 64% – 74%, and 74% – 84% (Fig. 2). The type of sago palm with similarity coefficient values between 45% – 54% is thought to be a different type of sago palm, while those with similarity coefficient values between 54% – 64% are types of sago palm that have been cross-pollinated. In this type of sago with a similarity coefficient value between 64%–74%, it is suspected that there was a cross between close relatives and the growing environment. In the type of sago palm with a similarity coefficient value between 74%–84%, it may only be caused by differences in the growing environment. One sample of sago palm has the lowest similarity coefficient value of 45%. The smaller the similarity coefficient value that is formed, it indicates that the individual is more distantly related and vice versa. The sample is thought to be an accession that is different from other samples.

Based on the results of the analysis of sago palm genetic resemblance obtained, the morphological characters of spine or spineless on sago palm cannot be used as a benchmark to distinguish one individual from other individuals for naming sago palm. The morphological characters in the Keton 1 and Keton 2 samples had spines, but the genetic relationship was very far away. This is different from the samples Teluk 2 spine and Musai 1 spineless which have the closest genetic relationship.

Conclusions

DNA isolation for RAPD analysis was successfully carried out with good-quality DNA even though smears were still present. Smear on the isolated DNA occurs because the DNA that comes out due to the lysis process is cut by the endonuclease enzyme during the extraction process in the CTAB buffer during the DNA isolation process. The results of DNA amplification showed that there was polymorphism in the pattern of DNA fragments with different sizes. The difference in the size of the amplified DNA fragments (polymorphism) is caused by the distribution of nucleotide base locations in the genome which are the sites for primer attachment. RAPD analysis results show that the genetic variation of sago palm in Lingga District originates from differences in the growing environment, cross-pollination, crosses between close relatives, and different types of sago palm. The results of genetic resemblance analysis showed that the morphological characters of spine or spineless on sago palm could not be used as a benchmark to distinguish one individual from others for naming sago palm. The morphological characters in the Keton 1 and Keton 2 samples had spines, but the genetic relationship was very far away. This is different from the samples Teluk 2 spine and Musai 1 spineless which have the closest genetic relationship.

References

[BMKG] Badan Meteorologi Klimatologi dan Geofisika 2022 Data Harian Kabupaten Lingga *2022*. Jakarta (ID): Badan Meteorologi Klimatologi dan Geofisika.

[BPS] Badan Pusat Statistik 2021a Potret Sensus Penduduk 2020 Menuju Satu Data Kependudukan. Direktorat Statistik Kependudukan dan Ketenagakerjaan, editor. Jakarta (ID): BPS RI.

[BPS] Badan Pusat Statistik 2021b Buletin Statistik Perdagangan Luar Negeri Desember 2021. Jakarta (ID): BPS RI.

[BPS Kabupaten Lingga] Badan Pusat Statistik Kabupaten Lingga 2019 Kabupaten Lingga dalam Angka 2019. Lingga (ID): BPS Kabupaten Lingga.

[FAO] Food and Agriculture Organization 2022 Food Outlook: Biannual Report on Global Food Markets. Roma (IT): Food and Agriculture Organization of the United Nations.

[USDA-FAS] United States Department of Agriculture Foreign Agricultural Service 2023 Grain : World Markets and Trade. Washington (US): United States Department of Agriculture Foreign Agricultural Service. Februari.

Abbas, B., H. M. H. Bintoro, Sudarsono, M. Surahman, H. Ehara. 2009. Genetic relationship of sago palm (*Metroxylon sagu* Rottb) in Indonesia based on RAPD markers. Biodiversitas. 10(4):168-174.

Abhal, N. E. I. 2022 Identifikasi berbagai aksesi sagu (*Metroxylon* spp.) di Kecamatan Mamuju, Kabupaten Mamuju, Provinsi Sulawesi Barat [skripsi]. Bogor (ID): Institut Pertanian Bogor.

Bintoro, H. M. H. 2008. Bercocok Tanam Sagu. Bogor (ID): IPB Press.

Bintoro, M. H., H. Ehara, A. Azhar, R. K. Dewi, M. I. Nurulhaq, D. Ahyuni 2021 Ekofisiologi Sagu. Bogor (ID): IPB Press.

Bintoro, M. H., M. Y. J. Purwanto, S. Amarillis 2010 Sagu di Lahan Gambut. Bogor (ID): IPB Press.

Dewi, R 2015 Karakterisasi berbagai aksesi sagu (*Metroxylon* spp.) di Kabupaten Sorong Selatan, Papua Barat. Bogor (ID): Institut Pertanian Bogor.

Ehara, H., Y. Toyoda, D. Johnson 2003 Sago Palm Multiple Contributions to Food Security and Sustainable Livelihoods. Ed ke-18. Singapura (SG): Springer Open.

Firmansyah, A. N. A. 2022 Identifikasi berbagai aksesi sagu (*Metroxylon* spp.) di Taman Nasional Siberut, Kepulauan Mentawai, Sumatera Barat. Bogor (ID): Institut Pertanian Bogor.

Gusmiaty, M. Restu, I. Pongtuluran 2012 Seleksi primer untuk analisis keragaman genetik jenis bitti (*Vitex coffassus*). Jurnal Perennial. 8(1): 25-29.

Hikmatyar, M. F., J. I. Royani, Dasumiati 2015 Isolasi dan amplifikais DNA keladi tikus (*Thyponium flagelliform*) untuk identifikasi keragaman genetik. Jurnal Bioteknol Biosains Indonesia. 2(2):42. doi:10.29122/jbbi.v2i2.507.

Husniyati, T. 2012 Analisis variasi genetik populasi tanaman kare (*Hevea* brasiiliensis) sumber eksplan untuk perbanyakan in vitro berdasarkan RAPD. Bogor (ID): Institut Pertanian Bogor.

Iqbal, M., I. D. Buwono, N. Kurniawati 2016 Analisis perbandingan metode isolasi DNA untuk deteksi White Spot Syndrome Virus (WSSV) pada udang vaname (*Litopenaeus vannamei*). Jurnal Perikanan Kelautan. VII(1):54–65.

Rohlf, F. J 2009 NTSYSpc: Numerical Taxonomy and Multivariate Analysis System. New York (US): Applied Biostatistics Inc.

Kusumawaty, Y., E. Maharani, S. Edwina 2018 Proses produksi gula sagu dan saran pengembangan di Desa Sei Tohor , Kecamatan Tebing Tinggi Timur , Kabupaten Kepulauan. Di dalam: Prosiding Forum Komunikasi Perguruan Tinggi Pertanian Indonesia (FKPTPI). Banda Aceh (ID): Universitas Syiah Kuala.

Miyasto 2014 Strategi ketahanan pangan nasional guna meningkatkan kemandirian dan daya saing ekonomi dalam rangka ketahanan nasional. Jurnal Kajian Lemhanas RI. 2. 17:17–34.

Mulyani, Y., A. Purwanto, I. Nurruhwati 2011 Perbandingan beberapa metode isolasi DNA untuk deteksi dini Koi Herpes Virus (KHV) pada ikan mas (*Cyprinus carpio* L.). Jurnal Akuatika Indonesia. 2(1):244185.

Pranata, R., S. Karepesina, S. Botanri 2018 Distribusi spasial tumbuhan sagu (*Metroxylon* spp.) di Pulau Ambon. Jurnal Agrohut. 9(2):117–126.

Ramadhani, D. A., S. Mulyani 2018 Pengaruh substitusi tepung terigu dengan tepung sagu bolu kemojo. Jurnal Proteksi Kesehatan. 7(2):68–73. doi:10.36929/jpk.v7i2.136.

Riska 2018 Pengaruh komposisi tepung terigu, tepung dangke dan tepung sagu terhadap nilai gizi dan kesukaan biskuit. Makassar (ID): Universitas Hasanuddin.

Susantidiana, A. Wijaya, B. Lakitan, M. Surahman 2009

Identifikasi beberapa aksesi jarak pagar (*Jatropha curcas* L.) melalui analisis RAPD dan morfologi. Jurnal Agronomi Indonesia. 37(2):167–173.

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Genetic Relationship of Sago (*Metroxylon* spp.) in West Siberut and North Siberut, Mentawai Islands Regency, West Sumatra

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Abstract Sago plants have long spread in Indonesia and are thought to originate from the Maluku and Papua regions. In several areas in Indonesia besides Maluku, Irian Jaya, and Aceh, sago is used as a staple food for the Mentawai Islands in West Sumatra. The diversity of sago plant species in Indonesia is still largely unknown. Differences in the diversity of sago plants based on morphological and genetic characteristics were observed directly through measurements (quantitative) and visual observations (qualitative). This study aims to determine the genetic relationship of various sago accessions found in West Siberut and North Siberut Districts, Mentawai Islands Regency, West Sumatra. Genetic characters were observed using the *Random Amplified Polymorphic* DNA (RAPD) method. There were six sago accessions observed in the two sub-districts of West Siberut and North Siberut, namely the *Saikoat, Limu, Betaet, Ukra, Sirilanggai*, and *Sibeotcun* accessions, all of which included non-thorny sago species. Based on genetic character analysis (RAPD), there is a fairly close diversity of the six sago accessions, with similarity coefficient values ranging from 61% to 77%. The *Ukra* accession has the most distant similarity coefficient with the other accessions, namely 61%. Based on the analysis of genetic characters from a total of 24 samples taken from the Mentawai Islands Regency, 11 samples that had a similarity coefficient value above 77% were samples that were still in the same area, but 13 samples had a similarity coefficient value of around 63%-77% despite being in a different area. Differences in the similarity coefficients can occur due to different accessions or crossings or due to differences in their living environment.

Key words: Character, Diversity, Genetics, RAPD, Sago accession

Introduction

The sago plant is native to Indonesia with the widest area distribution in the world, which is approximately 51% of the total world sago area (Papilaya 2009). More than 50% of Indonesia's sago grows in Papua. Other provinces that have rather extensive sago are Maluku, North Maluku, Aceh, Riau, West Kalimantan, South Sulawesi, Southeast Sulawesi, and North Sulawesi (Bintoro 2008). Sago plants have long spread in Indonesia and are thought to originate from the Maluku and Papua regions. In several areas in Indonesia besides Maluku, Irian Jaya, and Aceh, sago is used as a staple food, including in the Mentawai Islands, and West Sumatra (Bintoro *et al*. 2010). Sago plants are C3 plants and can be found in the wet tropics in Southeast Asia and Oceania and dominate permanently or semi-permanently flooded swamplands, peat soils, and minerals with a minimum pH of 4.5 (Okazaki *et al*. 2013). According to Mulyanto and Suwardi (2000), sago can be found at an altitude of 0-700 m asl (above sea level), but grows optimally at an altitude of 0-400 m asl with temperatures ranging from 24-30ºC, humidity 60-90% and has a type entisols, histosols, and inseptisols.

The Mentawai Islands are an archipelago consisting of four major islands, namely Siberut, Sipora, North Pagai, South Pagai, and several smaller islands on the west side of Sumatra Island. Siberut Island is the largest island in the Mentawai Islands, which is 400,030 hectares and is divided into four districts, namely South Siberut, Central Siberut, North Siberut, and West Siberut (Kusbiantoro *et al*. 2016). Siberut National Park is included in the province of West Sumatra, Mentawai Islands, which is 155 km from the city of Padang. This area has a diversity of sago plants that have not been widely exploited. Approximately 60% of the area is covered by primary dipterocarp forests, mixed primary forests, swamps, coastal forests, and mangrove forests.

Analysis of the genetic diversity of sago plants is one way to determine their characteristics of sago plants. According to Barahima (2006), sago plants store their genetic information in the core genome and organelles, namely chloroplasts and mitochondria. One of the molecular marker techniques that have been used to see patterns of diversity is *Random Amplified Polymorphic* DNA (RAPD). RAPD which is used to identify sago plant genotypes has several advantages in its implementation and analysis (Suryanto 2003). The advantages of RAPD include that the procedure is easier, cheaper, and faster, requires a small amount of DNA sample (0.5-50 ng), and does not require radioisotopes (Sharma *et al*. 2008). RAPD molecular markers are used for various purposes, namely the study of genetic diversity, genetic hierarchy, genetic differentiation, genetic kinship, and genetic structure (Sripaoraya *et al*. 2001).

Abbas *et al*. (2009) conducted research related to the genetic relationship of sago plants using the RAPD method. Samples were taken from several islands in Indonesia and the result is that there is a genetic relationship between sago plant samples. Papua is the center of origin for the development of sago plants (*center of origin*) which is characterized by a high level of diversity and wide area for sago growth. The results of the analysis are shown in three main groups. The first group is sago plants from Papua which are genetically related to sago plants from Kalimantan and Sumatra. The second group, namely sago plants from Ambon, are closely related to sago plants from Sulawesi, and the third group, namely sago plants from Java, is not related to the others.

The diversity of sago plant species in Indonesia is still largely unknown. Morphologically, sago plants are distinguished based on the presence or absence of thorns, but the morphological characters are not sufficient to describe the diversity because they are still influenced by internal (genetic) and external (environmental) factors. It is important to identify the genetic diversity of various sago accessions, especially the development of sago accessions that have high productivity and the potential to be cultivated commercially (Nurulhaq

2017). Determination of sago accession needs to be done by observing the physical appearance and also genetics so that it is more accurate. This can be expressed by a variety of molecular techniques. One of the simple molecular techniques with relatively inexpensive and easy preparation is the *Random Amplified Polymorphic* DNA (RAPD) molecular marker. This technique has several advantages in its implementation and analysis. The results of the morphological observations of sago accessions were compared with the results of DNA analysis using the RAPD method so that the genetic relationship of sago accessions will be known through genetic character analysis. This study aims to obtain information on the genetic relationships of various sago accessions found in West Siberut and North Siberut Districts, Mentawai Islands Regency, West Sumatra.

Materials and Methods

Field data collection activities were carried out from January to March 2022. The research locations were in West Siberut and North Siberut Districts, Mentawai Islands Regency, and West Sumatra. DNA analysis using the RAPD method was conducted from April to June 2022 at the PMB (Plant Molecular and Biotechnology) Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University.

The materials used are sago plants that have entered the ready-to-harvest phase in six accessions located in West Siberut District and North Siberut District, leaf samples from each stand, 70% alcohol, 90% alcohol, absolute alcohol, phenol-chloroform, isoamyl alcohol, CTAB buffer, agarose gel 10 mM dNTP mix hot start master kit and magnesium chloride hexahydrate. The tools used are cameras, plastic zippers, cooler boxes, blue ice, and PCR machines.

Observation of genetic characters in each accession of sago plants was observed using the RAPD method. DNA samples were obtained from the youngest leaf shoots in the tillering phase, then the leaves were stored in a plastic zipper and put in a cooler box to maintain the freshness of the leaf structure in the field. Leaf samples were taken with a size of 2 cm^2 and put into a CTAB buffer solution of 700 µl. The next stage is DNA extraction and PCR amplification as follows:

a. DNA extraction

1. Buffer solution and leaf samples are removed from the tube and put into the mortar.
2. PVP (*polyvinyl-pyrrolidone*) is added to the mortar and ground together.
3. The crushed leaf sample was transferred into a 1.5 ml microtube.
4. Microtubes are immersed in a 65^{o}C water bath for 30 minutes and incubated for 10 minutes at room temperature.
5. Add 700 µL of CIA solution to each microtube.
6. Vortex the microtube to mix the solution until it is homogeneous.
7. The sample is centrifuged at 10,000-15,000 rpm for 5 minutes.
8. The supernatant (upper phase) was taken and put into a new 2 ml microtube.
9. CIA has added again to the supernatant, and the tube is vortexed and centrifuged again.
10. The supernatant was taken back and transferred to a new 2 ml microtube.
11. Absolute ethanol (100%) as much as 2 times the initial volume is added to the supernatant (filled to 2 ml).
12. The solution is incubated at a cold temperature.
13. The microtubes were centrifuged again at 8,000 rpm for 5 minutes.
14. Precipitated DNA pellets are obtained.
15. The water is removed and the DNA pellet is dried in a vacuum desiccator.
16. The DNA pellets are stored in the freezer until ready to use.

b. PCR amplification for RAPD

The RAPD primers used in the experiment referred to 9 types of primers that had been selected by Ehara et al. (2003) as follows:

1. P01 (5'-GCGGCTGGAG-3')
2. P04 (5'-CGTCTGCCCG-3')
3. P06 (5'-TTCCGCGGGC-3')
4. P17 (5'-ATGACGACGG-3')
5. OPG02 (5'-GGCATCGAGG-3')
6. OPA04 (5'-AATCGGGCTG-3')
7. OPAB04 (5'-GGCACGCGTT-3')
8. OPAA17 (5'-GAGCCCGACT-3')
9. OPAB18 (5'-CTGGCGTGTC-3')

Primer was dissolved in aquabidest water and prepared in a concentration of 100 µM as a stock solution. The amount of water that must be added to make a stock solution is calculated by multiplying the number of molecules indicated on the package by 10 µL. Next, a working solution was made for each primer with a dilution of 5 times, to facilitate work.

Each microtube was loaded with PCR master mix, DNA template, and primer for PCR amplification with 5 µL taq polymerase, 2.5 µL DNA, and 2.5 µL primer respectively. The amplified fragments were electrophoresed using agarose gel in 1 x TAE buffer, fixed on ethidium bromide, and visualized using a Densitograph and the ATTA bioinstrument. Agarose gel was prepared by dissolving 0.6 g of agarose gel in 40 ml of TAE and heating it on a hot plate until homogeneous (boiling) for about 3 minutes. Once cold, the solution is poured into the mold and the comb is installed to make a hole (well), then wait for it to solidify. After solidification, the comb was removed and the TAE solution was added until it covered the agarose gel.

The PCR result solution (DNA) was put into the well as much as 2.5 µL. Next, 5 µL of marker (ladder) was added to the well. The gel electrophoresis results were then stained by placing it in ethidium bromide solution for 5 minutes and then taking pictures. The electrophoretic PCR results were photographed and analyzed by scoring. The DNA band profile from the RAPD analysis was scored based on the presence or absence of amplification results. If there is a band then the genotype is scored 1 and if there is no band on the other genotypes it is scored 0. Scoring is done in locus areas that have clear bands. Observations in the genetic analysis were carried out using RAPD markers and carried out in PCR machines, which were then processed using the NTSYS-pc version 2.02 program.

Results and Discussion

General Circumstances

The Mentawai Islands are a series of four large islands consisting of Siberut, Sipora, North Pagai, South Pagai, and several smaller islands. Siberut Island is the largest island, which is around 3818.18 km^2. Siberut Island is split into four districts, namely South Siberut, Central Siberut, North Siberut, and West Siberut. Field data obtained was executed in two locations, namely West Siberut and North Siberut. This area is part of the Area II National Park Management Section (SPTN II). West Siberut District has an area of 1163.64 km^2 or about 19.3% of the area of the Mentawai Islands Regency (6033.77 km^2). West Siberut District is the largest sub-district in the Mentawai Islands Regency which consists of three villages namely Simalegi Village, Simatalu Village, and Sigapokna Village with a total of 29 sub-villages. North Siberut District has an area of around 782.68 km^2 or about 13% of the area of Mentawai Regency (6033.77 km^2). This sub-district consists of six villages, namely Sirilogi Village, Muara Sikabaluan Village, Mongan Poula Village, Sotboyak Village, Bojakan Village, and Malancan Village with a total of 26 sub-village (BPS 2022).

Siberut Island with an area of 4,030 km^2 has been designated as the core zone of the National Park. The land area occupied by Siberut National Park is 190,500 hectares. Its designation as a national park is based on the Decree of the Minister of Forestry Number 407/Kpts-II/1993. Geographically, Siberut National Park is located at coordinates 01°05'-01°45' South Latitude and 98°36'-99°03' East Longitude. Administratively, Siberut National Park is bordered by the Indian Ocean (western part), Central Siberut District (Eastern part), North Siberut District (North part), and South Siberut District (Southern part). The zoning area in Siberut National Park was established in 2015 through the Decree of the Director General of PHKA No. 32/IV-Set/2015, which consists of a core zone of 45,620 hectares, a forest zone of 85,580 hectares, a utilization zone of 19,920 hectares, a traditional zone of 24,050 hectares, and a special zone of 15,330 hectares. The Siberut National Park Authority is divided into two Conservation Area Sections, namely the Region I Conservation Section in Muara Sikabaluan and the Region II Conservation Section in Muara Siberut. 60% of the Siberut National Park area is covered by relatively unspoiled forests such as Dipterocarpaceae primary forest, mixed primary forest, swamps, coastal forest, and mangrove forest dominated by large trees reaching 60 meters high and rich in endemic rare flora and fauna, and includes representatives of the tropical rainforest type. The topography of the Siberut National Park area is flat to hilly with a height of less than 400 m asl (above sea level) with the highest peak at 384 m asl. The plains area has a slope of 0% to 15% with a height ranging from 0 m to 50 m and is influenced by a tropical climate with an annual average rainfall of 3,320 mm, with temperatures ranging from 22-31^{o}C and average humidity ranging from 91-95 % (Haryani and Putri 2021).

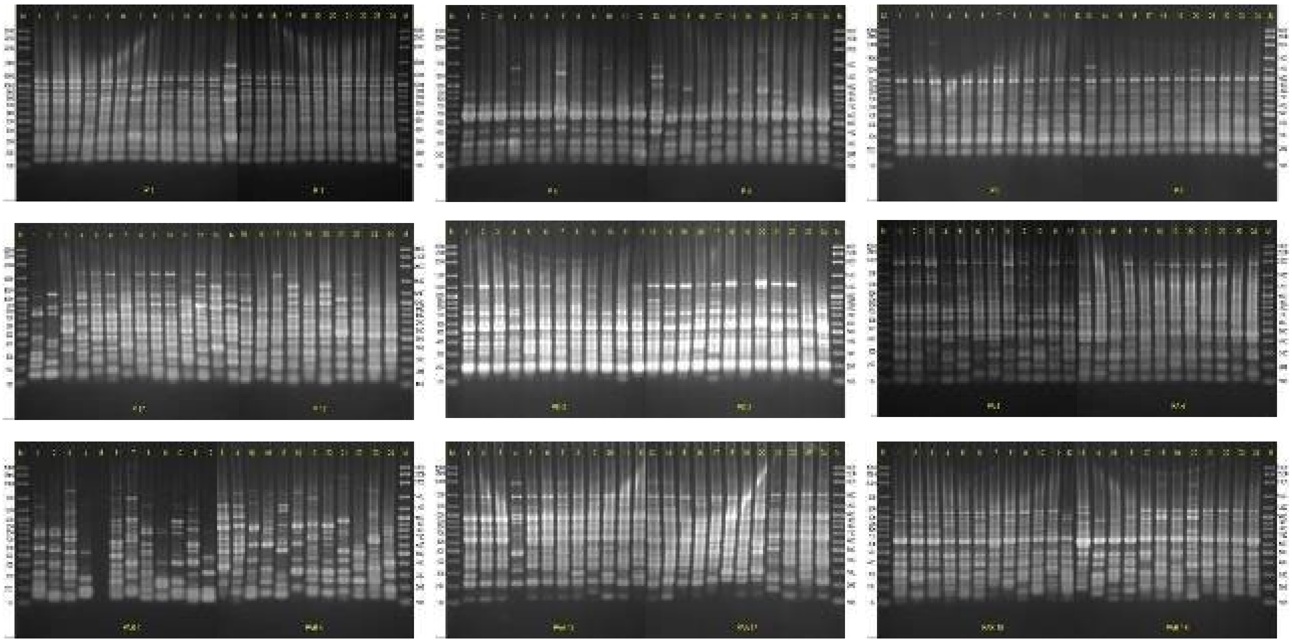
Sago accession

There are 6 sago accessions found in Mentawai Islands Regency, West Sumatra. These accessions are located in West Siberut District (*saikoat, limu*, and *betaet* accessions) and North Siberut District (*ukra, sirilanggai*, and *sibeotcun* accessions). All sago accessions found were types of sago that are not thorny and include plants that flower and bear fruit once (*hepaxanthic*). The location is a mixed forest that grows in it a variety of other vegetation. Sago in that location grows naturally so the saplings grow irregularly due to the absence of plant cultivation activities. Sago grows by forming clusters, in one cluster there is a mother and a sago sapling which have different growth phases, starting from the seedling phase (saplings still attached to the mother), saplings (saplings are separated from the mother but do not yet have stems), pole phase (saplings have had a trunk), and the saw-timber phase that is ripe for cutting and trees that have passed cutting maturity. The number of seedling phases found in one cluster is around 1-7 sago seedlings, some clusters only have one parent and tillers that are closely packed but are still in the seedling and weaning phases.

Fig. 1. Variations in the shape of the crown of various sago accessions in the Mentawai Islands District

Genetic Relations

Genetic characters in the DNA of each accession were taken from leaf samples in each 50 m x 50 m plot with four replicates and observed using the RAPD method using nine primers, namely primers P01, P04, P06, P17, OPG02, OPA04, OPAB04, OPAA17, and OPAB18. The result is a clear DNA amplification with the marked appearance of polymorphic bands (Figure 2). Each primer has several DNA yield fragments ranging from 7 to 30 bands, with an average of 17 bands per primer. P01 primer has 15 bands, P04 primer has 14 bands, P06 primer has 7 bands, P17 primer has 25 bands, OPG02 primer has 10 bands, OPA04 primer has 20 bands, OPAB04 primer has 30 bands, primer OPAA17 has 20 bands, and OPAB18 primer has 17 bands. The total number of fragments produced from 9 primers was 158.



Note: Samples 1-4 = *saikoat*; Sample 5-8 = *limu*; Sample 9-12 = *betaet*; Sample 13-16 = *ukra*; Sample 17-20 = *sirilanggai*; Sample 21-24 = *sibeotcun*

Fig. 2. Results of DNA amplification based on genetic characters (RAPD) of various sago accessions in Mentawai Islands District

The results of DNA amplification of various sago accessions in Siberut National Park based on genetic characters (RAPD) for six sago accessions produced dendrograms with coefficients of similarity ranging from 61% to 77% (Figure 3). Based on genetic characteristics, the accession that has the closest kinship relationship, namely the *limu* accession and the *betaet* accession with a similarity coefficient value of 77%. The accessions in West Siberut (*saikoat, limu,* and *betaet* accessions) have a fairly close similarity coefficient value, which is 69%, while the accessions in north siberut (*ukra, sibeotcun* and *sirilanggai* accessions) have a relatively close similarity coefficient value, which is equal to 61%. the *sibeotcun* and *sirilanggai* accessions in north siberut have a kinship relationship with the accessions in west siberut (*saikoat, limu,* and *betae*t accessions), namely 68%. only the *ukra* accession has the most distant similarity coefficient value to the accessions in north siberut and west siberut, namely 61%.

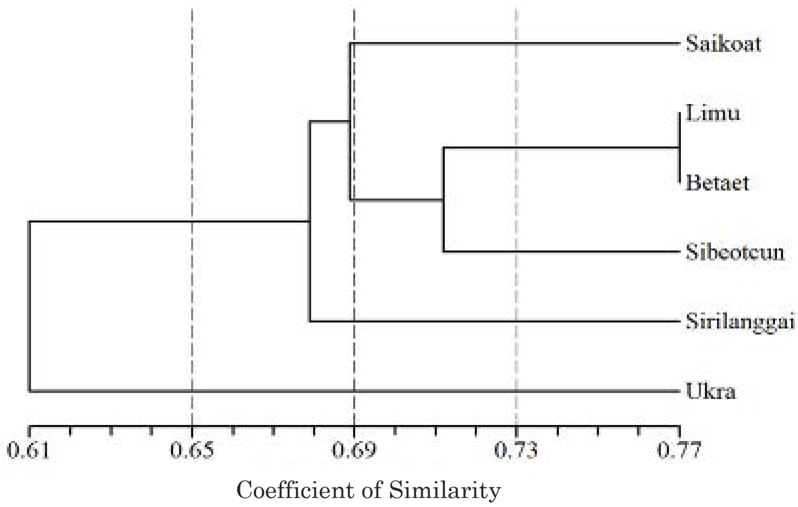


Fig. 3. Dendogram of six sago accessions based on genetic characters in Mentawai Islands District

The addition of the number of samples for each accession was carried out to find out in more detail the kinship relationship between sago accessions on Siberut Island. The accessions of *saikoat, limu, betaet, sibeotcun, sirirlanggai,* and *ukra* each have four samples. The DNA amplification results for 24 samples produced a dendrogram with a similarity coefficient between 63 and 81% (Figure 4). 11 samples have a similarity coefficient value above 77% and there are four samples that have a similarity coefficient value of less than 68%.

The dendogram results form three large groups at a similarity coefficient value of 65%. The first large group is found with a similarity coefficient value of 69%. Samples taken from Limu hamlet (West Siberut) have a kinship relationship with samples taken from Ukra and Sirilanggai sub-village (North Siberut) with similarity coefficient values ranging from 69% -73%.

The second large group is found in the similarity coefficient value of 68%. All samples taken from Betaet hamlet (West Siberut) have a coefficient of similarity between 73% -75%. Samples from Ukra and Sirilanggai sub-village (North Siberut) have a similarity coefficient value of 71%. Samples from Sirilanggai hamlet (North Siberut) have a kinship relationship with samples from Limu hamlet (West Siberut) with similarity coefficient values ranging from 75% -78%.

The third large group occurs in the sample with a similarity coefficient value of 67%. All samples from Sibeotcun hamlet (North Siberut) have a similarity coefficient value of 71% - 80%. All samples from Saikoat were clustered and had the closest kinship ranging from 77% -81%, except for one sample from the Saikoat hamlet (*saikoat*-4) which had the most distant kinship with the other samples, namely 63%. Samples from the Ukra hamlet (*ukra*-4) have similarity coefficient values ranging from 69% -72% with samples from Sibeotcun and Saikoat sub-village.

Analysis of genetic kinship in Siberut National Park showed that the 11 samples that had a similarity coefficient value above 77% were samples from the same area, but 13 samples had a similarity coefficient value ranging from 63% -77% even though they were in a different area. This shows that sago that grows in the same area does not always have the same type, but can be different because it is influenced by environmental factors.

The similarity of sago accessions illustrates the kinship of the sago. From observations in Mentawai District, particularly in North Siberut and West Siberut, the coefficient of similarity can be divided into a range between 63%-68%, a range between 68%-72%, a range between 72%-77%, and a range between 77%-81% (Figure 4). Accessions that have similarities with a range of 63%-68% are thought to have come from different accessions, while those in the range of 68%-72% may have come from different accessions but cross-pollination has occurred among the accessions. Accessions with a similarity range of 72%-77% likely occurred due to crosses of close relatives of sago accessions and due to differences in the growing environment, while in the range of 77%-81%, it is thought to have occurred due to differences in the growing environment of the sago accessions.

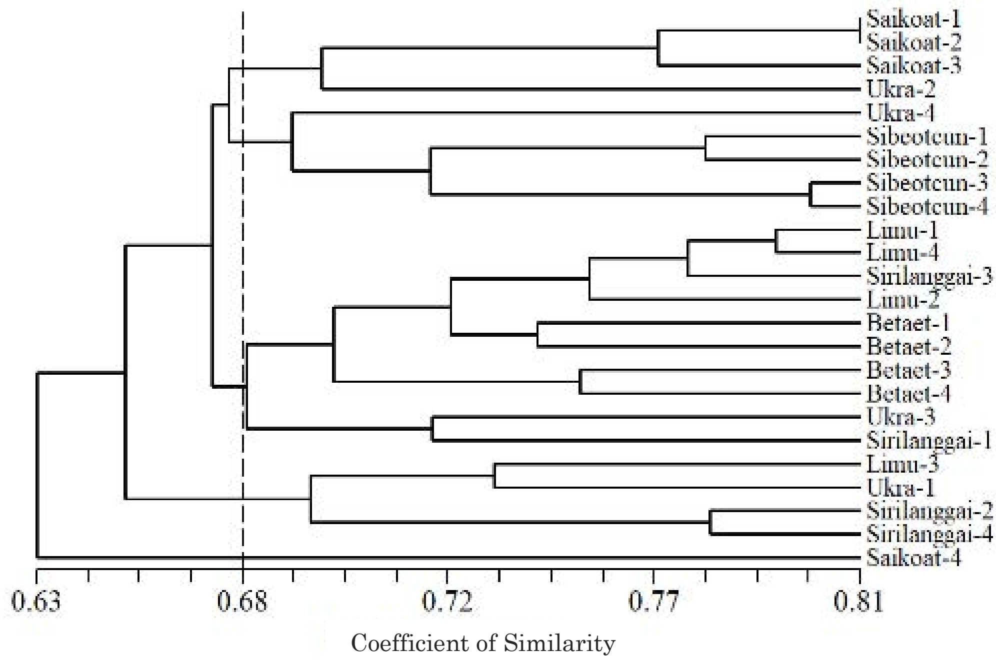


Fig. 4. Dendogram of 24 sago accession samples based on genetic characters in the Mentawai Islands District

Conclusions

The accession of sago found in the Mentawai Islands Regency, West Sumatra is a type of sago that is not thorny and belongs to the type of sago that flowers and bears very few fruits (*hepaxanthic*). There are accessions in West Siberut (*saikoat, limu,* and *betaet* accessions) and North Siberut (*ukra, sirilanggai*, and *sibeotcun* accessions). Based on the genetic character, the *ukra* accession has a very distant kinship relationship with the other accessions, namely 61%. Accessions with fairly close kinship are *limu* accession and *betaet* accession which have a similarity coefficient value of 77%. The diversity of sago accessions based on genetic characters in the two Districts of West Siberut and North Siberut based on 24 samples taken has a fairly close similarity coefficient, ranging from 63% to 81% even though they are found in different areas. 11 samples have a similarity coefficient value above 77% and there are 13 samples that have a similarity coefficient value below 77%. The accessions of sago growing in West and North Siberut are very diverse. This diversity is partly due to different accessions, crossing over, and differences in their living environment.

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References

[BPS] Badan Pusat Statistik. 2022 Mentawai Islands Regency in Figures. Sumatera Barat: BPS Kabupaten Kepulauan Mentawai.

Abbas B, Bintoro M, Sudarsono, Surahman M, Ehara H. 2009 Genetic relationship of sago palm (Metroxylon sagu Rottb.) in Indonesia based on RAPD markers. Biodiversitas J Biol Divers. 10(4):168–174. doi:10.13057/biodiv/d100402.

Barahima. 2006 Genetic diversity of sago plants in Indonesia based on molecular markers of the chloroplast genome and nuclear genome [dissertation]. Bogor(ID): Institut Pertanian Bogor.

Bintoro H. 2008 Sago Farming. Bogor(ID): IPB Press.

Bintoro M, Purwanto M, Amarillis S. 2010. Sago in Peatland. Bogor(ID): IPB Press.

Ehara H, Kosaka S, Shimura N, Matoyama D, Morita O, Naito H, Mizota C, Susanto S, Bintoro M, Yamamoto Y. 2003 Relationships between geographical distribution and genetic distance of sago palm in Malay Archipelago. Sago Palm. 11:8–13.

Haryani R, Putri MSE. 2021 Siberut National Park Office Statistics Book 2020. Sumatera Barat: Balai Taman Nasional Siberut.

Kusbiantoro K, Anthonius R, Santosa I. 2016 Modernization and Commercialisation of Uma In Mentawai Community: A Phenomenological Description. J Sociotechnology. 15(2):187–199.

Mulyanto B, Suwardi. 2000 Distribution and characteristics of land, the sago palm (*Metroxylon* spp.) habitat in Indonesia. In: Bintoro M, Suwardi, Sulistiono, Kamal M, Setiawan K, Hadi S, editor. Sustainable Utilization of Sago Palm as an Alternative Source of Food and Materials For Agroindustry in The Third Millennium. Proceeding of The International Sago Seminar; 2000 Mar 22-23; Bogor, Indonesia. Bogor (ID): IPB, JSPS, BCRG, PT Freeport Indonesia. p 38-44.

Nurulhaq MI. 2017 Identification of various accessions of sago (*Metroxylon* spp) in Iwaka District, Mimika Regency, Papua [thesis]. Bogor: Sekolah Pascasarjana, Institut Pertanian Bogor.

Okazaki M, Yonebayashi K, Katsumi N, Kawashima F, Nishi T. 2013 Does sago palm have a high δ13 value?. Sago Palm. 21:1–7.

Papilaya E. 2009 Sago for National Children's Education. Bogor(ID): IPB Press.

Sharma A, Namdeo A, Mahadik K. 2008 Molecular markers: new prospects in plant genome analysis. Pharmacogn Rev. 2(3):23–31.

Sripaoraya S, Blackhall N, Marchant R, Power J, Lowe K, Davey M. 2001 Relationships in pineapple by random amplified polymorphic DNA (RAPD) analysis. Plant Breed. 120(3):265–267.

Suryanto D. 2003 Seeing the Diversity of Organisms Through Several Molecular Genetic Techniques. Sumatera Utara: USU Digital Library.

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Genetic Relationship of Sago (*Metroxylon* spp.) Based on RAPD Analysis: A Case of Mamuju District, West Sulawesi Province, Indonesia

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Abstract Sago (*Metroxylon* spp.) is an original plant from Indonesia, and about 85% of the world's sago is grown in Indonesia. Sago has a high potential, especially as a salvation plant. The research aims to identify sago accession based on genetic characteristics in Mamuju District and the sago relationship in West Sulawesi Province using RAPD method. Three accessions of sago were observed based on local names in Mamuju District, i.e. 2 types of non spiny, *kasimpo* and *kapas*, and 1 type spiny *ruwi*. The genetic relationship of these accessions is known from the number of polymorphic bands in DNA. The bands are converted into binary data by comparing the presence or absence of bands belonging to selected samples from sago accessions. West Sulawesi Province consists of 6 districts, and sago sampling was collected in each of these 6 districts. Specifically, we collected 10 sago samples from Mamuju District, as well as 8 samples from Majene District and Polewali Mandar District. Moreover, 3 sago samples were taken from Donggala District, Central Sulawesi Province. The total sago samples used were 47. The genetic distance based on RAPD analysis of sago accessions in West Sulawesi Province was not too far, Kf value <80%. Uniqueness of gene expression was found in these accessions, and it is possible that there is a distant genetic relationship on spiny sago accessions, as well as non spiny sago accessions. However, there is a close genetic relationship between spiny sago and non-spiny sago. Thus, the local accessions based on morphological characteristics of sago should be explored further using RAPD analysis to determine genetic closeness.

Key words: Genetic closeness, RAPD method, Sago accession

Introduction

Indonesia is a country with a high diversity of vegetation, especially carbohydrate-producing plants. However, national food needs are still based on the commodity of rice (Oryza sativa). BPS (2021a) notes that the results of the 2020 population census amounted to 270.20 million people, experiencing an average increase of 1.25% per year when compared to the 2010 population of 237.63 million people. Population growth increases national food demand. National food needs are also based on rice commodities, which are concentrated from the production side on the island of Java. Population growth on Java can directly erode agricultural land, especially fertile paddy fields. According to Irianto (2016), the availability of land (paddy rice) in the supply of food is an important problem due to the population explosion and has the worst possibility of the threat of starvation. Rice production in Indonesia in 2020 is estimated at 54.65 million tons of GKG (BPS, 2021b). This production value is quite high compared with that of rice production in other countries. According to Nurulhaq (2017), Indonesia ranks 3rd in the world as the highest rice-producing country after China and India; however, national rice production is still unable to meet the needs of the population. To address these problems, it is necessary to diversify food. Sago is a plant with high potential, and in terms of sago productivity, it can produce 20-40 tons of dry starch/ha/year. Other uses of sago starch include industrial raw materials (glutamate, lactate, and fructose), as well as fuel (methanol and ethanol) (Bintoro et al., 2010).

Sago is a unique form of natural wealth owned by Indonesia. In addition, Djoefrie et al. (2014), Indonesia has 50% more potential for sago worldwide, with an area of 5.5 million ha. According to Bintoro et al., (2021) the world's sago area is 6,279,637 million hectares and Indonesia has 85% of the world's sago area or around 5,337,691 million hectares. The largest distribution of sago in Indonesia is found in the provinces of Papua and West Papua. The spread of sago in Indonesia is quite wide, and besides Papua and West Papua sago grow on the islands of Sulawesi, Sumatra, Kalimantan, and Java. The people of Sulawesi have used sago as a staple food for a long time, even though sago as a staple food has decreased but processed sago can still be found. The people of Sulawesi, especially West Sulawesi, usually process sago into *jepa* and *kapurung*. According to Ernawati et al. (2018), lime is usually served almost every day and is also often served at weddings, *aqiqah*, and traditional events as complementary food during family gatherings. *Letto* means sago wet starch in Mamuju local language.

Traditional societies generally divide sago into spiny and non-spiny sago. However, there are various types of spiny and non-spiny sago. Morphological diversity (visible through sight) often deviates from genotypic diversity due to environmental influences (Ahmad, 2017). Plant morphology is influenced by two factors: internal factors (genetic) and external factors (environment). Determining the type of sago using plant genetic material is more accurate than its morphological appearance. Therefore, it is necessary to determine the accession of sago by observing the genetic relationship between each type of sago. Observations were made using sago genetic material in the form of DNA which was analyzed using the RAPD (Random Amplified Polymorphic DNA) method. This study aims to determine sago genetic relationship scope mamuju and scope west Sulawesi province using RAPD analysis.

Materials and Methods

The research areas were 6 districts in West Sulawesi Province, consisting of Mamuju Regency, Mamasa Regency, Majene Regency, Polewali Mandar Regency, Central Mamuju Regency and North Mamuju Regency. This study was conducted from January to April 2022. RAPD (Random Amplified Polymorphic DNA) analysis at the PMB (Plant Molecular and Biotechnology) Laboratory, Department of Agronomy and Horticulture. Knowledge related to sago types based on morphological characteristics was obtained through interviews with key informants in the Mamuju Regency, West Sulawesi Province. Local naming was used as a marker for each sago sample. The unknown local name of the sago is marked with the name of the sampling district. The materials used were 70% alcohol, 90% alcohol, absolute alcohol, phenol chloroform, isoamyl alcohol, CTAB buffer, 10 mM agarose gel dNTP mix hot-start master mix kit, and magnesium chloride hexahydrate. The tools used consisted of microtubes, cooler boxes, scissors, labels, supporting equipment, and laboratory equipment.

Data were collected from leaf samples during the tillering phase. Sago DNA was isolated. The determination of genetic characteristics in the form of similarity value includes West Sulawesi Province. Six sago samples were taken from each district, consisting of 3 different districts, specifically for Mamuju Regency, and various accessions were used and each accession consisted of 3 samples. The selected sago leaves were cut into 2 cm2 sizes, then put into the cooler box by first preserving them using CTAB buffer solution.

The genetic characteristics of sago accessions were obtained from the results of RAPD analysis in the laboratory. The genetic relationship between accessions is known from the number of polymorphic DNA bands. The bands were converted into binary data by comparing the presence or absence of bands belonging to selected samples from the sago accessions. Certain base pairs (bp) were observed in the DNA bands. Each band was considered to be a homologous locus. The locus was then converted into binary data by assigning a value of one (1) for having a band and a value of zero (0) for not having a band. The RAPD data were analyzed descriptively and translated into a scoring table based on the presence of polymorphic bands. The scoring table was used in the analysis of similarity or relationship, and clustering analysis with the Numerical Taxonomy and Multivariate Analysis System (NTSYS-pc version 2.11). The data were processed using the Similarity of Qualitative (Simqual) procedure to determine the coefficient of similarity. Clustering analysis was performed using the Unweighted Pair-Group Method Arithmetic (UPGMA) method to create a dendrogram.

PCR amplification used 9 primers, consisting of P01 (5'-GCGGCTGGAG-3'), P04 (5'-CGTCTGCCCG-3'), P06 (5'-TTCCGCGGGC-3'), P17 (5'-ATGACGACGG-3'), PG2 (5'-GGCATCGAGG-3'), PA4 (5'-AATCGGGCTG-3'), PAB4 (5'-GGCACGCGTT-3'), PAA17 (5'-GAGCCCGACT-3') and PAB18 (5'-CTGGCGTGTC-3'). The stages of DNA extraction as follows:

1) The buffer solution and leaf samples are removed from the tube and put into the mortar.
2) PVP (polyvinyl-pyrrolidone) is added to the mortar and ground together.
3) Samples of crushed leaves were transferred to a 1.5 ml micro tube.
4) The micro tube is immersed in a 65°C water bath for 30 minutes and incubated for 10 minutes at room temperature.
5) In each micro tube, 700 pl of CIA solution is added.
6) Micro tube is vortexed to mix the solution until it is homogeneous.
7) The sample is centrifuged at 10,000-15,000 rpm for 5 minutes.
8) The supernatant (upper phase) was taken and put into a new 2 ml micro tube.
9) CIA is added again, into the supernatant, the tube is vortexed and centrifuged again.
10) The supernatant was taken again and transferred to a new 2 ml micro tube.
11) Absolute ethanol (100%) as much as 2 times the initial volume was added to the supernatant (full up to 2 ml).
12) The solution was incubated at cold temperatures.
13) The micro tube was centrifuged again at 8,000 rpm for 5 minutes.
14) The precipitate of the DNA pellet was found at the bottom of the surface of the micro tube.
15) The water was discarded and the DNA pellet was dried in a vacuum desiccator.
16) The DNA pellets were stored in the freezer until they were ready to use.

Primer was dissolved in aquabidest water and prepared in a concentration of 100 μM as a stock solution. The amount of water that must be added to prepare a stock solution was calculated by multiplying the number of molecules indicated on the package by 10 μL. A working solution was prepared for each primer at a dilution of five times to facilitate the work.

PCR amplification was carried out by inserting the PCR master mix, DNA template, and primers into each microtube. Each 5 μL of taq polymerase, 2.5 μL of DNA and 2.5 μL of primer. The amplified fragments were electrophoresed on agarose gel in 1 × TAE buffer, fixed on ethidium bromide, and visualized using a Densitograph ATTA Bioinstrument. Agarose gel was prepared by dissolving 0.6 g of agarose gel in 40 ml of TAE and heating it on a hot plate until homogeneous (boiling) for approximately 3 min. Once cooled, the solution was poured into the mold, the comb was installed to make a hole (well), and it was then allowed to solidify. After solidification, the comb was removed, and TAE solution was added until it covered the agarose gel.

The PCR solution (DNA) was added to the wells at a much of 2.5 μL. At the end of the well, 5 μL of the marker (ladder) was added. The gel electrophoresis results were then stained by placing them in an ethidium bromide solution for 5 min and then taking pictures. Electrophoretic PCR results were photographed and analyzed by scoring. The DNA band profile from RAPD analysis was scored based on the presence or absence of amplification results. If there is a band, then the genotype is scored 1, and if there is no band on the other genotypes, it is scored 0. Scoring was performed in locus areas with clear bands. Observations in genetic analysis were carried out using the RAPD marker and carried out in a PCR machine.

Results and Discussion

The people of Mamuju Regency have known sago and consumed it for a long time. Sago is widely used as an alternative food in Mamuju Regency, such as *jepa* and *kapurung*. Sago is also often processed into snacks, such as *bagea* with the basic ingredients of sago starch. Even though the use of sago starch covers many foods, the decline in sago production every year continues to occur. The decrease in sago area is caused by several factors, such as housing, land clearing for roads and buildings, and conversion of agricultural land. Information related to sago accession in Mamuju District is quite difficult to find out, and this is due to the loss of information within the scope of the general public. The community only classifies the types of sago based on the presence or absence of thorns on the sago fronds, even some people who used to work by processing sago into wet starch also do not know further information regarding the types of sago.

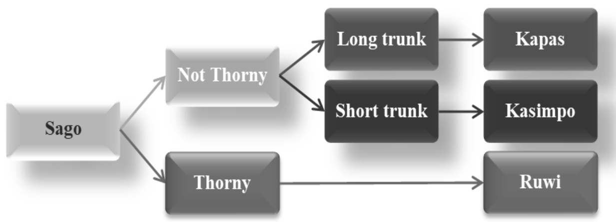


Fig. 1. Sago classification from key informants

Based on the results of interviews with key informants, it is known that there are 3 local accessions of sago in Mamuju District. These accessions are distinguished based on morphological characteristics that can be directly observed. The first distinguishing character is the presence of thorns (Figure 1). Furthermore, accessions that do not have thorns are divided into 2 based on stem length. Although the character of stem height is less accurate, there is also another distinguishing character, namely pith color. The *kasimpo* accession has a reddish-white pith color, while the *kapas* accession is white. The canopy shape of the three types of sago is presented in Figure 2.

a b c

Fig. 2. Crown shape of various sago accessions in Mamuju District (a = *kasimpo*, b = *kapas*, c = *ruwi*)

DNA amplification using the RAPD method on 3 accessions consisting of 10 sago samples showed clear differences. The resulting fragments from 9 primers are 130 bands. Differences are shown through DNA bands of a certain size that are not amplified or are called polymorphic bands. The sample used to determine the genetic closeness of various sago accessions in Mamuju District, consists of the 1st *kasimpo*, 4th *kasimpo*, 5th *kasimpo*, 2nd *cotten*, 3rd *cotten*, 4th *cotten*, 1st *ruwi* , 2nd *ruwi*, 3rd *ruwi* and 4th *ruwi*. There are differences in the sample in determining the sago genetic closeness.

DNA amplification using the RAPD method on 3 accessions consisting of 10 sago samples showed clear differences. The resulting fragments from 9 primers are 130 bands. Differences are shown through DNA bands of a certain size that are not amplified or are called polymorphic bands. The sample used to determine the genetic closeness of various sago accessions in Mamuju District, consists of the 1st *kasimpo*, 4th *kasimpo*, 5th *kasimpo*, 2nd *cotten*, 3rd *cotten*, 4th *cotten*, 1st *ruwi*, 2nd *ruwi*, 3rd *ruwi* and 4th *ruwi*. There are differences in the sample in determining the genetic closeness of sago. *Kasimpo* accessions congregate to form groups with Kf ranging from 76% -81% (Figure 3), and the diversity in the polymorphic band is only 5%. The 1st *kasimpo* and the 4th *kasimpo* have a very close similarity value, which is 81%. The 5th *kasimpo* sample is slightly far from the other two *kasimpo* (77%). The similarity value of *kasimpo*'s accession with *kapas* is 69%. The accession of *kasimpo* and *ruwi* has 3 similarity values, namely 64% (4th *ruwi*), 60% of 1st and 2nd *ruwi*, and 40% of Kf with 3rd *ruwi*. *cotten* accessions that have a Kf between 74%-81% or a diversity equivalent to 7%. The difference between the results of the dendrogram of genetic characters and the dendrogram of morphological characters is the closeness between accessions. The morphological character dendrogram shows that the *kasimpo* accession is more closely related to the *ruwi* accession, while the RAPD results show that the *kasimpo* accession is closer to the *kapas* accession, with a Kf value of 79%. The 2nd *cotten* has a slightly more distant genetic relationship with the 3rd *cotten* and 4th *cotten* with a Kf value of 75%. The similarity coefficient value of the 3rd *cotten* and 4th *cotten* is very large, namely 81%. *ruwi*'s accession was divided into 3 parts, the 4th *ruwi* sample has a 63% similarity with *kapas* and *kasimpo*. *ruwi* 1st and 2nd *ruwi* samples with a Kf value of 65%. The two *ruwi* samples are the *ruwi* samples that have the closest genetic relationship. *ruwi* 3 is distantly related to all sago accession samples, namely Kf of 40% (Figure 3). Based on the RAPD method, the *ruwi* accession has a high probability of splitting into 3 types of thorny sago.

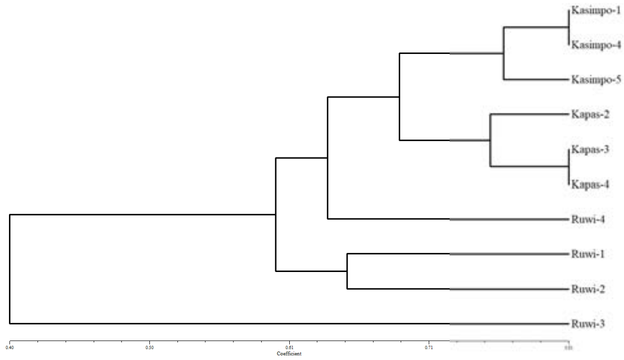


Fig. 3. Dendrogram sago accessions in Mamuju District based RAPD analysis

The RAPD (random amplified polymorphic DNA) method is used to quickly and efficiently identify a large number of DNA polymorphisms in the genome (Anggereini 2008). Samples taken in every district in West Sulawesi Province must be representative. Therefore, the samples taken came from several districts in each district. In Figure 4, the results of DNA amplification are presented which are then used in scoring polymorphic bands. The naming of the sample is adjusted to the sampling location. The sample taken in Polewali Mandar Regency with the *polman* code 1.2 has a meaning, namely the number 1 is a district and the number 2 means a family. The *polman* 2.3 sample was taken in a different district and cluster from the *polman* 1.2 sample, but administratively the sample was taken in the same district. The minimum number of sub-district samples in a particular district is 2 samples. Apart from that, sago samples were also taken in Donggala Regency, Central Sulawesi Province because they accidentally met sago processors in Donggala. The total samples used were 47 and 135 bands were produced, consisting of 3 P1 primers, 9 P4 primers, 28 P6 primers, 16 P17 primers, 14 PA4 primers, 11 PAA17 primers, 24 PAB4 primers, 17 PAB18 primers and 13 PG2. The average number of bands per primer was 15. Differences were found in various fragments, ranging from 120 bp to 3000 bp.

The dendrogram of RAPD analysis is represent in Figure 5. Variety of sago samples spread across West Sulawesi Province, forming 3 large groups and 2 small groups. The first large group consisted of samples from Mamuju Regency, Donggala Regency, and Polewali Mandar Regency. The similarity coefficient (Kf) in the first group is 62%. The *cotten* accession, which is the accession with the highest dry starch production, has a 78% similarity value with the sample taken in Donggala Regency (*donggala* 1). The 3rd *donggala* and *polman* 1.1 samples have a Kf value of 74%. The two accessions are quite closely related to the Mamuju Regency sample, with a similarity coefficient of 63%.

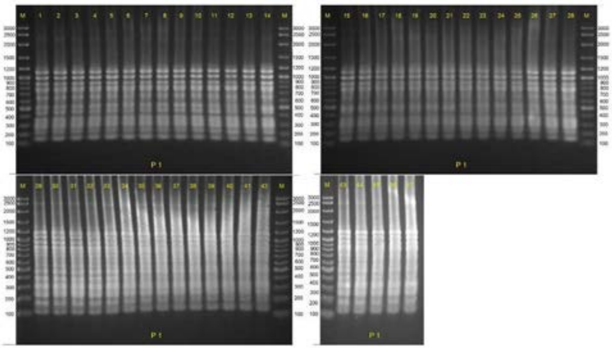
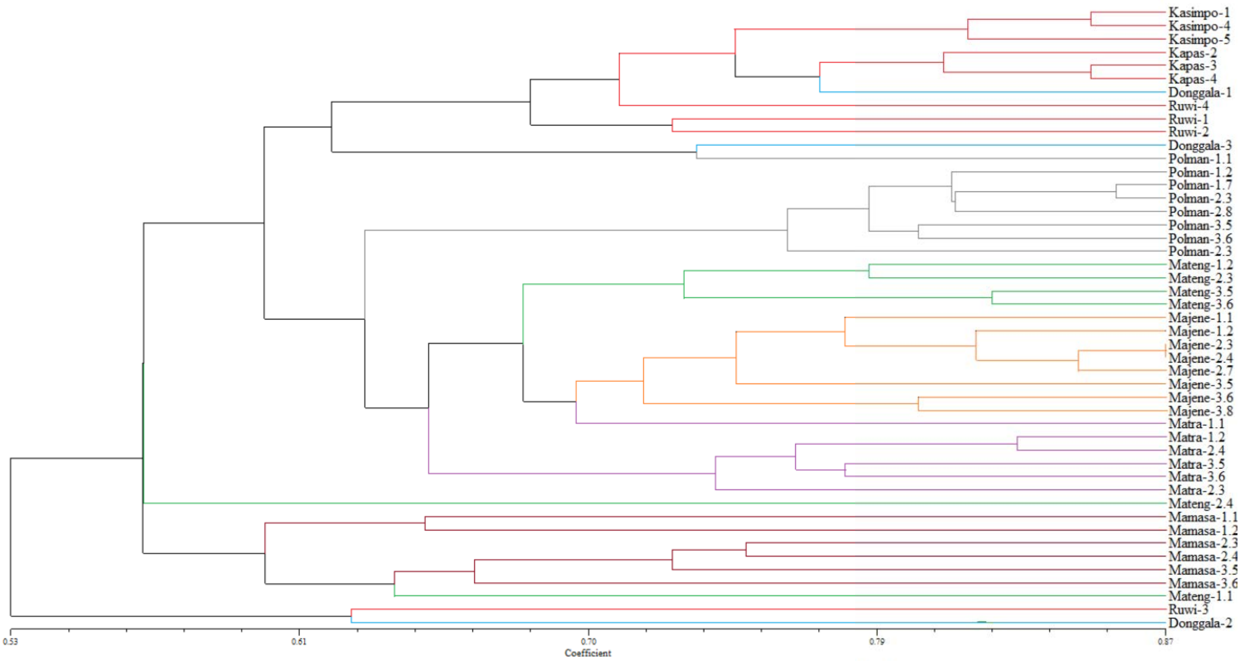


Fig. 4. Amplification 47 samples sago DNA P01 (5'-GCGGCTGGAG-3') around West Sulawesi Province

Big Group 2 consists of Polewali Mandar Regency, Central Mamuju Regency, Majene Regency, and North Mamuju Regency (Kf = 63%). Each sample in large group 2 forms small groups based on districts. Samples from Polewali Mandar Regency have Kf values ranging from 77% to 86%. In general, the sample of Polewali Mandar Regency is slightly different from other regencies in Big Group 2. The sago genetic relationship of Polewali Mandar Regency is successive from highest to lowest, namely *polman* 1.7 and *polman* 2.3 85%, *polman* 2.8 with *polman* 1.7 and *polman* 2.3 82%, then the three samples have a similarity value of *polman* 1.2 of 81%, and *polman* 3.5 with *polman* 3.6 of 80%. The *polman* 2.3 sample has the farthest similarity coefficient value to the other *polman* Regency samples in large group 2, which is 76%.

The total sample of sago taken to represent genetic closeness in Central Mamuju Regency is 6. The sample taken in Central Mamuju Regency has a fairly close similarity value with the sample taken in Majene Regency, which is 68%. A total of 8 sago samples were taken in Majene Regency. The Majene 2.3 and Majene 2.4 samples are the samples for Majene Regency with the highest similarity value (87%). The two samples have a similarity value of 84%, with Majene 2.7. The Majene 1.2 sample still has a relatively high value with the three previous samples, namely 83%. Majene 1.1 has a Kf of 78% with the aforementioned Majene sample. The Majene 1.1 sample and Majene 3.5 are still closely related, namely 75%. In addition, there are 2 Majene samples, namely Majene 3.6 and Majene 3.8, which have a fairly close similarity value, namely 81%. However, the Majene 3.6 and Majene 3.8 samples are closely related to sago samples taken in other Majene districts (Kf = 72%). There is one sample taken in North Mamuju Regency (*matra* 1.1), which has a close relationship with all of the Majene samples with a Kf value of 70%.

Sago in Central Mamuju Regency and Majene Regency has a 65% similarity value with sago in North Mamuju Regency. There is one sample from North Mamuju (*matra* 1.1) which is closely related to sago in Majene Regency (69%). *matra* 1.2 and *matra* 2.4 have the closest similarity value (84%) when compared to the Majene Regency sample. The two samples have a similarity value of 77% with Dimensions 3.5 and 3.6. Samples of *matra* 3.5 and *matra* 3.6 have a Kf value of 78%. *matra* 2.3 is 74% related to other *matra* samples. In general, sago in Central Mamuju Regency has a diversity of 13%.



Note: = Mamuju = Polewali Mandar = Majene = Mamasa
= Donggala = Mamuju Tengah = Mamuju Utara

Fig. 5. Dendrogram sago accessions around West Sulawesi Province based RAPD analysis

Generally, Central Mamuju Regency gathered to form its own group, but there were two samples that stayed away from the Central Mamuju Regency (*mateng*) group. The Central Mamuju 3.5 and Central Mamuju 3.6 samples had the highest similarity value among the other Middle Mamuju samples, which was 83%. The two samples are 74% related to Central Mamuju 1.2 and Central Mamuju 2.3. The Middle Mamuju 1.2 and Central Mamuju 2.3 samples have 79% similarity value.

The last large group consists of samples taken in Mamasa (Kf = 60%-76%). Mamasa 1.1 and Mamasa 1.2 stay away from other Mamasa groups with a similarity value of 66%. The Mamasa sample has the closest relationship, namely Mamasa 2.3 and Mamasa 2.4 (76%). The two previous samples had a 73% relative with Mamasa 3.5. Mamasa 3.6 has a similarity coefficient of 66% with Mamasa 3.5. There is a sample of sago from Central Mamuju Regency (*mateng* 1.1) which is related to the sample in Mamasa Regency, with a Kf of 64%. There is an independent sample of the RAPD results, also called a small group. Small group 1 consisted of 1 sample, namely *Mateng* 2.4 with a Kf value of 57% with the other large groups. Small group 2 consisted of 2 samples, namely the 3rd *ruwi* and 2nd *donggala*. The small group 2 kf value was 53% when compared to all groups (Figure 5).

There is a uniqueness in small group 2, namely a sizable similarity between the 2 samples (63%), while these samples have different morphological characters. The samples in question are the 3rd *ruwi* which has thorns and the 2nd *donggala* which has no thorns. There is ambiguity between the results of similarity value analysis based on morphological characters and genetic characters. In connection with the genetic character of thorny and thornless sago, Novero et al., (2012) suspected that there was an activator gene that caused the appearance of thorns in sago because the results of tracing the sago gene found no clear differences. The appearance of thorns in sago is also called epigenetic, namely gene expression that is influenced by the environment. According to Ehara (2003), the genetic distance of sago palm is not related to the presence of thorns on petioles and rachis.

Conclusions

The RAPD results presented in the form of a dendrogram based on genetic characters show that the *ruwi* accession has a Kf value ranging from 60% to 63% of the other accessions. The *kasimpo* and *kapas* accessions are quite closely related, with a Kf value of 69%. *ruwi*'s accession is suspected to consist of three types of sago. RAPD analysis to determine the genetic relationship of sago in 6 districts in West Sulawesi Province and 1 district in Central Sulawesi formed 3 large groups and 2 small groups. The Kf value for large group 1 is 62%, consisting of Mamuju Regency, Donggala Regency, and Polewali Mandar Regency. Big Group 2 (Kf = 63%) consists of Polewali Mandar Regency, Central Mamuju Regency, Majene Regency, and North Mamuju Regency. Big Group 3 consists of samples taken in Mamasa (Kf = 60%–76%). The sago sample taken in Central Mamuju Regency (*mateng* point 1.1) is quite closely related to the Mamasa Regency sample, with a coefficient of similarity (Kf) of 64%.

References

Ahmad, F. and M. H. Bintoro, Supijatno 2016 Morfologi dan produksi beberapa aksesi sagu (Metroxylon spp.) di Distrik Iwaka, Kabupaten Mimika, Papua. Bul Palma 17(2):115-125.

Bintoro, M. H., H. Ehara, A. Azhar, R. K. Dewi, M. I. Nurulhaq and D. Ahyuni 2021 Ekofisiologi Sagu. Bogor (ID): IPB Pr.

Bintoro, M. H., M. Y. J. Purwanto, S. Amarillis 2010 Sagu di Lahan Gambut. Bogor (ID): IPB Pr.

[BPS] Badan Pusat Statistika 2021a Hasil Sensus Penduduk 2020. Jakarta (ID): Badan Pusat Statistika.

[BPS] Badan Pusat Statistika 2021b Luas Panen dan Produksi Padi di Indonesia Tahun 2020 (Angka Tetap). Jakarta (ID): Badan Pusat Statistik.

Djoefrie, M. H. B., S. Herodian, Ngadiono, A. Thoriq and S. Amarillis 2014 Sagu untuk Kesejahteraan Masyarakat Papua. Jakarta (ID): Unit Percepatan Pembangunan Papua dan Papua Barat.

Ehara H., S. Kosaka, N. Shimura, D. Matoyama, O. Morita, H. Naito, C. Mizota, S. Susanto, M. H. Bintoro and Y. Yamamoto. 2003 Relationships between geographical distribution and genetic distance of sago palm in Malay Archipelago. Sago Palm 11: 8-13.

Ernawati, E., L. Heliawaty and P. Diansari 2018. Peranan makanan tradisional berbahan sagu sebagai alternatif dalam pemenuhan gizi masyarakat: Kasus Desa Laba, Kecamatan Masamba, Kabupaten Luwu Utara, Provinsi Sulawesi Selatan. JSEP 14: 31-40.

Irianto, G 2016 Lahan dan Kedaulatan Pangan. Jakarta (ID): Gramedia Pustaka Utama.

Novero, A. U., M. B. Mabras and H. J. Esteban 2012 Epigenetic inheritance of spine formation in sago palm (*Metroxylon sagu* Rottb). Omics 5: 559-566.

Nurulhaq, M. I 2017 Identifikasi berbagai aksesi sagu (Metroxylon spp) di Desa Hiripai Kecamatan Mimika Timur Kabupaten Mimika, Papua [tesis]. Bogor (ID): Sekolah Pascasarjana, Institut Pertanian Bogor.

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Soil Carbon Stock Comparison of Sago Palm Plantation and Monoculture Crop Around Converted Wetland in Southern Thailand

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Abstract Converting wetlands to monoculture crops affects the amount of carbon sequestration in soil. This study aimed to quantify and compare the bulk density, organic carbon (OC), soil organic carbon (SOC) stock, and carbon dioxide (CO_2) sequestration in soil between sago palm and other monoculture crops, namely, rubber, rice, and oil palm, which were converted from natural wetlands around the Khuan Khreng peat swamp. Forty-two soil samples were collected at a 30-cm layer from the agricultural areas using random sampling, both destructive and non-destructive techniques. Bulk density was determined by the core method, and soil organic carbon was determined by Walkley and Black. SOC stocks were calculated using measured organic carbon content and the corresponding soil bulk densities. The results showed that the average SOC stock of sago palm, rubber, rice, and oil palm were 3.44, 0.64, 1.23, and 0.76 tons C ha^{-1}, and the average CO_2 sequestrations were 12.64, 2.35, 4.52, and 2.80 respectively. The sago palm plantation had the highest average SOC stock and CO_2 sequestration compared to the monoculture crop areas. This study provides relevant information on the carbon storage capabilities of the four land-use types in the converted wetland**.** Effective planning and management of agricultural land must take into account the carbon storage capacity in the soil to develop a sustainable solution for preserving carbon pools in wetlands to mitigate the effects of climate change.

Keywords: Ecosystem Services, Oil Palm, Peatland, Paddy Filed, Rubber

Introduction

Peat swamp forests often serve as the dynamic link between soil and water and can maintain the balance of the ecosystem, the cycling of nutrients, control fire, and produce unique biodiversity (Anamulai et al., 2019). On a global scale, the peat swamp can be a sink and source of CO_2 from the atmosphere, helping to slow down the process. Currently, there is a widespread peat conversion to monoculture crops, causing deforestation and land cover change, particularly in Southeast Asian peatlands. Drainage associated with practically all peatland development led to lowered water tables and a more rapid release of CO_2 into the atmosphere (FAO, 2014).

Changes in peat swamp forest areas to monoculture crops areas occur in the Thale Noi (TN) non-hunting area and Khuan Kreng (KK) swamp forest in southern Thailand. Currently, 65 percent of the total wetland area is converted to monoculture crops area, and the top three commercial plants are oil palm, rubber, and rice plantations (Office of Natural Resources and Environmental Policy and Planning: ONEP, 2015**)**. This land use change plays a crucial role in the fight against climate change by controlling the carbon storage in wetlands which act as a sink and a source of atmospheric CO_2 in the long-term organic carbon pattern in soil.

One of the potential solutions to the abovementioned problem is promoting sago palm (*Metroxylon sagu* Rottb.) cultivation as an alternative to monoculture crops. Sago palm has several benefits, such as raw material for industry, food, and pharmaceuticals (Naim et al., 2016), its ability to grow on tropical peat soil without drainage of groundwater, and requires no chemicals to eliminate weeds and pests (Jong, 1995), and a source of carbon dioxide emissions reduction, which appears to be lower than other commercial crops (Hergoualc'h & Verchot, 2014).

Moreover, most agricultural soils have low soil organic matter due to farm management, such as fertilizer and tillage practices (Mcdonald et al., 2021). Therefore, promoting sago palm cultivation in converted wetlands can lead to the solution of soil carbon loss in wetlands and provide benefits for the ecosystem and environment (Jariyapong et al., 2021).

However, promoting sago palm cultivation as an alternative to solve land-use change problems in wetlands needs to consider ecological benefits, particularly the carbon storage capability in the cultivation area. Additionally, only the two previous studies of Pannual et al. (2015) and Kiriratnikom et al. (2014) focus on the aboveground carbon storage in the natural peat area at TN non-hunting area and KK swamp forest, but no study on SOC stock in the cultivation area. The lack of SOC stock in agricultural land around the peat swamp forest is still the gap that needs to be studied.

Therefore, this study aims to estimate the SOC stock and CO_2 in the soil of sago palm, rubber, rice, and oil palm plantations and later compare their qualifications. The result will provide a better understanding of the change in carbon stock and lead to a sustainable solution for preserving carbon pools in agricultural areas around wetlands.

Materials and Methods

Study area

The study sites were conducted on sago palm, rubber, rice, and oil palm plantations at the TN non-hunting area and KK swamp forest within the 2-kilometer boundary covering 19 subdistricts of Nakhon Si Thammarat, Phatthalung, and Songkhla provinces (Figure 1). The study areas were under similar rainfall influences, with an annual average rainfall of 1,500-2,700 mm (Climate Center, 2023). All these plantations are converted from natural wetlands. At first, farmers converted the natural wetland to rice and sago palm cultivations over the past 60 years (there is no clear information on the year of conversion from natural wetlands to monoculture crops). Later, they changed the land use from rice and sago palms to rubbers and oil palms and have remained so for the past two decades.

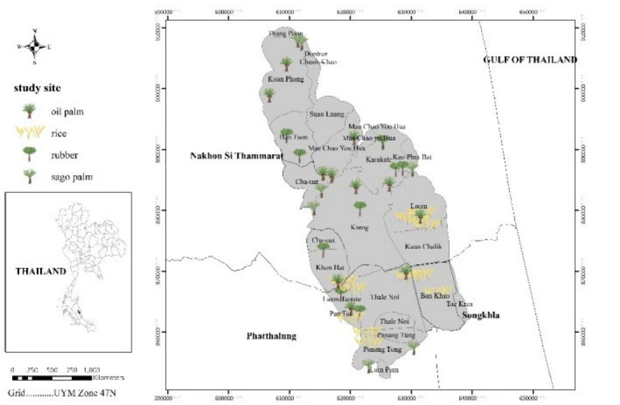

Fig 1 Study area of sago palm, rubber, rice, and oil palm plantations

Soil organic carbon stock sampling

Due to the COVID-19 pandemic and the limitation of budget, rainy season, and instruments, we specified sample site selection with the three criteria. The oil palm and rubber sample sites were collected from the farm which has the age of highest productivity: eight years and over for oil palm plantations (Pruekampai, 2005) and ten to 12 years for rubber plantations (Ongwang, 2010), while the sago palm and rice were collected from the farms that were flood-free and all sample sites were less than 1.6 hectares.

Soil samples were collected randomly from three random sampling plots at 0-30 cm soil depth with disturbed and non-disturbed techniques. Three random sampling points indicate three subsamples per point, resulting in a total of nine samples for each plot routine analysis. Ten soil samples for a sago palm and rubber plantation and eleven soil samples for a paddy field and oil palm plantation, a total of forty-two soil samples were collected at the same depths with soil core for bulk density analysis and bulked as composite samples, representative of each plot. Labeling was performed with a detailed description of the study site on both soil-plastic bags and soil core before being sent to the laboratory for analysis at the Central Analysis Center of the Faculty of Natural Resource, Prince of Songkla University. The bulk density of soil and soil organic carbon was determined by the core method (Blake & Hartge, 1986) and the Walkley and Black method, respectively (1934).

Calculation of soil organic carbon stock

The SOC stock was calculated using the FAO (2018) Following Eq. (1):

$$\text{SOC stock} = \text{OC} \times \text{BD} \times \text{D} \times 0.001 \qquad (1)$$

Where

SOC = the soil organic carbon stock (ton C/ha),

OC = organic carbon (%)

BD = bulk density (g cm^{-3})

D = soil depth (cm)

0.01 = a factor for converting kg C/ha to ton C/ha

Calculation of CO_2 sequestration

To convert SOC stock to CO_2 sequestration, a conversion factor of 3.67 was used to multiply the estimated amount of carbon (IPCC, 2003), following Eq. (2).

$$CO_2 \text{ sequestration} = \text{SOC stock} \times 3.67 \qquad (2)$$

Results

The bulk density, organic carbon, SOC stock, and CO_2 sequestration under difference cropping are shown in Table 1. The SOC stock and CO2 sequestration amount varied from 0.14 to 11.35 tons C ha^{-1}. The highest values of SOC stock were observed in the sago palm plantation from 0.81 to 11.35 tons C ha^{-1} with an average of 3.44 ton C ha^{-1} and CO_2 sequestration from 2.97 to 41.67 tons CO_2 eq/ha^{-1} with an average 12.64 tons CO_2 eq/ha^{-1}. The lowest value of SOC stock was observed in the oil palm plantation from 0.14 to 1.46 tons C ha^{-1} with an average of 0.76 ton C ha^{-1} and CO_2 sequestration from 0.52 to 5.36 t CO_2 eq/ha^{-1} with an average of 2.80 t CO_2 eq/ha^{-1}. SOC stock and CO_2 sequestration values in rubber plantations are higher than in oil palm plantations, but a comparison of the average value shows that rubber plantations have the lowest value: both SOC stock and CO_2 sequestration was 0.64 tons C ha^{-1} and 2.35 tons CO_2 eq/ha^{-1}.

Discussion

This study compares the SOC stock and CO_2 sequestration under different land uses, particularly the sago palm and monoculture crops, such as oil palm, rubber, and rice, around the converted wetland. The results showed that sago palm plantations could store SOC stock more than other monoculture crop plantations. Therefore, the cultivation of sago palms in wetlands could absorb CO_2 from the atmosphere and transform it into dead organic matter with the decomposition process better than other commercial crops.

These highest values can be explained by farm management factors. Currently, land uses around the TN non-hunting and KK swamp forest areas were dominantly converted to monoculture crops. The largest areas are oil palms, rubbers, and rice. These three monoculture crops are the major stable crops with highly intensive management, such as tillage, fertilizer, and weed management. On the contrary, sago palm has not been promoted as a commercial crop. Sago palms do not require fertilizer and tillage, only cutting off the leaf crown, sucker pruning, and weed management. These practices commonly affect the organic carbon content in the soil (Amin et al., 2020) since considerable tillage disturbs the decomposition of native soil organic matter (Martinsen, 2017). Notice that the land use change for rice and sago palm occurred during the same period, but the amount of dead organic material that returned to the soils in the rice area is lower than for sago palm plantation because the rice needs to be till before planting every year. This practice also occurs with oil palm and rubber plantations, which need to be tilled in the second conversion, including weed management by tractors two times a year in oil palm plantations. Therefore, intensive farming of commercial crops is affecting the SOC stock.

Additionally, chemicals for weed management and fertilizer application are widely used in most oil palm and rice areas and may be related to emission factors of CO_2 and N_2O in soil. Therefore, future research should focus on the greenhouse gas emission in soil, which can compare the indirect benefit of the four monoculture crops.

Conclusion

Sago palm plantation can be a carbon pool capability that stores soil organic carbon greater than rubber, rice, and oil palm. This information will be crucial for making decisions on land use planning, particularly in wetland management, where wetlands have been converted into monoculture crops. However, this result focuses only on SOC stock; therefore, future research needs to focus on the carbon emissions from the soil and calculate the net of carbon storage because this net of carbon storage relates to farm management which can be developed as a solution for a low-carbon agricultural ecosystem.

References

Amin, M. S., Khan, M. Z., Laskar, T., & Rabbi, S. M. F. 2020 Carbon Sequestration in Soil Aggregates under Different Cropping Patterns of Bangladesh. Open Journal of Soil Science, 10(10), 459–485. https://doi.org/10.4236/ojss.2020.1010024

Anamulai, S., Sanusi, R., Zubaid, A., Lechner, A. M., Ashton-Butt, A., & Azhar, B. 2019 Land use conversion from peat swamp forest to oil palm agriculture greatly modifies microclimate and soil conditions. PeerJ, 2019(10), 1–16. https://doi.org/10.7717/peerj.7656

Anokye, J., Logah, V., & Opoku, A. 2021 Soil carbon stock, and emission: estimates from three land-use systems in Ghana. Ecological Processes, 10(1). https://doi.org/10.1186/s13717-020-00279-w

Blake, G.R., and Hartge, K.H. 1986 Bulk density. In: Klute, A., editor. Methods of soil analysis. Part I. Physical and mineralogical methods. Soil Science Society of America, Inc., Madison, WI. 363-376.

Climate Center. 2023 Thirty years climate statistics. http://climate.tmd.go.th/statistic/ stat30y (Thai)

Food Agriculture and Organization (FAO). 2014 Towards climate- responsible peatlands management. *In*: Biancalani R, Avagyan A (eds) Mitigation of Climate Change in Agriculture Series (MICCA). http://www.fao.org/3/a-i4029e.pdf

Food Agriculture and Organization (FAO). 2018 Measuring and modeling soil carbon stocks and stock changes in livestock production systems: Guidelines for assessment (Version 1). Livestock Environmental Assessment and Performance (LEAP) Partnership. http://www.fao.org/partnerships/leap/publications/en/%0

Hergoualc'h, K., & Verchot, L. V. 2014 Greenhouse gas emission factors for land use and land-use change in Southeast Asian peatlands. In Mitigation and Adaptation Strategies for Global Change. https://doi.org/10.1007/s11027-013-9511-x

Intergovernmental Panel on Climate Change (IPCC). 2003 Good Practice Guidance for Land-Use Change and Forestry. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf

Jariyapong, M., Roongtawanreongsri, S., Romyen, A., & Somboonsuke, B. 2021 Growth prediction of sago palm (*Metroxylon sagu*) in Thailand using the Linear Mixed-effect model. Biodiversitas, *22*(12), 5293–5301. https://doi.org/10.13057/biodiv/d221209

Jariyapong, M., Roongtawanreongsri, S., & Somboonsuke, B. 2023. Estimating the Economic Value of Carbon Sequestration by Sago Palm (*Metroxylon sagu* Rottb.) in Thailand. https://doi.org/10.18280/ijdne.180517

Kiriratnikom, A., S, K., T, S., & K, A. 2014 Value of carbon stock in aboveground biomass of peat swamp forest, Nakhon Si Thammarat. RMUTP research journal. 8(2), 127-134.

Martinsen, V., Shitumbanuma, V., Mulder, J., Ritz, C., & Cornelissen, G. 2017 Effects of hand-hoe tilled conservation farming on soil quality and carbon stocks under on-farm conditions in Zambia. Agriculture, Ecosystems & Environment, 241, 168–178.

Mcdonald, H., Frelih-Larsen, A., Lóránt, A., Duin, L., Andersen, S. P., Costa, G., & Bradley, H. 2021 Carbon farming Making agriculture fit for 2030, Study for the committee on Environment, Public Health and Food Safety (ENVI). November.

Naim, H. M., Yaakub, A. N., & Awang Hamdan, D. A. 2016 Commercialization of Sago through Estate Plantation Scheme in Sarawak: The Way Forward. International Journal of Agronomy, 2016.

Office of Natural Resource and Environmental Policy and Planning. 2015 Conservation plan project rehabilitation and adaptation to climate change in a wetland area, Thale Noi Wildlife Hunting Area, and Khuan Kreng Swamp Forest. http://slbkb.psu.ac.th/xmlui/handle/2558/192?locale-attribute=en.

Ongwang, C. 2010 Comparison on socio-economic model of rubber production system and oil palm production system in Tambon Khuanpang, Amphoe Ron Phibun Changwat Nakhon Si Thammarat (Master Thesis, Prince of Sonkla University). Prince of Sonkla University.

Pannual, W., Chuchip, K., & Jintana, V. 2015 Above-ground carbon stock assessment of Kuan Khaeng Swamp Forest after severe burning in 2012 using satellite imagery. Thai J. For. 34(1), 16–28.

Pruekampai, A. 2005 Oil palm handbook. Pet Plant Publishing Press. [Thai]

Walkley, A.; Black, J.A. An examination of the dichromate method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934 37, 29–38.

Table 1. Bulk density, Organic carbon, SOC stock, and CO_2 sequestration of sago palm, rubber, rice, and oil palm plantation around the Thale Noi non-hunting and Khuan Kreng swamp Forest area, Southern Thailand.

Sample site	Plantation site															
	Sago palm				Rubber				Paddy field				Oil palm			
	Bulk density (g cm^{-3})	OC[1] (%)	SOC Stock[1] (t C/ha)	CO_2 sequestration[1] (t CO_2 eq/ha)	Bulk density (g cm^{-3})	OC (%)	SOC stock (t C/ha)	CO_2 sequestration (t CO_2 eq/ha)	Bulk density (g cm^{-3})	OC (%)	SOC stock (t C/ha)	CO_2 sequestration (t CO_2 eq/ha)	Bulk density (g cm^{-3})	OC (%)	SOC stock (t C/ha)	CO_2 sequestration (t CO_2 eq/ha)
Panang Tung 1	1.76	2.82	3.14	11.53	-	-	-	-	1.86	2.74	1.53	5.60	1.91	2.08	1.18	4.32
Panang Tung 2	1.96	2.03	2.88	10.58	-	-	-	-	1.67	2.98	1.50	5.51	-	-	-	-
Panang Tung 3	-	-	-	-	-	-	-	-	1.77	2.76	1.49	5.49	-	-	-	-
Laem Tanote 1	-	-	-	-	1.85	1.03	0.56	2.04	1.74	3.18	1.64	6.03	-	-	-	-
Laem Tanote 2	-	-	-	-	1.88	0.65	0.36	1.33	1.76	3.71	1.96	7.19	-	-	-	-
Khon Hat 1	-	-	-	-	2.01	1.07	0.64	2.37	-	-	-	-	-	-	-	-
Khon Hat 2	-	-	-	-	1.97	0.48	0.29	1.05	-	-	-	-	-	-	-	-
Kreng 1	1.94	1.30	1.73	6.35	2.08	2.24	1.38	5.08	-	-	-	-	1.84	1.63	0.89	3.27
Kreng 2	1.96	1.09	1.49	5.46	-	-	-	-	-	-	-	-	-	-	-	-
Cha-Uat 1	2.16	1.04	1.53	5.62	-	-	-	-	-	-	-	-	1.78	2.03	1.08	3.97
Cha-Uat 2	1.55	1.91	2.07	7.60	-	-	-	-	-	-	-	-	-	-	-	-
Ban Tuon 1	-	-	-	-	2.26	1.14	0.77	2.84	-	-	-	-	-	-	-	-
Ban Tuon 2	-	-	-	-	2.27	0.45	0.31	1.12	-	-	-	-	-	-	-	-
Mae Chao Yu Hua	-	-	-	-	-	-	-	-	-	-	-	-	1.75	2.78	1.46	5.36
Karakate	-	-	-	-	2.00	1.45	0.86	3.17	-	-	-	-	1.97	0.67	0.37	1.36
Khao Pra Bat 1	2.0	1.37	1.56	5.71	1.99	0.78	0.47	1.72	-	-	-	-	-	-	-	-
Khao Pra Bat 2	1.40	7.86	7.88	28.93	1.98	1.31	0.78	2.86	-	-	-	-	-	-	-	-
Laem 1	-	-	-	-	-	-	-	-	2.05	1.17	0.72	2.65	1.85	0.93	0.51	1.89
Laem 2	-	-	-	-	-	-	-	-	1.82	2.92	1.59	5.85	1.91	0.74	0.42	1.54
Laem 3	-	-	-	-	-	-	-	-	1.78	2.1	1.10	4.04	1.99	0.24	0.14	0.52
Ban Khao 1	-	-	-	-	-	-	-	-	2.14	0.93	0.59	2.15	2.05	1.13	0.70	2.56
Ban Khao 2	-	-	-	-	-	-	-	-	1.98	1.36	0.79	2.91	1.83	1.18	0.64	2.34
Ban Khao 3	-	-	-	-	-	-	-	-	2.05	1.04	0.64	2.37	1.88	1.80	1.01	3.69
Thang Poon 1	1.58	10.53	11.35	41.67	-	-	-	-	-	-	-	-	-	-	-	-
Thang Poon 2	1.98	1.31	0.81	2.97	-	-	-	-	-	-	-	-	-	-	-	-

Note. [1] The data was calculated by the researchers in a previous study: Jariyapong et al. (2023).

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Ethnobotany of Sago in the Malay Community in Lingga Regency, Riau Islands-Indonesia

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Abstract Sago (*Metroxylon* spp.) is a palm species found in Southeast Asia, particularly in Indonesia, Papua New Guinea, Malaysia, and the Philippines. Sago can grow in natural conditions or can be cultivated in underutilized wetlands and peat swamps. Lingga Regency, with a sago plantation area of 3,449 ha, is one of the areas with sago potential. The purpose of this research is to determine how the Malay community in Lingga Regency, Riau Islands, uses sago. The study was carried out in six sago-producing villages in the Lingga Regency: Panggak Laut, Nerekeh, Musai, Pekaka, Keton, and Teluk. Data was gathered through interviews with sago farmers and field observations. According to the study's findings, the Lingga Malay community has been using sago for a variety of purposes since the time of the Linga Sultanate. The main sago product used by the Lingga Malay community is pith, which is used to make starch. The Lingga Malay community produces three types of sago starch: dirty sago (quality II), clean sago (quality I), and dry sago. The Lingga Malay community's sago products are typically marketed in Lingga as well as other areas such as Cirebon, Jambi, Tanjungpinang, and Malaysia. Aside from the pith, the community also uses the leaves as roofing, the bark (*guyung*) as garden fences and firewood, sago fronds as the wall of the cage, the sago shoots (*umbut*) as vegetables, the sago pulp (*serampin*) as animal feed and organic fertilizer, and the sago waste (*bidat*) as animal feed. Currently, the community depends on sago that grows naturally on sago forest lands planted during Sultan Lingga's reign. As a result, efforts must be made to rejuvenate natural sago forests and convert them into sago plantation forests.

Key words: Local knowledge, Malay community, Sago palm, Traditionality

Introduction

Sago (*Metroxylon* sp.) is a type of palm that grows throughout Southeast Asia, including Indonesia, Papua New Guinea, Malaysia, and the Philippines. Several species of sago palm are known, including *M. sagu, M. amicarum, M. vitiense, M. solomonense, M. warburgii*, and *M. paulcoxii*. Sago can be grown in the wild or in underutilized wetlands and peat swamps (Ruddle, 1977; Syauki et al., 2022). Sago palms can generate 180-200 kg of dry sago starch per year (Yamamoto, 2011).

Indonesia is the world's largest sago starch-producing country, producing 585,093 tons per year (Ahmad, 2014). Sago pith can be used to make sago starch. The chemical composition of sago starch consists mainly of carbohydrates. This allows sago starch to be used to make biscuits, noodles, and other food products widely accepted and known by the public, such as brownies or cakes (Putri et al., 2019). Apart from starch, other parts of the sago tree can be used to make roofs, house floors, animal feed, production of sago caterpillars, and matting (Ditjenbun, 2019).

Sago contains carbohydrates that can be processed into sugar and bioethanol, so it can create food and energy security for the nation's future (Hayati et al., 2014). Sago has the potential for significant and inexpensive starch supplies (Karim et al. 2008; Singhal et al., 2008). Sago can produce up to 25 tonnes ha^{-1} of starch produced at the end of an 8-year growth cycle (Zhu, 2019).

Sago was particularly significant to the early Southeast Asian population and was one of the first crops to be used as part of a subsistence strategy (Ave, 1977; Rhoads, 1982; Flach, 1983). The Malay community in Lingga Regency, Riau Islands, is one of those that still use sago in their daily lives. The Malay people of Daik Lingga began to use sago after Sultan Mahmud Riayat Syah (1761-1812) transferred the center of his empire from Riau to Daik Lingga on July 24, 1787. As a result, sago has become a community staple (Minah and Izati, 2021). Lingga Regency currently has 3,449 ha of sago plantation land (BPS Lingga, 2022). This research aims to determine how the Malay community in Lingga Regency, Riau Islands Province, uses sago.

Research Methods

Time and Location

The research was conducted from June to August 2022 in six sago-producing villages in Lingga Regency: Panggak Laut, Nerekeh, Musai, Pekaka, Keton, and Teluk. Astronomically, Lingga Regency is located between N0°20' and S0°40', and between E104°–105°. In terms of geographic position, Lingga Regency has boundaries as follows: North - Batam City and North Natuna Sea; South - Bangka Sea and Berhala Sea; West – Indragiri Hilir Sea; East - North Natuna Sea. Lingga Regency has tropical and wet seasons with a variation of rainfall average of 261.7 mm for the year 2022. It means that Lingga Regency has a high rate of rainfall. While May, June, and December have the highest rank in the number of rainy days. The average temperature of Lingga Regency in 2022 was 24.1 °C, whereas the average of its relative humidity was 86% (BPS Lingga, 2022).

Research Methods

Data collection on the sago ethnobotany was carried out using participatory interviews and observation methods.

Interviews were conducted with selected respondents in depth (in-depth interviews). Respondents were determined using the simple random sampling method, with the respondent criteria being sago farming communities and sago entrepreneurs. Determination of the number of respondents is calculated using the Slovin formula as follows:

$$n = \frac{N}{1+(N(\alpha^2))} \quad (1)$$

Information:
n: sample size
N: total population
α: percentage error (error)

In the Slovin formula, there are the following conditions:
The value of $\alpha = 0.1$ (10%) for a large population
The value of $\alpha = 0.2$ (20%) for a small population

Interviews were conducted using an interview guide that had been prepared previously. The participatory observation followed the respondents' activities to verify data from interviews and findings at the research location.

Results

Characteristics of the Sago People

Age

Respondents' age groups were distinguished based on the category of the Republic of Indonesia Ministry of Health (2010), namely the age group 17-25 years (adolescents), 26-35 years (early adults), 36-45 years (late adults), 46-55 years (early elderly), 55-65 years (late elderly), and > 65 years (elderly). The characteristics of respondents by age group are presented in full in Table 1.

Table 1. Characteristics of respondents by age class.

Age group (years)	Total (people)	Percentage (%)
17-25	2	1.67
26-35	23	19.17
36-45	33	27.50
46-55	37	30.83
56-65	19	15.83
>65	6	5.00
Total	120	100.00

Based on the results of the interviews, the most dominant age group of respondents was the early elderly (30.83%) and the least age group was teenagers (1.67%). One of the problems faced by sago farmers in Lingga Regency is the absence of regeneration of sago farmers. People in the productive age group mostly migrate to cities to seek a more decent livelihood, such as migrating to Dabo, Tanjungpinang, and Batam. This is in accordance with research conducted by Jamaludin (2015) that many young people prefer to go abroad looking for jobs and lack skills in utilizing forest products.

Gender

Based on data from the PPSI Lingga (2019), the number of sago farmers in the Lingga Regency is 397 people. Respondents interviewed in this study were 120 respondents from six sago-producing villages. Most of the sago farmers and processors in Lingga Regency are male, namely 110 respondents (Fig. 1).

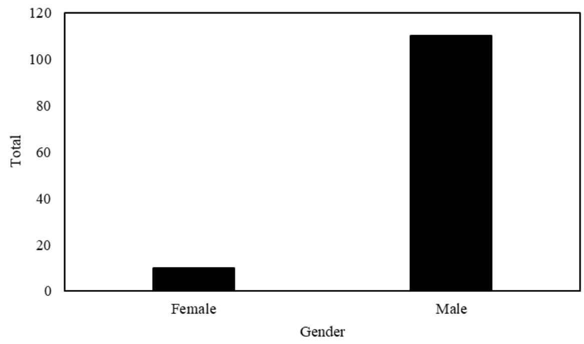

Fig. 1. Gender characteristics of respondents.

Level of Education

Education is a process that cannot be separated from humans, the subjects and objects of these educational efforts (Rahmat 2010). Based on the results of the interviews, most of the respondents had an elementary school education level (79.17%), and the education level of the least respondents was S1 (1.67%). Characteristics of respondents based on education level are presented in Fig. 2.

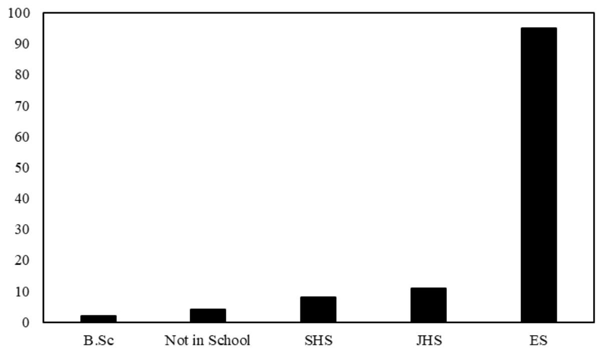

Fig. 2. Education characteristics of respondents.

The Primary Job

Most respondents have their primary job as sago farmers (47 respondents). Aside from being sago farmers, most respondents also have their primary job as sago processors (33 respondents). The following presents the characteristics of respondents based on the primary type of work (Table 2).

Table 2. Characteristics of respondents based on the primary job.

No	Type of Work	Total (people)
1	Gardeners	1
2	Laborer	1
3	Woodcutter	1
4	Trader	1
5	Village apparatus	2
6	Housewife	9
7	Fisherman	25
8	Sago processor	33
9	Sago farmers	47
	Total	120

Side Job

The Lingga community is a Malay community with work based on the season. During the northern monsoon, most of the Lingga people will work as fishermen, while during the southern monsoon, the people will become sago farmers. Based on the results of the interviews, most of the respondents had side jobs as fishermen (79 people) and the minor part job was traders (one person). Characteristics of respondents based on side jobs are presented in Fig. 3.

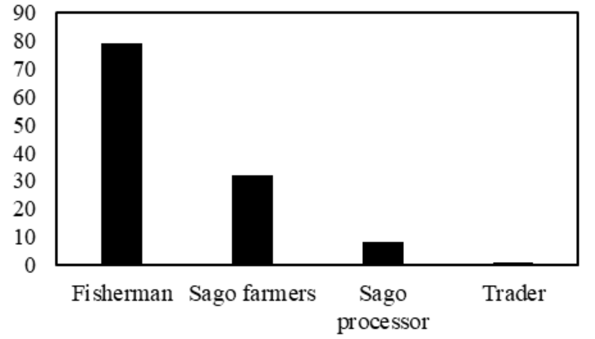

Fig. 3. Characteristics of respondents based on side jobs.

The Lingga community has local wisdom regarding the division of seasons. The Lingga people divide the seasons into the west, south, north, and east winds or seasons. The division of the seasons is based on the direction the wind blows. The west wind is a wind that blows from the west, lasting from September to November. The west wind blows very fast (strong) therefore, fishermen usually stay out to sea. The north wind is a wind that blows from the north and lasts from December to February. When the north wind blows, it is usually accompanied by rain and has cool air. The fishermen stay out to sea during the north monsoon because the wind is not too strong. During north winds, most people use their time to look for squid (cuttlefish) in locations close to islands or bays (Evawarni, 2011).

The east wind is a wind that blows from the east and has hot weather. The east wind blows during the dry season, from March to May, and blows slowly and only occasionally a bit fast. During the east wind, the sea conditions are calm, and fish are abundant, so the fishermen go down to the sea both during the day and at night. South winds blow from the south, lasting from June to August. The south wind usually blows strongly, so people do not look for fish in the open sea but only look for fish in locations on small islands (Evawarni. 2011).

Utilization of Sago

Currently, the Lingga community uses sago for various needs. Sago is not only used for its pith as a starch producer but its biomass and sago waste have also been utilized by the community. The form of sago utilization by the community in Lingga Regency is presented in Table 3.

Table 3. Utilization of sago by the Lingga Malay community.

No	Bagian yang Dimanfaatkan	Bentuk Pemanfaatan
1	Sago pith	Production of wet sago and dry sago
2	Sago bark (*guyung*)	Material for roads, firewood, house and garden fences
3	Leaves	The roof of the house, roof and *kelong* walls
4	Sago frond	Wall of cage and roof rope
5	Sago pulp (*serampin*)	Livestock feed and fertilizer
6	Sago waste (*bidat*)	Livestock feed
7	*Umbut*	Vegetable
8	Sago worm	Fishing bait

Discussion

History of the Utilization of Sago

The use of sago in Indonesia has been carried out since the era of the Sriwijaya kingdom (7th century AD), this is evidenced by the contents of the Talang Tuo inscription, which contains the soul of the leadership of a sage, just, firm, and religiously devout Srivijaya king, namely King Dapunta Hiyang Sri Jayanasa who ordered to make of the Sriksetra garden. The garden contains plants beneficial to all creatures, such as coconut, sago, aren, areca nut, bamboo, and other plants, with the aim of welfare for all of its people (Sholeh, 2017).

The use of sago by the Malay people of Daik Lingga began to develop when Sultan Mahmud Riayat Syah (1761-1812) moved the kingdom's center on July 24, 1787, from Hulu Riau to Daik Lingga. This makes sago a staple food needed by the community. Sultan Sulaiman Badrul Alam Syah II (1857-1883) continued sago development to advance the community's economy (Minah and Izzati, 2021). This is in accordance with the research by Gemilang et al., (2019), which states that the popularity of sago on Lingga Island increased in the period 1857-1883 under the leadership of Sultan Sulaiman Badrul Alam Syah. During this period, the processing and planting of sago were intensified. Sago plants spread to various areas on Lingga Island after focusing only on the palace environment.

Based on the official Dutch East Indies government document on Afdeeling Handel (1919), ten factories were established in the Riau region: five in Lingga, three in Karimun, and two in Indragiri. When the Dutch entered the Lingga region, the sago trade from Lingga experienced a setback, and several sago processing factories in the Lingga area, including those built during Sultan Sulaiman Badrul Alamsyah II, were also neglected and abandoned. The sago factory built during the Lingga Sultanate era only has a few buildings left, such as chimneys and ponds. The following is the remains of a sago factory building in Kerandin Village, East Lingga District (Fig. 4). The Lingga community currently uses two types of sago, namely thorny sago (*sagu*) and non-thorny sago (*bemban*) (Al Manar et al., 2023).

Fig. 4. Remains of the chimneys of the sago factory during the sultan's era.

Utilization of Sago Pith

Sago pith is used by the Lingga Malay community to be processed into sago starch. The Linga Malay community processes sago pith into wet sago products (dirty and clean) and dry sago. The sago pith used comes from *tua*l sago, harvested by farmers, and is usually stored in the river to prevent damage caused by wildlife and livestock (Fig. 5).

Fig. 5. *Tual* sago stored in the river.

Utilization of Leaves and Midrib

The leaves are another part of the sago tree utilized by the Lingga community (Fig. 6). The Lingga people use sago leaves to make roofs and *kelong* walls (Fig. 7). Some Lingga people sell roofing sago leaves for IDR 100,000.00-130,000.00 per 100 pieces. The sago leaf roof produced by the community is 100-130 cm in size. Making a sago leaf roof is done by combining sago leaves and fronds. Sago fronds are used as a rope to tie the roof of sago leaves.

Fig. 6. Sago leaves as roofing material.

Fig. 7. The use of leaves as the roof of *kelong*.

Utilization of Sago Biomass

The Lingga Malay community also uses sago biomass in their daily lives, such as bark (*guyung*), dregs (*serampin*), and sago waste (*bidat*). As waste from pith processing activities, Sago bark is used by the Lingga community as a material for making roads (Fig. 8), firewood, and fences for houses and gardens (Fig. 9). The chemical content contained in sago bark consists of 8.26% extractive, 42.02% lignin, 47.07% holocellulose, 24.56% α-cellulose and 22.51% hemicellulose (Lestari et al., 2022).

Fig. 8. Utilization of sago bark as a road.

Fig. 9. Utilization of bark as a fence.

The Lingga community also uses sago waste (*serampin*) as animal feed and plant fertilizer. The utilization of sago bark and waste in Lingga Regency is still not optimal. Research conducted by Rasyid et al., (2020) in Riau also shows that the use of sago in the region is still focused on sago starch as its main product. The development of downstream products is still relatively limited, so the by-products in sago bark (*uyung*) and sago pulp waste (*repu*) have yet to be utilized optimally.

McClatchey et al., (2006) stated that in a sago processing process, around 17 to 25% of waste in the form of bark is produced (Fig. 10). Around 75 to 83% of sago waste (Fig. 11). Sago pulp consists of 58% starch, making it relatively more accessible and cheaper to process compared to other lignocellulosic biomass (Vincent et al., 2015). Syamsiro et al., (2020) research shows that the potential for sago pulp as an energy source in Papua is very promising. The potential for sago waste in Papua is 9,323 tons year^{-1} or around 25.54 tons day^{-1}.

Fig. 10. Waste bark (*guyung*).

Fig. 11. Sago waste (*serampin*).

Conclusions

The sago community in Lingga Regency is dominated by men in the early elderly age group and low education. The sago community has a primary job as a sago farmer and a side job as a fisherman. The Lingga community has utilized all parts of sago for various needs, including food, crafts, and building materials. The main part of the sago tree used by the Lingga people is the pith which produces starch as a raw material for making various kinds of traditional and processed food products.

References

Afdeeling Handel 1919 Publicates Van De Afdeeling Handel No.2: Sago en Sago Producten. Papyrus (Weltevreden) pp. 23.

Ahmad, M. 2014 Farmer empowerment to increase productivity of sago (*Metroxylon sago* spp) farming. International Journal on Advanced Science Engineering Information Technology 4(3): 5-9.

Al Manar, P., E. A. M. Zuhud, N. Andarwulan and M. H. Bintoro 2023 Morphological characteristics and potential of sago (*Metroxylon* spp.) in Lingga Regency, Riau Islands, Indonesia. Jurnal Manajemen Hutan Tropika 29: 11-21.

Avé, J. B. 1977 Sago in Insular South-East Asia: historical aspects and contemporary use. *In*: Proceeding of the 1st International Sago Symposium. (Tan, K. ed.) Kuching, 21-30.

Badan Pusat Statistik Kabupaten Lingga 2022 Kabupaten Lingga dalam Angka 2022. BPS Kabupaten Lingga (Daik Lingga). (in Indonesian)

Direktorat Jenderal Perkebunan 2019 Statistik Perkebunan Indonesia 2018-2020. Sekretariat Direktorat Jenderal Perkebunan (Jakarta). (in Indonesian)

Evawarni 2011 Teknologi Tradisional yang Berhubungan dengan Mata Pencaharian di Daik Lingga. Balai Pelestarian Sejarah dan Nilai Tradisional (Tanjungpinang). (in Indonesian)

Flach, M. 1983 The Sago Palm: Domestication Exploitation and Products. Food and Agriculture Organization (Roma).

Gemilang, R., R. R. Irwanto and A. Dwiartama 2019 Studi etnobotani pemanfaatan sagu (*Metroxylon sagu* Rottb.) di Pulau Lingga, Kepulauan Riau. *In*: Proceeding of the Seminar Nasional Biologi. (Hasby, R. M., Fadillah, A. and Kulsum, Y. ed.) Bandung, 36-43. (in Indonesian)

Hayati, N., R. Purwani and A. Kadir 2014 Preferensi masyarakat terhadap makanan berbahan baku sagu (*Metroxylon sagu* Rootb) sebagai alternatif sumber karbohidrat di Kabupaten Luwu dan Luwu Utara Sulawesi Selatan. Jurnal Penelitian Sosial dan Ekonomi Kehutanan 11(1): 82-90. (in Indonesian)

Jamaludin. A. N. 2015 Sosiologi Perkotaan: Memahami Masyarakat Kota dan Problematikanya. Pustaka Setia (Bandung). (in Indonesian)

Karim, A. A., A. P. L. Tie, D. M. A. Manan and I. S. M. Zidul 2008 Starch from the sago (*Metroxylon sagu*) palm tree-properties, prospects, and challenges as a new industrial source for food and other uses. Comprehensive Reviews in Food Science and Food Safety 7(3): 215-228.

Lestari, P., W. T. Istikowati, Sunardi, D. H. Y. Yanto, W. Fatiasari and R. S. Ningrum 2022 Analisis kandungan kimia kulit batang sagu (*Metroxylon sagu* Rottb.) sebagai bahan baku pulp dan kertas. Jurnal Sylva Scienteae 5(2): 187-193. (in Indonesian)

McClatchey, W., H. I. Manner and C. R. Elevitch 2006 *Metroxylon amicarum*, *M. paulcaxii*, *M. sagu*, *M. salomonense*, *M. vitiense*, and *M. warburgii* (sago palm) Arecaceae (palm family). Species Profiles for Pacific Island Agroforestry. www.traditionaltree.org.

Minah, M. S. A. M. and N. Izzati 2021 Etnomatematika pada makanan tradisional melayu Daik Lingga sebagai sumber belajar. JEP 5(1): 1-7. (in Indonesia)

Perhimpunan Pendayaguna Sagu Indonesia Kabupaten Lingga 2019 Dokumen Deskripsi Indikasi Geografis Sagu Lingga. PPSI Kabupaten Lingga (Daik Lingga). (in Indonesian)

Putri, A. A. K., Fatriani and T. Satriadi 2019 Pemanfaatan pohon sagu (*Metroxylon* sp) dan kualitas pati sagu dari Desa Salimuran Kecamatan Kusan Hilir Kabupaten Tanah Bumbu Kalimantan Selatan. Jurnal Sylva Scienteae 2(6): 1082-1093. (in Indonesian)

Rahmat, A. 2010 Pengantar Pendidikan: Teori, Konsep, dan Aplikasi. MQS Publishing (Bandung). (in Indonesian)

Rasyid, T. H., Y. Kusumawaty and S Hadi 2020 The utilization of sago waste: prospect and challenges. IOP Conf Series: Earth and Environmental Science 415: 012023.

Rhoads, J. W. 1982 Sago palm management in Melanesia: An alternative perspective. Archaeology in Oceania 17: 20–27.

Ruddle, K. 1977 Sago in the new world. *In*: Proceeding of the 1st International Sago Symposium. (Tan, K. ed.) Kuching, 53-64.

Sholeh, K. 2017 Prasasti Talang Tuo peninggalan Kerajaan Sriwijaya sebagai materi ajar sejarah Indonesia di sekolah menengah atas. Jurnal Historia 5(2): 173-192. (in Indonesian)

Singhal, R. S., J. F. Kennedy, S. M. Gopalakrishnan, A. Kaczmarek, C. J. Knill and P. F. Akmar 2008 Industrial production, processing, and utilization of sago palm-derived products. Carbohydrate Polymers 72: 1-20.

Syamsiro, M., M. N. Aridito and S. Ma'arif 2020 Potential application of sago pulp briquette for electricity generation using gasification technology in Papua Province, Indonesia. Key Engineering Materials 849: 20-26.

Syauki, A. Y., A. Ogawa, U. R. P. Simanjuntak, I. G. Mangiwa, M. Doi, S. Kageyama, R. Inoue, N. A. Taslim and Y. Irie 2022 Protein-energy nutritional status of moderately low protein intake-sago diets compared to sufficiently protein intake-rice diets in well-nourished lowlanders in Papua, Indonesia. F1000 Research. 11: 1-18.

Vincent, M., E. Jabang, N. M. Nur, E. Esut, L. B. Unting and D. S. A. Adeni 2015 Simultaneous co-saccharification and fermentation of sago hampas for bioethanol production. AgricEngInt: CIGR Journal 17(2): 160-167.

Yamamoto, Y 2011 Starch productivity of sago palm and the related factors. *In*: Proceedings of the 10th International Sago Symposium (Siregar, I. Z., Sudaryanto, T., Ehara, H., Suwardi, Lubis, I. and Ardie, S. W. ed.) Bogor, 9-15.

Zhu, F. 2019 Recent advances in modifications and applications of sago starch. Food Hydrocolloids 96: 412-423.

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Sago Ethnobotany (*Metroxylon Sagu* Rottb.) in Mentawai Community, Siberut National Park, Mentawai Islands District, Indonesia

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Abstract The study of ethnobotany is a science that studies traditional community knowledge of the diversity of plants around it and the utilization of these plants. The Mentawai community have used sago plants as a staple food since their ancestors, both for staple food, roofing, and traditional marriages. This study aimed to describe the ethnobotany of sago (*Metroxylon sagu* Rottb.) and to compare the use of several other communities in Indonesia. When the data was collected, the method of snowball sampling technique was adopted. The people in Mentawai community utilize some parts of sago, and they use 4 out of 9 parts, which are leaves, bark, stem(pith) and roots. These communities have not utilized sago optimally, compared to other Indonesian communities.

Key words: Ethnobotany, Mentawai, *Metroxylon sagu*, Snowball sampling

Preface

Sago (*Metroxylon sagu* Rottb.) is a non-timber forest product that grows in swamp habitats, tidal areas, along river banks, pond edges, or near water sources (Gusmailina 1992). Sago contains carbohydrates that can be processed into bioethanol and has the potential as a substitute for food in the food industry, thereby creating food and energy security for the nation's future (Hayati et al. 2014). The nutritional value of sago is not inferior to other food sources such as rice, corn, cassava, and potatoes. Sago is a source of carbohydrates in supporting food security.

The Mentawai community have used the sago plant for a long time for staple food, roofing, and traditional marriages. Processing of sago in the Mentawai is carried out traditionally, starting by opening the skin of the sago, grinding it by chopping it, and processing it into starch. This activity is called *menyagu* (Febrianto and Fitriani 2012). Other parts such as sago leaves are used as roofs and sago bark as walls and floors. As for another use, sago is used as fuel, which makes sago a valuable multi-purpose plant for the Mentawai community (Pradipta 2019). The activities carried out by the Mentawai community are called ethnobotany, namely the study of interactions between humans and plants in their use in a particular culture (Pratiwi and Sutara 2013).

Community's views on sago are currently experiencing a shift due to the entry of rice brought and introduced by the government and community outside the Mentawai. The Mentawai community have the perception that consuming rice is an honor in the form of a better social status from an economic point of view and is equal to community outside the Mentawai Society. The availability of rice causes the identity of sago food to be increasingly threatened due to the substitution of local food for rice.

The study of ethnobotany is a science that studies traditional community knowledge of the diversity of plants around it and the use of these plants. The results of sago ethnobotanical research on the Anak Rawa Community in Penyengat Village, Siak Regency, Riau, namely the part of sago that is used consists of roots, stems, leaves, flowers, and fruit. These parts are used as food ingredients, buildings, traditional rituals, and medicines (Sariasih 2019). The activity of using sago plants in the life of the Mentawai community is only a fulfillment of daily needs and is starting to be abandoned. This is due to a shift in culture which has consumed sago food every day for a long time, but now community are starting to consume food from rice imported from outside the island. It is feared that the sustainability of sago ethnobotany is increasingly threatened (Zamzami 2013).

Based on this, it is necessary to research "Ethnobotany of Sago (*Metroxylon sagu* Rottb.) in Mentawai community in Siberut National Park, Mentawai Islands Regency". The existence of sago used by the Mentawai community has never been documented and a survey of sago utilization has never been conducted.

Research methods

The research was conducted in Siberut National Park, Mentawai Islands Regency, West Sumatra. The time of research was from January 15 to March 5, 2022. The tools used in this study were writing instruments, laptops, interview guides, road boards, cameras, voice recorders, and Microsoft Excel software. Materials used include documents or research reports on ethnobotany, guidebooks for sago plant species, and tally sheets. The data collection method was carried out by conducting in-depth interviews with a snowball selection of informants, namely interviews with key respondents.

The selection of respondents was carried out by considering the knowledge possessed regarding the utilization of sago plants, such as sago farmers and *sikerei* (medicine healers).

The interview started with one key respondent and then rolled from one respondent to another until the information obtained was saturated (the same information was found in other respondents). Field observation is carried out through direct observation by looking at the activities in detail in the field situation. Field observation activities consist of recording and taking documentation of behavior, events, and the necessary data.

The number of respondents obtained was 47 community with criteria based on gender, age structure, livelihood, and level of education.

1. Data Analysis Procedures

Data obtained from field observations and interview results as well as other supporting data are processed using the formula and analyzed by descriptive qualitative.

2. Percentage of Utilization and Part of Sago Plants that are utilized

The formula used to calculate the percentage of sago utilization for aspects of community's lives and the part of the sago plant utilized refers to Syahdima et al. (2013) as follows:

a) Percentage of utilization of sago plants from the aspect of life

$$\text{Aspect of life} = \sum \frac{\text{Utilization of Sago plants}}{\text{Total benefits of Sago plants}} \times 100\%$$

b) Percentage of utilization of sago plant parts

$$\text{Part of the Sago Plant} = \sum \frac{\text{The part of the sago plant is used}}{\text{Total part of sago plant}} \times 100\%$$

Results

Utilization of Sago Based on Part Used

The use of parts of the sago plant by the Mentawai community consists of roots, stems, leaves, flowers, and fruit. Respondents who used sago stems, leaves, midribs, and bark were 47 community (100% of respondents). Only 20 respondents (43% of respondents) used sago root and only 1 person used sago fruit (2% of respondents). Respondents knew less about the use of roots because only *Sikerei* (shaman) knew the uses of roots. Sago root is used as a toothache remedy (Figure 1).

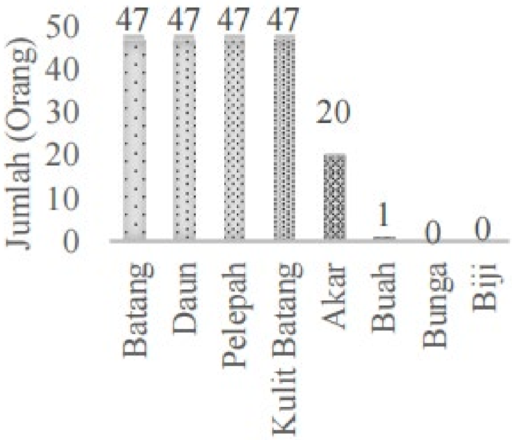

Figure 1 Utilization of sago plant parts by Mentawai community

Discussion

1. Roots

The Mentawai community know using sago root to relieve and cure toothache. The sago root used is a young root with reddish-white characteristics. How to process sago root as a toothache medicine is as follows:

1) Young sago root with reddish-white color is prepared;
2) Sago roots are cleaned of dirt with water;
3) Bamboo is prepared as a cooking medium;
4) The sago roots are crushed and then put into the bamboo;
5) After that, the bamboo is given water and placed on the fire;
6) Sago roots are cooked until boiling, then removed;
7) Cool down until it's not too hot;
8) Sago root water is drunk and gargled on the aching tooth.

This knowledge is still used today, but only *sikerei* (Shaman) and some community know the function of the sago root (Figure 2).

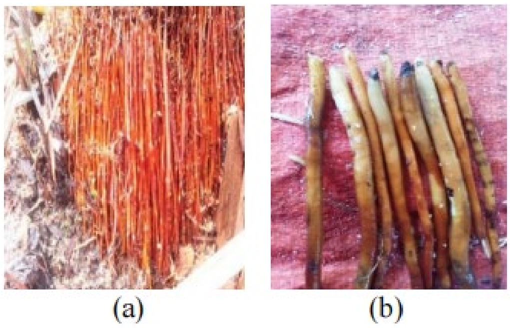

Figure 2
(a) Sago roots in sago plants
(b) Sago root as a toothache medicine

2. Stem

The Mentawai community use sago stems to extract their sago starch. Sago starch is the staple food of the Mentawai community. Processed from sago starch is called *kapurut tagu*. Before being processed into lime *tagu*, there are several processes to obtain sago starch which is used as a raw material. Processing of sago into starch is carried out in a traditional way called *maigorot tagu* (shredding sago) (Figure 3a). The grating process is carried out after the process of harvesting and transporting the sago stems. The grating is done at night and in the morning. This time is taken so that the next day the process of filtering or squeezing the sago can be carried out. The process of squeezing sago is carried out in a place that has sufficient water sources so that the process of squeezing sago can be carried out.

Usually, the community establishes a sago milking place in swamp water or flowing water sources, such as in river areas (3b). The steps for squeezing sago are;

1) Sago is placed in the top tub (*karuk*);
2) Water is taken using *dedeybu* (water bucket) and sago is watered evenly;
3) Sago is trampled so that the starch is separated from the sago dregs (*ponyit tagu*);
4) Sago is squeezed continuously until the filtered water looks clear;
5) Sago is left to settle for about 30 minutes;
6) After the sago starch settles, the water is drained;
7) Sago starch is taken and put into sacks (Figure 3c);
8) Sago is placed in a place that allows sunlight;
9) Sago is dried for 2-3 days;
10) Sago is ready to take home.

Processed sago starch will be used as *kapurut tagu*.

Figure 3
(a) Grated sago
(b) Sago extortion
(c) Packaging of sago
(d) *Kapurut tagu*

The process of making *kapurut tagu* is carried out through 9 stages, namely:
1) Tools and materials are prepared;
2) Sago starch mixed with grated coconut evenly;
3) Some sago leaves are separated from the veins, so the leaves can be used as a binder for sago leaf wrap;
4) Sago dough is put into boned leaves;
5) *Kapurut tagu* is ready to be cooked;
6) Prepared cooking utensils for sago, namely firewood, matches, and a mat for burning *papurut tagu*
7) *Kapurut tagu* is grilled over a fire for 15 minutes;
8) *Kaput tagu* is turned over so that it cooks evenly;
9) When it is ripe and the leaves look black, *Papurut Tagu* is removed;
10) *Kapurut Tagu* is ready to eat (Picture 3d).

Communities can consume 10 *kapurut tagu* in one meal so that in a day each person can consume up to 20 *kaput tagu*. Apart from self-consumption, community can sell sago to fulfill their family's economic needs. Sago is sold in sacks of 10 kg at Rp. 50,000.00 or sacks of 20 kg at Rp. 100,000.00. Typical Mentawai food apart from *kramut tagu* is *nyobbug tagu*, *tagu ginailug*, *tagu kinarak*, and *bothag*. *Nyobbug* has the same method of making as *lime tagu*, except that it is cooked in bamboo. *Tagu ginailug* is cooked in a cauldron by stirring until dry, then mixed with grated coconut and coconut water until the sago dough becomes round, while *tagu kinarak* is the same process as *tagu ginailug*, but cooked using a medium pot. *Bothag* is cooked on bamboo media, and sago is cooked using coconut water and added sugar, and grated coconut. The community also uses sago beetle eggs to become sago caterpillars which can be consumed as side dishes. How to consume sago caterpillars the community is directly or raw and cooked first.

3. Bark and midrib

The Mentawai community use sago bark as a path in the sago growing area. The community usually uses sago bark as the walls of their houses, bathrooms, chicken coops, huts in sago fields, and firewood. Crafts from sago plants by the Mentawai community are used to support daily living activities. The craft is a bag made of sago bark. These bags are known as *bolobok* bags. The use of bags can be used to transport sago, transport agricultural products such as fruits and vegetables (Figure 4).

Figure 4
(a) The bark is the base for the road
(b) Firewood
(c) The walls of the house
(d) Crafts in the form of *bolobok* bags

4. Leaf

Sago leaves are used by the Mentawai community as roofs for houses. The leaves used have characteristics that are not too old and not too young. According to the community, the roof of a house made of sago leaves is more comfortable because it makes the room feel cooler compared to a house that uses a roof made of tin. The roof of sago leaves is usually made 2.0-2.5 meters long and requires 250 leaves. Dalimunthe (2019) states that sago plants produce 24 leaves which are the growth and starch production phases. Leaves can be harvested and used as the roofing material. A house usually requires 300-500 sago roofs. This is equivalent to 75,000-125,000 leaves or 44-74 sago plants. The community can make roofs from sago independently because they have expertise. A house roof made of sago that is ordered from a craftsman will be charged a price ranging from IDR 3,000 to IDR 5,000/roof (Figure 5). If each house requires 300-500 roofs, the craftsmen can earn IDR 900,000.00-IDR 2,500,000.00. The use of sago leaves as roofs for houses by the Mentawai community began to decline with the development of corrugated iron roofs. This is because roofs made of sago leaves can only last 5 years, while roofs made of zinc can last more than 20 years.

Figure 5
(a) Sago leaves as a container for sago (*tatap*)
(b) sago leaves as the roof of the house
(c) Sago leaves as a sago roofing craft

5. Flowers and Fruit

Sago flowers are not used, while some community use sago fruit to spread it on sago fields so that new sago grows. Based on the results of observations, sago flowers, and fruits were not found, because the community harvested sago before it flowered and bore fruit.

6. Utilization of all parts of the plant

In marriages with Mentawai custom, the provisions for proposing with the condition of owning sago land are now starting to disappear. According to the Mentawai community, this was done at the time of their ancestors, but now the decision to propose to a woman is done by giving a set of five types of objects that must be given to the woman, namely machetes, cauldrons, mosquito nets, axes, and cooking pots.

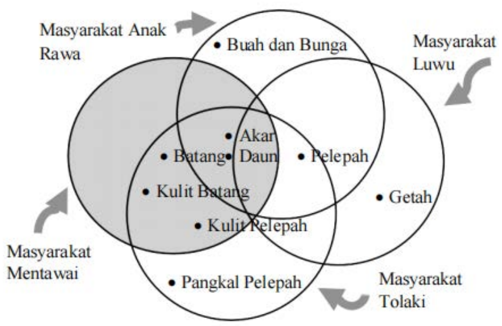

Figure 5 Comparison of the use of sago parts by several communities in Indonesia

Sago Ethnobotany in Other Communities in Indonesia

Comparison of several communities in Indonesia with the Mentawai community in terms of sago ethnobotany aims to obtain basic knowledge possessed by each region that is not owned by the Mentawai community. It becomes a reference in optimizing the sago resources owned by the Mentawai community in Siberut National Park (Figure 5).

The Radda community, Anak Rawa community, Tolaki community, and Mentawai community have differences in terms of utilizing sago optimally. In each region, community have different levels of knowledge in utilizing sago. The Mentawai community use only 5 of the 9 parts of the sago plant, consisting of leaves as roofs for houses and containers for sago starch; midrib skin as a material for making *bolobok* bags (multipurpose bags); bark used as road mats, firewood, and house walls; stems (pith) as a staple food (*kaputut tagu*) and roots as toothache medicine. The sago plant is used by the community of Luwu only 6 out of 9 parts of the morphology of sago which consists of leaves as roofs for houses and menstrual medicine; midrib as a medicine for eye disease and house walls; frond skin as material for sewing roofs and ceilings; stems as staple food ingredients, house floor materials, and house fences; roots as a medicine for impotence and uric acid and sap as a medicine for bleeding wounds (Syahdima et al. 2013).

The Tolaki community use 7 of the 9 morphological parts of sago which consist of leaves as roofs for houses; midrib as the wall of the house; frond skin as artistic wall woven; the base of the frond as a material for making sago baskets and baskets and bark as floors, walls of houses, firewood, and garden fences (Suharno and Rusdin 2010).

The Anak Swamp community utilizes 6 of the 9 morphological parts of sago which consist of roots as facilitating breast milk (breast milk); stems as a producer of sago starch, shoots, and special food; bark as the base for the yard, firewood, and the fence for the yard; leaves as the roof of the house; Sago fronds are used as material for making ships (traditional events), clothesline poles, yard fences, flower pots, firewood, and bird cages as well as flowers and fruit as fuel (Sariasih 2019).

The Mentawai community have not optimally utilized the sago part compared to other communities, especially compared to the Anak Swamp Community. The use of sago parts starting from the leaves and midrib shows that the utilization of sago parts by the Mentawai community is not optimal and there is a need for government intervention in the form of education to increase public knowledge in utilizing sago as a whole.

Conclusion

Ethnobotany of sago by the Mentawai people in Siberut National Park occurs in the process of harvesting, grating, squeezing, and division of labor in processing one sago stalk. This is part of local wisdom. Utilization of sago for the necessities of life of the Mentawai people based on the part of the sago plant used is the leaves as roofs and sago food wrappers, sago stems from which starch is taken as food and animal feed, leaf midribs as material for making multipurpose bags (*bolobok*), sago bark as lining roads and walls of houses, and roots as a remedy for toothache. The Mentawai people have not optimally utilized the sago part compared to other communities. Only 5 out of 9 parts of sago are used, namely leaves, midrib bark, bark, stems, and roots.

References

Dalimunthe, L.H., Rana, G.K., Ekasari, N., Iskak, P.I., Andriani, J. 2019 *Sagu* (*Metroxylon sagu* Rottb.). Setyorini E, Sutriswanto S. Bogor: Pusat Perpustakaan dan Penyebaran Teknologi Pertanian.

Febrianto, A., Fitriani, E. 2012 Orang Mentawai: peladang tradisional dan ekonomi pasar. Humanus. 11(2):119- 133.

Gusmailina. (1992). Prospek Agroindustri di Sumatera Barat khususnya di Kepulauan Mentawai. Jurnal Penelitian Hasil Hutan. 10(6): 222- 226.

Hayati, N., Purwani, R., Kadir, A. 2014 Preferensi masyarakat terhadap makanan berbahan baku sagu (*Metroxylon sagu* Rottb.) sebagai alternatif sumber karbohidrat di Kabupaten Luwu dan Luwu Utara Sulawesi Selatan. Jurnal Penelitian Sosial dan Ekonomi Kehutanan. 11(1):82-90.

Pradipta, L. 2019 Peralihan pangan pokok dari sagu ke beras: sebuah kajian ketahanan pangan dan masyarakat adat. Society. 7(1):39-51.

Pratiwi, F.M., Sutara, P.K. 2013 Etnobotani kelapa (*Cocos nucifera* L.) di Wilayah Denpasar. Jurnal Simbiosis. 1(2):102-111.

Sariasih, P. 2019 Etnobotani dan potensi bioprospeksi sagu (*Metroxylon rumphii*) pada Masyarakat Suku Anak Rawa Kampung Penyengat Kabupaten Siak, Riau [skripsi]. Bogor (ID):Institut Pertanian Bogor.

Syahdima, Yuniati E, Pitopang R. 2013 Kajian etnobotani tumbuhan sagu *Metroxylon* spp. Arecaceae) pada masyarakat Desa Radda Kecamatan Baebunta Kabupaten Luwu Utara Provinsi Sulawesi Selatan. Biocelebes. 7(1): 17-26.

Zamzami, L. 2013 Sekerei Mentawai: keseharian dan tradisi pengetahuan lokal yang digerus oleh zaman. Anthropology Indonesia. 34(1):29-40.

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Agronomic Prospects for New Sago Palm Cultivation by farmers: Time to Harvest and Associated Cultivation Management

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Abstract In supporting long-term research on the cultivation of sago palm, a 1.2 ha sago planting experimental plot was established in Pengkajoang Village, one of the traditional sago-producing community in South Sulawesi. In the plot, total of 157 selected sago suckers were transplanted from September 2012 with an interval of 10 m x 8 m. After that, data of the number of leaves, the number of leaflets on the lowest leaf, length of leaf, length of rachis, length of longest leaflets, the width of widest leaflets, and the number of leaf scars on the trunk was counted. After about 10 years and 9 months from transplanting, individual sago palms began to show the characteristics of being ready to harvest. At that plot, 149 clumps are growing, and 73 individuals are ready for harvest. The growth of the sago palm in this experimental plot was faster and the yield also much more than farmer's expectation. Sago palms planted in the experimental plots are capable of producing 13 tons ha^{-1} of dry sago flour at present time and will continue to increase. The expert farmer estimates that the property value of this plot will be higher in the future. It is suggested that cultivation management can shorten the time to harvest and increase the yield.

Key words: Cultivation management, Growth characteristics, Prediction of yield, Trunk formation

Introduction

Sago palm is an underutilized and neglegted crop that has the potential to contribute to global food security, especially Indonesia. It is a promising crop with high starch yield potential that grows in marginal land where other food crops can't grow (Konuma, 2018). Sago flour production currently uses more natural stands of sago palms. A major problem with the discussions on the feasibility of developing sago palms so far is that there have been very few discussions based on empirical research results, and many have been based on desk calculations. As a result of investigating the factors influencing the motivation for farmers to plant sago palm in the selection of crops, the largest factor was the lack of agricultural information on sago palm cultivation, such as selection of excellent seedlings, leaf speed, planting density, time to trunk formation stage, time to harvest to compare with another crop (Trisia, 2017).

Sago farmers in the east part of Indonesia, such as Southeast Sulawesi, South Sulawesi, Maluku, and Papua, differently from farmers in the west part of Indonesia, such as Riau. Farmers in the east part of Indonesia consider sago palm to be a forest plant that is grown naturally, resulting in limited agronomical knowledge which negatively affects the sustainability of sago production. A study in South Sulawesi showed that knowledge and information positively correlates with the participation of a farmer to cultivate sago (Trisia, 2021).

In order to obtain empirical information contributing to the domestication of sago palm, an experimental plot was established in Penkajoang Village, South Sulawesi Province, to conduct a sago palm growth survey on a scale of 1.2ha in September 2012. Providing such empirical data is important for villagers to select sago palms. We studied the growth of sago palms which had been regulated by plant density, pruning dry leaves, arranging suckers that grew densely in this experimental plot.

The main production area of sago palm in South Sulawesi provice is Luwu region (Tana Luwu). The Villagers are very skilled at classifying the growth stages of sago palms based on their botanical sense. The sago farmers in this area have a wealth of empirical knowledge about sago palms, and it was thought that cooperation with them would be necessary for the cultivation of sago palms in the future.

The experimental plot is located along the road from Penkajoang village to Pembunian village, width of the plot is 80 m from east to west, and the depth to the south is 150m. 157 sago sucker seedlings were transplanted to this plot as part of field training in collaboration with Ehime University and Hasanuddin University with the support of a local NGO (Lembaga Pelangi and Kampong Sagu) and local farmers in September 2012.

We collaborated with local farmers to cultivate sago by simple techniques without using fertilizers and pesticides in the experimental plots, lead by local sago farmer as research assistant. Providing such empirical data is important for villagers to select sago palms. It is hoped that cultivation of sago palm will be able to shorten the harvest time and increase the potential for production.

Research Methods

The growth survey was conducted in June 2023 by collaboration with sago farmers. Among them, Mr. Sumardin (a village elder who is familiar with the growth of sago palms) taught us how to identify the growth stages of sago palms. In addition, other farmers removed dead leaf sheaths and leaves that had accumulated in the clumps to make it easier to measure the stem length. About 100 leaves died and accumulated around the sago palm clump in the research plot over the last 3 years and 10 months, which was a hard work.

The main objective of this survey is to identify individual sago palms that are suitable for harvesting, and to measure the stem lengths of all individuals whose trunks appear. These data were predictive of continued yields for this plot.

From 1986 to 1988, Osozawa conducted a correlation analysis between the production volume of 31 cases from 131 sago palms and the external characteristics of the sago palm used (stem length, number of leaf scars, number of fresh leaves, average diameter of the trunk). The regression equation is

$Y = -41.396 + 28.633X$ where Y: yield(kg/stand), X: trunk length（m）

This yield prediction model was used to predict the future yield of the plot.

A Laser Rangefinder (Bosch professional GLM 500) was used to measure stem length. The sago stem is measured from the bottom where the farmer will place the sago harvesting tool until the top of the stem is about 30 cm upper above the lowest fresh leaves. The length of the sago stem is an important factor for the growth of sago plants in estimating the potential yield of production in land units (Sari *et al*. 2020).

Result

There were 149 clumps, 355 trunks and more than 90 sucker still at the rosette in the experimental plot. Fig 1 shows the frequency distribution of the all stem length in experimental plot of 1.2 ha.

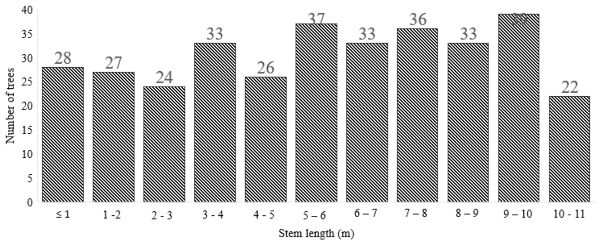

Fig. 1. Histogram of sago stem lengths in June 2023 observations

The stem length varied greatly from 1 m to 11 m (Fig 1). Although the frequency distribution for each stem length is slightly biased at 5 m or more, there is no large gap overall, and the range varies from 22 to 37 for each trunk length. This value is slightly higher than the frequency distribution of the trunk length of the existing sago palm forest under unmanage condition, and the gap is small, but there is not much difference.

Local farmers are experts in determining which trees are ready for harvest based on their own growth stage classification of sago palm (Fig 2). The following is the distribution of Growth stage classification by local farmers (Osozawa, 1990).

I. *ana* : Stages from germination to trunk formation

II. *ma'babakung* : Stem emerges and grows stage

III. *pettu sese* : The stage where the black streak (*sese*) at the base of the petiole begins to cut and looks blurry

IV. *ma'baru* : The stage where white powder (*baru*) appears near the base of the petiole

V. *bulu bongko* : Stage at which small leaves resembling shrimp (*bongko*) appear

VI. *ma'tanduk jonga* : Inflorescence emergence stage

VII. *ma'bua belu* : Stage at which the 2nd and 3rd lateral branches of the inflorescence develop

VIII. *ma'bua* : Fruiting

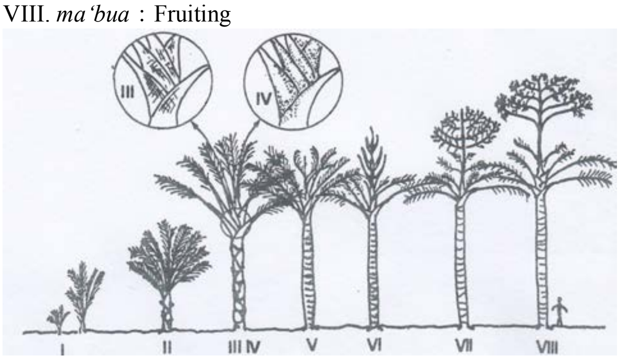

Fig.1. Growing stage of sago palms by villagers (Osozawa, 1990).

The growth stage classification is divided in detail after the suitable harvesting period, and it can be seen that they are interested in selecting the harvest time. The actual harvest is concentrated after stage III (*pettu sese*). Importantly, villagers skilled in sago palm should not harvest before stage III. Although sago palms can be harvested at stage V and beyond, this is very rare. Osozawa's research (1990) studied 157 times when farmers harvested sago trees, as many as 90% of farmers harvested sago trees at stages III and IV during their growth stage were observed in this long-term cultivation plot.

There are 68 individuals that can be harvested until June 2023, namely 16 trees in *pettu sese* (growth stage III), 26 *ma'baru* trees (IV), 23 *bulu bongko* trees (V), and 3 *ma'tanru jonga* trees (VI). In addition, based on information from the farmers guarding the plots, there have been 5 trees that have been cut down in the last 1-2 years, so a total of 73 sago trees can be harvested at that experimental plot (Table 1).

Based on the length of the sago stem, we tried to calculate the yield potential of dry sago starch using Osozawa's empirical formula from previous research.

Table 1. Yield Prediction using empirical formula (Y = —41.396+28.633X)

Growth Stage	No. of tree observed	Stem Length (m)		Yield Prediction (kg/palm)
		min	max	
ma'babakung	16	1.5	7.6	-
pettu sese	16	6.9	10.2	156 – 251 (203.5)
ma'baru	26	7.3	10.6	167 – 262 (214)
bulu bongko	23	8.9	10.7	213 – 265 (239)
ma'tanru jonga	3	8.5	9.8	201 – 239 (220)
Harvested	5			(220)

Every harvest stage has a different average production potential. At *pettu sese* stage, average production potential is 203.5 kg/palm so that 16 palms can produce 3256 kg of dry sago flour. The 26 sago palms during *ma'baru* stage were able to produce 5564 kg, *bulu bongko* 5497 kg, *ma'tanru jonga* 660 kg, and it is estimated that the harvested sago palms were able to produce 1000 kg. At present (after 10 years and 9 months of planting) an experimental plot of 1.2 ha is capable of producing around 16 ton (13.3 ton/ha) and will continue to increase.

There are 3 sago trees that have entered *ma'tanru jonga*, where inflorescence emergence indicating that their growth is faster than the other 70 individuals.

Discussion

The frequency of each stem length became almost uniform was that most of the plants. On the other hand, the fact that 157 seedlings were planted and a total of 355 trunks grew was considered significant. The number of sago palms grows and develops twice as much as the number of seeds planted so that the sago trees grow at tighter intervals. As we observed, there is no problem even if multiple individual grow as long as there is no big difference in tree height. Each leaf crosses appropriately and can receive light together with the difference in stem height is not too much (Fig 3).

Fig. 3. Sago palm individuals growing close together

Based on that, It is very important to consider how to grow multiple individuals dividing at the same time as in Figure 3.

Sago palms planted with interval 10m x 8m in the experimental plot are expected to produce an average of 203-239 kg of dry sago flour per hectare. This estimate is certainly higher than the average yield per palm by Flach (1980), which is 185 kg with a planting density of 6 m x 6 m. Differently, the dry starch yield of each trunk estimated by Yanagidate *et al* (2009) is 329kg ~ 495kg per palm and Yamamoto *et al* (2000) reported the yield potential for the *molat* variety in Kendari to be 425 kg, it may indicate an overestimation.

The production potential in experimental plots ranges from more than 200 kg per stem, in line with the results of research by Manar (2023) reporting that sago superior accession in Linggau regency, Riau island has a production potential of more than 200 kg per stem with a potential yield range of 3.37 to 14.55 tons per ha. This indicates that the sago palms that were tried to be cultivated have a yield potential that is not much different from the yield potential of superior sago in the Riau Islands.

It is different from the estimation of starch yield during the growth period of *matanru jonga* (Inflorescence emerging stage). Jong's research (1995) showed that the flowering stage reached the maximum yield (203.4-219.4 kg) at around 12.5 years of age, while in the experimental plots sago palms entered flowering at around 10 years of age. *Ma'tanru jonga* stage is estimated to occur from two to three years after *pettu sese* (growth stage III) which is the first suitable harvest period. This fact indicates that it is estimated that there are individuals that can be harvested 8 to 9 years after transplanting.

However, further research is needed on the causes of sago palms entering the *ma'tanru jonga* stage earlier, whether caused by environmental influences, plant arrangements (such as sucker control), or the influence of genetic heredity.

In order to verify all, future researchers collaborated with farmers in Penkajoang village to make a plan to conduct an empirical yield survey of mature trees in this experimental plot.

Conclusions

A simple sago cultivation technique carried out together with farmers is able to produce sago trees which have the potential to produce dry flour of 203 - 239 kg per stem. By finding sago individuals that had entered the flowering period (*ma'tanru jonga*) at the age of 10 after transplanting, it was concluded that cultivation techniques were able to shorten harvest time.

References

Flach, M. 1980 Comparative ecology of the main moisture-rich starchy staples. In; Sago: The equatorial swamp as a natural resource (Proceedings of the 2nd International Sago Symposium) (Stanton, W. and M. Flach eds.) Martiu Nijhoff (London) 110-127.

Jong, F.S. 1995 Research for the development of sago palm (*Metroxylon sagu* Rottb.) cultivation in Sarawak, Malaysia. Ph.D. thesis of Agricultural University, Wageningen, The Netherlands. In The Society of Sago palm studies (2015). The Sago Palm. Kyoto University Press

Konuma, H. 2018 Status and Outlook of Global Food Security and the Role of Underutilized Food Resources: Sago Palm. In: Ehara, H., Toyoda, Y., Johnson, D. (eds) Sago Palm. Springer, Singapore. https://doi.org/10.1007/978-981-10-5269-9_

Manar P A, Zuhud E A M, Andarwulan N, M H Bintoro. 2023 Morphological Characteristics and Potential of Sago (Metroxylon spp.) in Lingga Regency, Riau Islands, Indonesia. Jurnal Manajemen Hutan Tropika, 29(1), 11-21.

Osozawa, Katsuya. 1990 Sago palm and sago production in South Sulawesi-Essay on Tropical Low land Development. Ph.D. thesis, Fac of Agriculture, Kyoto Univ, pp,275. (in Japanese)

Sari D R, Asrul L, Sjahril R, Osozawa K. 2020 Path coefficient analysis for growth characters of sago palm related to trunk formation in three years after transplanting. IOP Conf. Ser.: Earth Environ. Sci. 486 012010

Trisia M A, Tachikawa M, Ehara H. 2021 The Role of the Sago Supply Chain for Rural Development in Indonesia: A Review and Perspective. Reviews in Agricultural Science, 9: 143–156, 2021 https://dx.doi.org/10.7831/ras.9.0_143

Trisia M A, Metaragakusuma A P, Osozawa K, Bai H. 2017 Do Small-Scale Farmers Want to Plant Sago Palm? An Empirical Analysis of the Factors Influencing Farmer Participation in Luwu Utara Regency, Indonesia. Journal of Agriculture and Crops, 2017, 3(12): 97-109

Yamamoto, Y., K. Omori, T. Yoshida, Y. Nitta, Y. B. Pasolon and A. Miyazaki. 2000 Growth characteristics and starch productivity of three varieties of sago palms in Southeast Sulawesi, Indonesia. Abstract of the 15th Conference of the Society of Sago Palm Studies. 15-22. (in Japanese)

Yanagidate I, Rembon F S, Yoshida T, Yamamoto Y, Pasolon Y B, Jong F S, Irawan A F, Miyazaki A. 2009 Studies on Trunk Density and Prediction of Starch Productivity of Sago Palm (*Metroxylon sagu* Rottb.): A Case Study of a Cultivated Sago Palm Garden near Kendari, Southeast Sulawesi Province, Indonesia. SAGO PALM 17: 1－8 (2009)

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Utilization of Palm Oil By-products for Sustainable Crop Production in Marginal Land

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Abstract This experiment purpose was to evaluate the chemical properties and the potential uses of palm oil by-product as organic fertilizer for sustainability of crop production in marginal land of South-east Sulawesi. We collected two types of organic by-product from two industrial of CPO: dust of empty bunch fruit (AT) and sludges (S), mixed with ratio of AT/S (w/w): 22/78 for ormula-22 (F-22). Mixed of AT and S then fermented for 10 days, enriched by bio-activator and analysis for pH, C-organic, N-total, P_2O_5-availabel, K_2O-total and C/N ratio. F-22 were enriched by urea then used as organic fertilizer for rice cultivation in rainfed soil. The result indicated that the increase of AT concentration was more prominent in induce rice growth and production.

Key words: Marginal land, Organic fertilizer, Palm oil by-products

Introduction

Both sago palm (*Metroxylon sagu* Rottb.) and palm oil (*Elaeis guineensis*) are important crops for Indonesia. Sago palm mainly produce "sago starch" and palm oil for industrial crude palm oil (CPO). The rest of sago palm area in Indonesia was predicted less than 2.0 million ha, and palm oil plantation was around 15,077,022 ha distributed at Sumatera, Kalimantan, Sulawesi, Java and Papua islands (Direktorat Statistik Tanaman Pangan, Hortikulturan dan Perkebaunan, 2022). It was reported that Indonesian CPO production was around 46.50 million ton per year, which resulted an organic by-product around 51.67 million ton per year. This by-product containing higher content of K_2O, C-organic, N, P_2O_5, Ca, Mg and some micro nutrients. (Pasolon and Ariffin, 2021, Pasolon 2022).

This paper purpose was to discuss an innovation formula of organic fertilizer recycled from palm oil by-product and its application on rice farming.

Materials and Methods

1. *Material Preparation*

Materials for this experiment collected from two palm oil industries: PT. Merbaujaya Indahraya located in South Konawe Prefecture and PT. Utama Agrindo Mas located in Konawe Prefecture South-east Sulawesi Province. Each factory has capacity to extract 60 t fresh fruit bunch per hour. From this extracting was resulted 26.5 % CPO and kernels and 73.5%. From this waste there are 33 % as organic material consist of empty fruit bunch (EFB): 23.0 %), sludge (S): 7.0 % and fiber (F): 3.0 %, respectively. EFB recycled by open burning or furnace in incinerator which resulted EFB dust with local term *abu tandan kosong* (AT), S where stocking in settling ponds and F mixed with palm oil shell for furnace steam water and electric power plant.

2. *Chemical Analysis*

AT and S were collected and mixed with ratio (w/w): 22/78 to formulated organic fertilizer namely formula 22 (F-22). This formula then mixed with *bio-activator* produced by KSU Karya Bangsa with ratio (w/w): 90/10, fermented for 10 days, homogenized, keeping for 7 days until it reaches normal temperatures (30 °C) and moisture 21 to 24 %, and then took 500 g for chemical analysis in PT. Sucofindo Laboratory (Pasolon and Ariffin, 2021).

Field Application

Soil sampling was conducted before land preparation. Soil was taken by core sampler at 0-30 and 30-60 cm, air dried, sieved, oven dried at 100 °C for 24 hours and analyzed for pH, CEC, C-organic, N, P, and K contents according to Sulaeman, et al. (2005).

Land preparation by plowing one times, keeping 10 days, puddling by rotary two times and constructed plots (2.5 m × 2.5 m). Nutrient level in this experiment was standardized and equivalent to KCL (50 % K_2O_5) at the rate: 0.0, 50.0, 75.0, 100.0 and 125.0 kg/ha. These levels then converted to F-22 organic fertilizer which equivalent to 0.0, 132.0, 198.0, 265.0 and 331.0 kg/ha and NPK-15-15-15 which equivalent to 0.0, 167.0, 250.0, 333.0 and 417.0 kg/ha. Each level of F-22 was enriched by mixed with Urea (46 % N): 150.0, 141.0, 138.0, 133.0 and 130.0 kg/ha and for NPK-15-15-15 by 150.0 kg/ha.

Fertilizer application by broadcasted and mixed with soil prior transplanting. Three plants per hill of middle seedling of Mutiara rice cultivar was hand transplanted after 25 days seeding. Plant distance was 20 cm x 20 cm, respectively. Chlorophyll content measured by SPAD meter (Minolta SPAD-502), number of tiller and panicle, harvested dry grain and percentage of full grain production were measured from three replications plots size 1.0 m^2 at ripened stage. Percentage of full grains was measured use salt solution water 1.06 gravity as explained by Hoshikawa (1989).

Results

1. Soil and Organic Fertilizer Characteristic

Table 1 shown that soil pH was acidity, N-total was low, P-available was medium, K was higher, C-organic was low and CEC was higher based on Sulaeman, et al. (2005). Table 2 showed that total elements content in F-22 organic fertilizer was higher, however, availability depending on mineralization process, therefore, in application should be enriched by chemical fertilizers which containing N and P elements

Table 1. Soil characteristics before treatment.

Elements	Unit	Values	Analysis method
pH-H2O	–	4.90	pH-meter
C-organic	%	1.40	Walkley-Black
N-total	%	0.10	Kjeldahl
P_2O_5-available	ppm	5.50	Bray-2
K_2O-available	me/100 g	0.27	NH4-OAc, 1 M, pH-7
CEC	me/100 g	25.84	NH4-OAc, 1 M, pH-7

(Source: Syah, 2022).

Table 2. Characteristic of F-22 organic fertilizer.

Elements	**Unit**	**Values**	**Analysis method**
pH	–	9.43	Potentiometry
C-organic	%	21.55	Gravimetry
N-total	%	2.94	ACOAC (2016) ed.20
P_2O_5-total	%	0.72	ACOAC (2016) ed.20
K_2O-total	%	18.94	ACOAC (2016) ed.20
Ca	ppm	271.20	ACOAC (2016) ed.20
Mg	ppm	370.80	ACOAC (2016) ed.20

(Source: Pasolon and Ariffin, 2021).

to meet plant's requirement at early stage. This organic F-22 also containing higher amount of micronutrients e.g. Fe-total, Zn, Cu and Mn: 4210.5, 182.60, and 389.75 ppm.

2. *The Effect Organic F-22 on Growing of Rice*

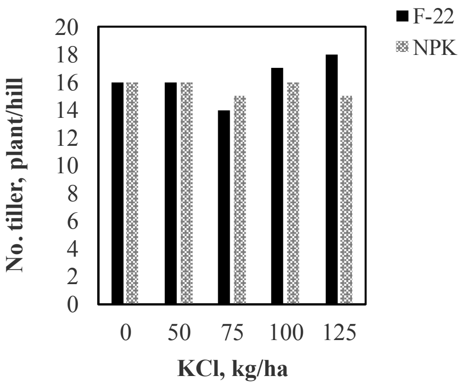

Fig.1. Effect of F-22 organic and NPK-15-15-15 application on tiller number at 22 DAT.

There are several variables of rice growing was observed in this experiment: Tiller number, SPAD values, grain production and percentage of full grain as shown in Fig.1., Fig.2., Fig.3 and Fig.4.

Organic fertilizer F-22 application tend to show the increase of tiller number with the increase of organic fertilizer level, however, in the low level there was no different effect of F-22 and NPK fertilizer as shown in Fig.1. Such possibility that mixing of F-22 fertilizer with urea was adsorbed by F-22 and release slowly in early stage of rice growing stage, however, increased of F-22 rate was increase capacity to release adsorbed nutrients.

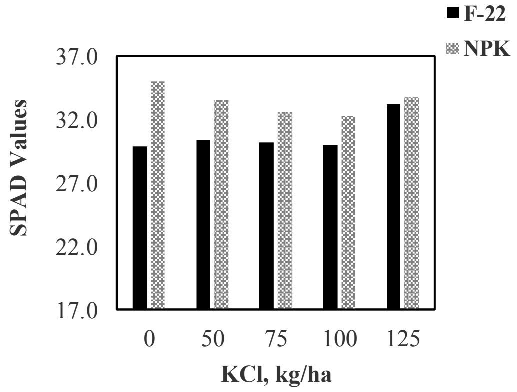

Fig.2. Effect of F-22 organic and NPK-15-15-15 on SPAD values at 22 days after transplanting.

Fig.2 shown that SPAD values in early stage was higher in NPK application than F-22. The higher of SPAD values in NPK treatments indicated that N release from NPK-15-15-15 sources was faster than from F-22 organic fertilizer. This phenomenon may relate to the increase of chlorophyll content in NPK treatment as one indicator that N content was higher in plant as explained by Tisdale et al. (1993). They also expected that, N mineralization from organic material need for 2 to 3 months from application. This process accelerated by warm and humid conditions as in rainfed soil.

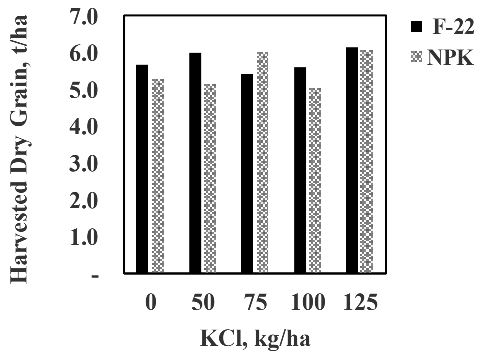

Fig.3. Effect of F-22 organic and NPK-15-15-15 on harvested dry grain.

The data showed that the increase of organic application tend to induce tiller number at 22 DAT (Fig.1) and chlorophyll content at 22 and 64 DAT (Fig.2). Higher of harvested dry grain was produced at 331 kg/ha of F-22 as shown in Fig. 3. How ever, grain quality as indicated by percentage of full grain was increased by NPK application as shown in Fig. 4. This phenomenon shown that F-22 and NPK applications was produced positive effect on rice grain quality.

The residue of P and K at harvest stage increased as the increase of F-22 application. However, C-organic and N-total was lower as shown in Table 3. This data showed that F-22 application was remarkably improved P and K content in soil medium, N was reduced to very low and lower level.

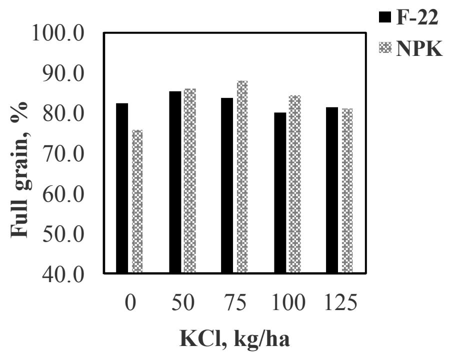

Fig. 4. Effect of F-22 organic and NPK-15-15-5 application on percentage of full ripened grain.

Tabel 3. Soil chemical properties after harvest.

F-22, kg/ha	pH-H_2O	C-org. (%)	N-tot. (%)	P_2O_5 (ppm)	Exch.K_2O (me/100 g)
132	5.46	0.16	0.12	24.34	0.68
265	5.58	0.48	0.14	26.75	0.78
331	5.73	0.58	0.15	31.42	0.82

(Source: Sholeha, 2023).

C-organic content was very low level in soil medium after harvest season, however, F-22 application at 265.0 and 331 kg/ha was increased C-organic three times than 132 kg/ha.

Discussion

Generally, that rice growing in this soil was shown nutrient deficient as indicated by reddish at leaf tip, lower tiller and panicle numbers which implicated to lower grain production. These phenomena indicate that this soil categorized as marginal rainfed land. The lower of N and C-organic may be due to N volatilization and C mineralization during the dry season. From this data (Table 3) indicate that N level during plantation should be taking care by N top-dressing at tillering, panicle initiation, and heading stage.

Soil texture in this experimental was silty loam (Syah, 2022). This texture was dominated by silt fraction which has low capacity for nutrient adsorbing at complex adsorption, therefore, organic treatment is one strategy in improved nutrient level at silty loam texture.

P_2O_5 available prior to treatment was low as shown in Table 1, however, after harvest season P_2O_5 residue in rice field was increased 4 to 6 times as shown in Table 3. The same tendency was shown by exchangeable K_2O after season as shown in Table 3. In case of K, this parallel with higher K content in F-22 as shown in Table 2.

Based on the above results, we can explain that organic treatment in this experiment, where nutrient level was standardized on K_2O-total content in organic fertilizer (F-22) may not accurate. Therefore, in another experiment we change nutrient standardization based on P_2O_5 level (data not shown). Nutrients application level should be calculate based on the lower content as explained by concept of Liebig's "Low of the Minimum" (Morris et al., 2007) especially in long term organic management in marginal land.

Use of organic fertilizer from Palm Oil by-product, may economic profitable and environmentally friendly. Potential of ESD organic by-product from CPO extraction in Indonesian palm oil plantation was predicted around 52 million t per year, which equivalent to 55.30 million t of F-22 per year. Based on N, P and K content in F-22 (Table 2), this potential may equivalent to Urea, SP-36 and KCl: 3.533, 1.105 and 20.094 million t/year, respectively. This potential was much higher than Indonesian total fertilizers import 6.249 million t per year in 2020 (BPS, 2022).

Conclusions

Based the above results we concluded that formula F-22 fermented from palm oil by-product have shown no significantly different with NPK-15-15-15 on rice grown, which indicated that F-22 formula may suitable for long-term nutrient management in marginal land.

Acknowledgement.

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References

BPS-Statistics Indonesia 2022 Statistical yearbook of Indonesia. Direktorat Diseminasi Statistik (Ed.) Badan Pusat Statistik ISSN: 0126-2912. (Jakarta) pp. 779. (in Indonesia).

Direktorat Statistik Tanaman Pangan, Hortikulturan dan Perkebaunan 2022 Direktori perusahaan perkebunan kelapa sawit Indonesia 2021. Badan Pusat Statistik. ISSN; 2301-6817. (Jakarta) pp. 434. (in Indonesia).

Hoshikawa, K. 1989 The Growing Rice Plant. *In*: An Anatomical Monograph. Nosan Gyosan Bunka Kyokai (Tokyo) pp. 305.

Morris, S.J. and C.B. Blackwood 2007 The Ecology of Soil. *In*: Soil Micro Biology, Ecology and Biochemistry (Third Edition). www. sciencedirect.com. Online Cit. 5 July 2023.

Pasolon, Y.B. and B. Ariffin 2021 Optimalization production of rice in rainfed with organic basis in South-East Sulawesi Province. Matching Fund Report, Halu Oleo University (Kendari) pp.170. (in Indonesia)

Pasolon, Y.B. 2022 Production and use of organic potassium recycling from palm oil waste in South Konawe Prefecture Southeast Sulawesi Province. Matching Fund Report. Halu Oleo University (Kendari) pp. 170. (in Indonesia)

Puput, S.I. 2023 The Effect of palm oil organic waste application on soil chemical properties and growth of rice in rainfed. Graduation Thesis, Soil Science Department, Faculty of Agriculture, Halu Oleo University (Kendari). pp.54. (in Indonesia)

Sulaeman, Suparto and Eviati 2005 Petunjuk teknis, analisis kimia tanah, tanaman, air dan pupuk. Balai Penelitian Tanah. e-mail: soil-RI@indo.net.id, Bogor pp. 136. (in Indonesia).

Syah, A. M. 2022 Soil fertility evaluation in rainfed of Pombulaa Jaya Villages. Graduation Thesis, Soil Science Department, Faculty of Agriculture, Halu Oleo University (Kendari) pp. 45. (in Indonesia)

Tisdale, S.L, W.L. Nelson, J.D. Beaton and J.L. Havlin 1993 Soil fertility and fertilizers. 5th Edition. Maxwell Macmillan Canada (Ontario) pp. 613.