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Analysis of sago starch (*Metroxylon sagu*) quality from various cultivars in the Yapen Islands, Papua, Indonesia

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Abstract. *Moeljono S, Gunawan E, Husodo SB, Nugroho JD, Mofu WY, Tampang A, Beljai M, Sadsoeitoeboen BMG, Kesaulija FF, Mahmud, Iwanggin MP, Simbiak VI, Tasik S, Worabai MS, Padang DA, Yogaswara R. 2025. Analysis of sago starch (*Metroxylon sagu*) quality from various cultivars in the Yapen Islands, Papua, Indonesia. Biodiversitas 26: 2717-2725.* Sago (*Metroxylon sagu*) is a palm plant that produces carbohydrates and possesses significant potential to support food security and industry in the Yapen Islands District, Papua. This study aimed to analyze the quality of sago starch from the various cultivars that thrive in the region. A quantitative method using a survey research design was applied, with sampling conducted in the Eastern and Western Yapen Sub-Clusters from January to March 2024. The physicochemical analysis of sago starch was carried out at the Forest Products Technology Laboratory of the University of Papua. The results indicate a diversity of sago cultivars in both areas, with the Woru and Noyn cultivars dominating Western Yapen, and Kurai and Amiri in Eastern Yapen. The starch yield varied significantly between cultivars, with the Noyn (630 kg/tree) and Huworu (264 kg/tree) cultivars recording the highest production. The physicochemical characteristics revealed a variation in moisture content (1.66-4.78%), fineness (88.98-95.12%), ash content (0.91-1.39%), and degree of acidity (1.3-5.7). The Kurai, Huworu, and Woru cultivars exhibited superior characteristics for food industry applications, while Makubong and Dami showed potential for non-food applications. The development of sago agro-business in the Yapen Islands District necessitates the selection of appropriate cultivars and the strengthening of post-harvest management systems to optimize both economic and ecological value.

Keywords: Cultivars, *Metroxylon sagu*, quality evaluation, sago starch, sustainable development

INTRODUCTION

The island of Papua is endowed with remarkable biodiversity and is recognized as a megadiversity region (Kavitha et al. 2023). Among the various natural riches it possesses, sago (*Metroxylon sagu* Rottb) holds a significant position in the social, economic, and cultural aspects of Papuan society. Indonesia has a sago forest area covering 1,398,000 hectares, with 86%, or approximately 1,200,000 hectares, located in Papua (Fetriyuna et al. 2025). The extensive potential of natural resources remains underutilized.

Sago is a palm plant that possesses the highest starch productivity among other carbohydrate-producing crops. Each mature sago trunk can yield between 200-400 kg of dry starch, with productivity reaching up to 25 tons per hectare per year (Masluki et al. 2024). The ability of sago to thrive in marginal lands such as swamps and peatlands positions it as a crop with significant potential to support future food and energy security. Furthermore, sago offers various ecological advantages, including its capacity for carbon sequestration, maintenance of swamp ecosystem stability, and minimization of soil erosion (Wulanningtyas et al. 2020).

Sago starch possesses unique characteristics that render it suitable for various applications. The composition of amylose and amylopectin in sago starch varies according to cultivar, which in turn determines its physicochemical and functional properties. Recent research indicates that sago starch can be utilized as a raw material for the production of bioplastics, biosorbents, and enzymes (Tan et al. 2022). Furthermore, sago starch has the potential to be developed into functional food products with a low glycemic index, which could be beneficial for individuals with diabetes (Lokman et al. 2023).

The Yapen Islands District is one of the regions with a significant distribution of sago in Papua Province. Despite its considerable potential, the utilization of sago in this area remains limited to local consumption and has yet to be developed on an industrial scale. The primary challenge in the development of the sago industry in the Yapen Islands District is the lack of scientific data regarding the quality of sago starch from various cultivars that grow in the region. According to (Chairul et al. 2023), the variation among sago cultivars results in differing starch characteristics, which in turn affect processing applications and their economic value.

Several prior studies have been conducted regarding the characteristics of sago starch from various regions in Indonesia. Kiptiyah et al. (2024) discovered that the local sago cultivar has a high amylose content, which is beneficial to the bioplastics industry. Meanwhile, Kadir et al. (2022) investigated the functional properties of sago starch from West Papua and identified its potential as a stabilizing agent in food products. However, research specifically analyzing the quality of sago starch from cultivar variations in Yapen Islands District remains significantly limited (Putra et al. 2024).

The genetic variation among sago cultivars can influence the chemical composition and functional properties of the starch produced. Research conducted by (Han et al. 2023) reveals that different sago cultivars exhibit varying amylose-amylopectin ratios, which significantly affect viscosity, thermal stability, and textural properties of the starch. The importance of characterizing sago starch based on cultivar is underscored in order to determine appropriate industrial applications, such as in food products, bioethanol, or bioplastics.

The East Yapen Sub-clustering, particularly the Randawaya area, has been identified as a zone for the development of sago agribusiness in Yapen Islands District. To optimize the development of the sago industry in this region, it is essential to acquire scientific data regarding the quality of sago starch from various existing cultivars (Novarianto 2023). This information will be beneficial in determining management and processing strategies that are appropriate to the characteristics of local cultivars.

Based on the aforementioned exposition, this research aimed to analyze the quality of sago starch (*M. sagu*) from various cultivars grown in Yapen Islands District, Papua. The study will focus on the analysis of the physicochemical and functional properties of sago starch, including amylose-amylopectin content, viscosity, swelling capacity, and thermal properties. The findings of this research are expected to provide valuable scientific information for the development of the sago industry in Yapen Islands District, whilst also supporting efforts towards the conservation and sustainable utilization of sago resources in Papua.

MATERIALS AND METHODS

This research employs a quantitative approach with a survey research design to analyze the quality of sago starch (*Metroxylon sagu*) from various cultivars in Yapen Islands District, Papua Province, Indonesia (Figure 1). This method was chosen to obtain representative data regarding the physicochemical characteristics of sago starch from different cultivars growing in the region. Both macroclimate and microclimate temperature and humidity under the stand affect plant growth and development. The average macro air temperature in Yapen Islands District for 10 years has been 27.6°C to 8.3°C, with 79.6-84.1% humidity. This data indicates that Yapen Islands District has more green space than open space and is well maintained. The macroclimate in the Yapen Islands District is generally stable with relatively low volatility of rainfall. This is due to the existence of rainforest with dense tree cover in steep mountainous and lowland areas of the Yapen District, which is still under protection, and the relatively small area of open land with permanent settlements and seasonal farming, which is overgrown with vegetation, i.e. 155.92 km^2 (15,591.87 ha), or 6.41 of the total area.

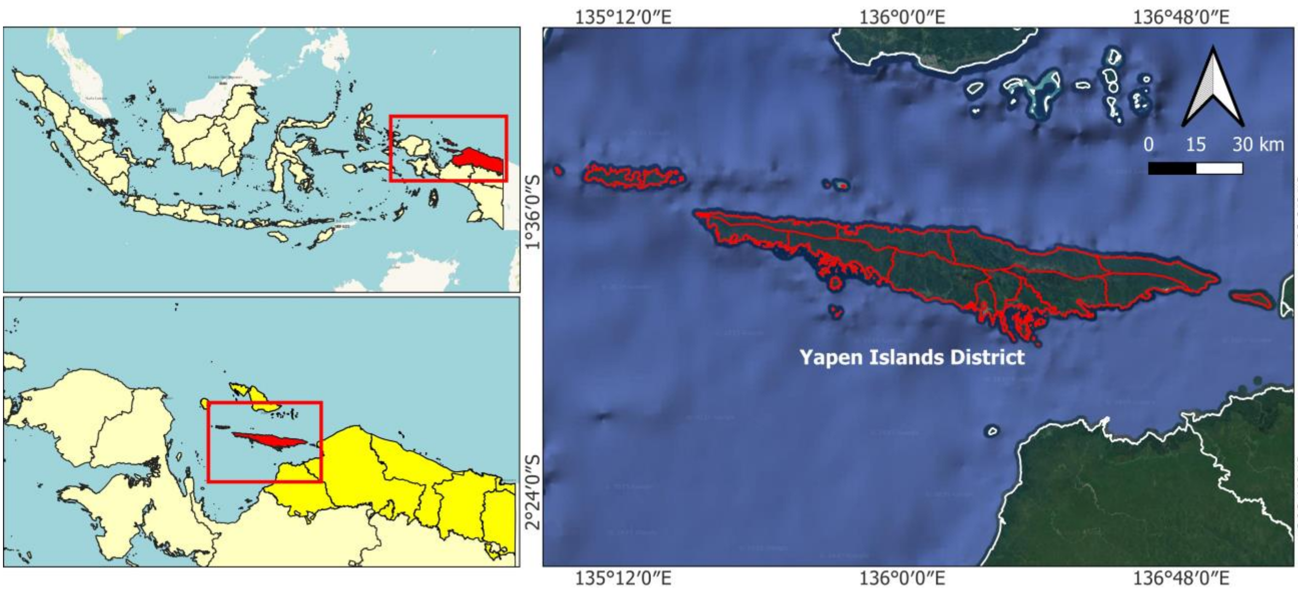

Figure 1. Location of sub-district areas in Yapen Islands District, Papua, Indonesia

Moreover, the protected area of 1,250.14 km^2 (51.39% of the total area) comprising nature reserves and protected forests is still in good condition and plays an important role in promoting the sustainability of natural forest functions. Based on the soil classification system, the types of soil in the Yapen Islands District include Entisol, Inceptisol, Alfisol, Ultisol and Oxisol. The geological structure in the Yapen Islands region varies greatly due to the distribution of diverse parent rock materials and varied geological formations. The land area of the Yapen Islands District is around 2,432.49 km^2 with geological forms of alluvium, volcano, Rosbori Volcano, Wurui Limestone, Sumboi Napal Stone, Jobi Ophiolite Breccia, Kurudu Formation, Alluvium Fan, Ansus Conglomerate, uplifted coral reef and Ambai Formation.

Timing and location of the research

The research was conducted in the sago hamlet area of Yapen Islands District, Papua, specifically in the East Yapen Sub-cluster, which encompasses the Randawaya region. Sampling was carried out from January to March 2024. The physical and chemical analysis of sago starch was performed at the Forest Product Technology Laboratory (THH) of the Faculty of Forestry, University of Papua.

Administratively, Yapen Islands District consists of 12 sub-districts, 5 urban villages, and 106 villages. The locations of the sub-districts within the district are depicted in Figure 1. The majority of the sub-districts and villages are situated along the coastal areas. There are 6 sub-districts with a marine area proportion exceeding 60%, namely Angkaisera Sub-district, Ambai Islands Sub-district, West Yapen Sub-district, Poom Sub-district, and Wonawa Sub-district, all of which are located in the western part of Yapen Island, alongside Raimbawi Sub-district in the eastern part of the island. Angkaisera Sub-district is the only district with the highest proportion of land area, accounting for 86.67% of its total area, whereas the other districts maintain a relatively balanced proportion of land and marine areas.

Research procedures

Data sources

The data utilized in this study comprises both primary and secondary data. Primary data were obtained through direct observation of the physical and chemical characteristics of sago starch from various cultivars sampled at the research site. Secondary data include information regarding the area of the sago hamlet, which was sourced from the Forest Area Consolidation Center (BPKH) of Papua Province in 2022, as well as supplementary information from relevant reports and literature.

Data collection techniques

Determination of observation plots

The determination of observation plots was conducted based on the sago area map from the Papua Province BPKH (Dimara and Auri 2023; Dimara et al. 2023), which indicates that the area of sago potentially found in East Yapen is 6,849 hectares. The sampling intensity employed is 2.5%, with a plot observation unit ratio of 1:40 hectares of sago area. The sampling method used is systematic random sampling for regions of sago with extensive coverage, and random sampling for areas of sago that are dispersed in groups with smaller areas. Observation plots measuring 2 × 0.5 hectares (1 hectare) are positioned on the left and right sides of the transect line-oriented East-West or North-South.

Sample tree selection

The selection of sample trees was carried out purposively, taking into account the growth stage of sago palms that have reached the harvestable phase, as indicated by the emergence of flowers at the tips of the stems. The criteria for selecting sample trees refer to the research conducted by Senewe et al. (2021), which describes the morphological characteristics of sago trees at the harvestable stage.

Sago trees are cut into three trunk pieces: base, middle, and tip. The pith section is sampled from the part near the bark (4 cubes in the cardinal directions) and the center of the trunk (1 cube), each 10 cm × 10 cm × 10 cm. Each tree has 15 test samples: 3 (trunk section) × 5 (horizontal direction). Weigh the fresh pith sample, crush it with a grater, add water, and squeeze it with a cloth filter. Precipitating Water-Soluble Polysaccharide (WSP) yields sago starch. Wet sago pulp and starch are weighed. Drying the starch and sago pulp separately until stable and weighing them. Lab samples are dried in a dryer to below 30% water. In paper envelopes, the samples are dried at 50°C (Figure 2).

Figure 2. Illustration of preparing sago stem plates as samples

Sago trunk sampling

For each selected sago palm, three stem discs (comprising the base, middle, and tip) were extracted in accordance with the method developed by Bocobo et al. (2022). From each stem disc, five positions of pith were sampled for testing purposes: the area near the bark (four cubes oriented according to the cardinal directions) and the central area of the stem (one cube), with each cube measuring 10 cm × 10 cm × 10 cm. Thus, the total number of test samples for each tree amounts to 15 samples (3 stem sections × 5 horizontal directions).

Data analysis techniques

Sago starch extraction

The extraction of sago starch was conducted following the method developed by Rahim et al. (2022). The parenchyma of the test sample was weighed in its fresh state and subsequently crushed using a grater. Water was then added and the mixture was strained through a cloth to separate the starch from the residue. The water containing the sago starch (Water-Soluble Polysaccharide (WSP)) was allowed to settle until the sago starch was obtained. Both the starch and the sago residue were weighed in their wet state and then dried separately using a dryer until a constant weight was achieved for the determination of yield.

Physical analysis of sago starch

The physical analysis of sago starch encompasses the determination of yield, moisture content, fiber content, and impurities, as well as the particle size of the starch. The yield is calculated based on the ratio of the final weight to the initial weight, multiplied by 100%. The moisture content is determined using the oven drying method at a temperature of 105°C until a constant weight is achieved. The fiber content and impurities are analyzed using a filtration method with a 150-mesh sieve. The particle size of the starch is determined through sieving with an 80-mesh sieve.

Analysis of amylose and amylopectin content

The determination of amylose and amylopectin content was conducted using spectrophotometric methods as developed by Zailani et al. (2023). The amylose content was determined based on the formation of an amylose-iodine complex, which produces a blue color, the intensity of which is measured at a wavelength of 625 nm. The amylopectin content is calculated as the difference between the total starch content and the amylose content.

Analysis of functional properties of sago starch

The functional properties of sago starch that were analyzed include swelling capacity, solubility, and viscosity. The swelling capacity and solubility were measured by modifying the method developed by Ghalambor et al. (2022). The viscosity of the starch was assessed using a Rapid Visco Analyzer (RVA) to determine the pasting properties of sago starch from various cultivars.

Statistical analysis

The data obtained was analyzed using Analysis of Variance (ANOVA) to compare the quality of sago starch among cultivars. If significant differences were identified, Duncan's Multiple Range Test (DMRT) was subsequently conducted at a significance level of 5%. Pearson correlation analysis was also performed to ascertain the relationship between the physical and chemical characteristics of sago starch and its functional properties. All statistical analyses were conducted using IBM SPSS Statistics version 26, in accordance with the methods outlined by Wagner (2019).

The quality data of sago starch obtained was subsequently compared with the quality standards for starch required by the industry. The research findings are expected to provide scientific information regarding the characteristics of sago starch from various cultivars grown in Yapen Islands District, thereby serving as a foundational basis for the development of the sago industry in the region.

RESULTS AND DISCUSSION

Composition and diversity of sago cultivars

The Yapen Islands District, Indonesia exhibits a high diversity of sago cultivars, which are distributed across various natural sago villages (DSA) and cultivated sago villages (DST). This diversity reflects the ecological adaptations and traditional cultivation practices of the Papuan community. Table 1 illustrates that the dominance of the Woru and Noyn cultivars demonstrates superior production performance and starch quality, which are favored by the local community. The morphology of some Sago cultivars from Yapen Islands District are shown in Figure 3.

Sago structure and stand

Table 2 presents that a balanced structure of the sago stands, consisting of young shoots, potential trunks, and mature harvestable trees (PMT), is crucial for maintaining production continuity.

Starch production potential based on cultivar

The yield analysis demonstrates significant variation among cultivars, with Noyn and Woru occupying the highest positions (Table 3).

The results of physical and chemical analysis of sago starch

The results of the laboratory tests indicate variation in moisture content, ash content, fineness, fiber, and impurities among the observation blocks in East and West Yapen (Table 4).

Yield analysis in Marau and Wooi-Woinap regions

Table 5 indicates that the Marau region exhibits the highest yield for the Hawa cultivar (30.89%), while Table 6 shows that the Huworu and Noing cultivars demonstrate high productivity in Wooi-Woinap.

Table 1. Composition and number of sago clumps/cultivars in Papuma sago farming hamlet, Yapen Islands District, Indonesia

Variables	Sago cultivars							
	Woru	Anta	Noyn	Ami	Awa	Asina	Makubong	Awanyari
Number of clumps/Ha	5	2	36	1	3	(0.6)	(0.3)	(0.1)
Total number of sago clumps	1.312	525	9.443	262	787	157	79	26

Table 2. Sago clump structure in Papuma sago plantation hamlet, Yapen Islands District, Indonesia

Study plot (1 Ha)	Number of clumps	Sago shoots		Sago tree		
		Young shoots	Trunk candidate	BMT*)	MT*)	LMT*)
1	52	3.135	380	127	17	2
2	51	3.233	336	146	22	5
3	41	2.796	226	71	116	4
4	41	4.024	373	56	40	5
5	37	4.620	597	127	45	1
6	56	1.197	332	51	15	4
Average/Ha	46	3.168	374	96	43	4

Note: *): Not Ripe Cut (BMT), Ripe Cut (MT), and Past Ripe Cut (LMT)

Table 3. Sago starch yield of each cultivar in Papuma, Yapen Islands District, Indonesia

Cultivars	Wet starch yield (%)	Air-dried starch yield (%)	Wet starch weight/tree (Kg)	Dry starch weight/tree (Kg)	One way ANOVA (*p*-value <0.05)
Ami	34 ± 1.7	34 ± 1.7	339	331	0.00001
Anta	40 ± 2.0	40 ± 2.0	169	165	
Asina	17 ± 0.9	17 ± 0.9	167	164	
Awa	28 ± 1.4	28 ± 1.4	514	515	
Noyn	29 ± 1.5	28 ± 1.4	649	630	
Woru	30 ± 1.5	29 ± 1.5	602	589	
Average	29.67 ± 7.23	29.33 ± 6.83			

Table 4. The physical and chemical properties of sago starch in the Wanampompi Block, Yapen Islands District, Indonesia

Cultivars	Physical properties of starch				Chemical properties of starch	
	Water content (%)	Color	Fineness (80 mesh passing grade) (%)	Fiber and impurity content (%)	Ash content (%)	Degree of acidity
Amiri	2.09	Light gray	93.50	5.07	1.12	2.3
Awui	-	-	-	-	-	-
Barari	2.63	White	92.59	6.07	1.23	2.8
Kurai	4.78	Light gray	95.12	3.65	1.39	1.3
Pampuma	4.53	Light gray	88.98	8.83	0.91	5.7
Wewa	1.66	White	94.23	4.17	1.21	1.6

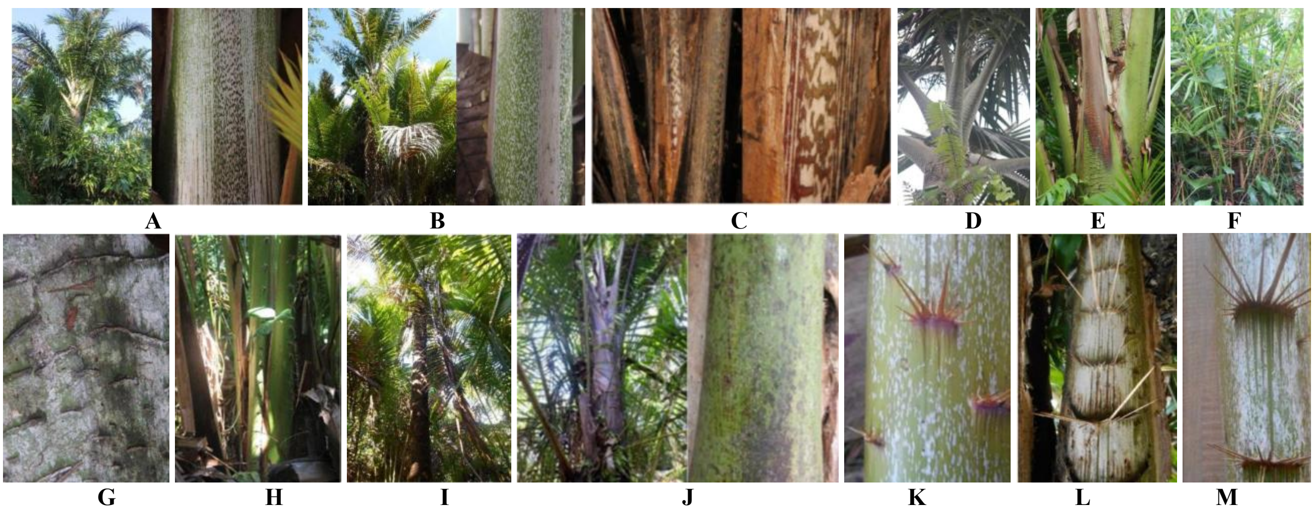

Figure 3. Morphological of Sago cultivars in Yapen Islands District, Indonesia includes: A. Anta; B. Ami; C. Woru; D. Nyon; E. Awa; F. Asina; G. Makibong; H. Awanyari; I. Awui; J. Barari; K. Kurai; L. Pampuma; and M. Wewa

Table 5. Average dry starch yield of six cultivars in Marau, Yapen Islands District, Indonesia

Cultivars	Length of the stem (m)	Trunk section	Disc pith weight (Kg)	Disc skin weight (Kg)	Total disc weight (Kg)	Dry field starch (Kg)	Field dry starch yield (%)	Average yield (%)
Hawa	11.9	Base	16.05	6.45	22.50	0.300	28.38	30.89 ± 2.41
		Tip	18.50	3.50	22.00	0.398	31.09	
		Middle	21.50	6.50	28.00	0.316	33.19	
Huworu	12.6	Base	14.50	7.50	22.00	0.326	25.65	23.98 ± 1.48
		Tip	21.00	6.00	27.00	0.385	22.85	
		Middle	17.25	6.25	23.50	0.395	23.44	
Noyn	13.1	Base	10.00	6.50	16.50	0.154	14.43	22.75 ± 7.62
		Tip	9.50	2.50	12.00	0.231	24.44	
		Middle	21.50	6.00	27.50	0.355	29.39	
Anta	4.3	Base	13.50	5.50	19.0	0.375	22.73	28.47 ± 6.30
		Tip	6.75	3.00	9.75	0.244	35.21	
		Middle	9.25	4.00	13.25	0.501	27.47	
Ami	10.2	Base	10.00	5.00	15.00	0.188	20.89	25.88 ± 6.09
		Tip	15.00	3.50	18.50	0.279	24.09	
		Middle	11.50	4.50	16.00	0.375	32.67	
Makubong	12.0	Base	7.75	5.25	13.00	0.131	19.55	19.54 ± 3.62
		Tip	12.00	3.00	15.00	0.179	15.91	
		Middle	18.00	7.00	25.00	0.276	23.15	

Table 6. Dry starch production in Wooi-Woinap, Yapen Islands District, Indonesia

Cultivars	Total PMT of all hamlets (trees)	Dry starch weight/tree (Kg)	Dry starch production (Kg)
Anandong	1	-	-
Ananrong	2	-	-
Anta	3	179.24	537.73
Hawa	17	156.81	2,665.85
Huworu	123	264.47	32,529.65
Kuroi	0	114.56	0
Makubong	0	-	0
Noing	20	272.58	5,451.69
Yerirang	1	7.78	7.78
Amount	167		41,192.70
Average per hectare	41.75		10,298.17

Table 7. Pearson correlation matrix of six parameters in Marau, Yapen Islands District, Indonesia

Parameter	Disc pith weight (Kg)	Disc skin weight (Kg)	Total disc weight (Kg)	Dry field starch (Kg)	Field dry starch yield (%)	Length of stem (m)
Disc pith weight (Kg)	1	0.35	0.85	0.3	-0.11	0.29
Disc skin weight (Kg)	0.35	1	0.76	0.14	-0.44	0.36
Total disc weight (Kg)	0.85	0.76	1	0.31	-0.32	0.41
Dry field starch (Kg)	0.3	0.14	0.31	1	0.31	-0.26
Field dry starch yield (%)	-0.11	-0.44	-0.32	0.31	1	-0.2
Length of stem (m)	0.29	0.36	0.41	-0.26	-0.2	1

Discussion

Cultivar diversity as a local genetic capital

The diversity of sago cultivars found in Yapen Islands District, such as Woru, Noyn, Kurai, Amiri, and Huworu, indicates that this region harbors a potentially rich gene pool. This genetic variation is crucial in addressing environmental challenges and optimizing production. The study conducted by Dimara et al. (2023) reinforces the notion that cultivar diversity in *Metroxylon sagu* plays a vital role in the adaptation of local ecosystems and resistance to diseases.

The dominant distribution of the Woru and Noyn cultivars in West Yapen, as well as Kurai and Amiri in East Yapen, indicates an adaptation to the local agroecological conditions and a community preference for sago varieties characterized by high productivity and starch quality (Sulaiman et al. 2023). This variation ecologically reinforces the carrying capacity of the local agroforestry system and supports the concept of sustainable agriculture grounded in local wisdom (Rusli et al. 2022).

Structure of the stand and its implications for productivity

The data on the stand structure of sago in various villages reveal significant variation in clump density and plant age composition. The low number of mature plants (PMT) and the dominance of young shoots (BMT) indicate a suboptimal planting pattern and a lack of adequate regeneration maintenance practices. An imbalanced stand structure may reduce energy conversion efficiency and adversely affect the quality of the pith as a raw material for starch extraction.

Observations in Papuma and Wanampompi reveal an average clump density of 46 clumps per hectare and high regeneration rates (>3000 shoots per hectare); however, the frequency of harvesting mature plants (PMT) is very low. This confirms the findings of Soplanit et al. (2021), which emphasize that the imbalance in growth phases directly impacts productivity cycles and leads to inefficiencies in the management of sago villages.

Starch production potential and yield efficiency

The yield rates and dry starch weights of various cultivars show substantial variation, with the Noyn and Huworu cultivars recording the highest results in their respective regions. Data from Tables 3 and 5 indicate that Noyn is capable of producing up to 630 kg of dry starch per tree, while Huworu records a production of over 260 kg per tree. This efficiency is closely related to the stem size, pith density, and morphology of the starch storage tissues.

Research indicates that higher levels of amylopectin and greater pith density correspond to an increased capacity for energy storage in the starch within the stem. The Noyn and Huworu cultivars tend to have larger stems and thicker piths, which supports this theory. Furthermore, the rate of starch accumulation is also influenced by the harvest age and the ratio of photosynthates allocated to the main stem.

Nevertheless, several cultivars, such as Pampuma and Anare, exhibit high acidity levels (pH>5) and excessive moisture content (>20%), which pose a risk of reducing quality during storage and accelerating natural fermentation. This is consistent with findings by Kavitha et al. (2022), who reported that moisture content exceeding 15% in tropical starch increases the risk of microbial contamination and amylose degradation.

Correlations with sago quality indicators

Dry field starch (Kg) (absolute starch amount) shows a weak positive correlation with Disc Pith Weight (Kg) (r = 0.30) and total disc weight (Kg) (r = 0.31). This suggests that discs with heavier pith and overall greater weight tend to yield slightly more starch in absolute terms. It has a very weak positive correlation with disc skin weight (Kg) (r = 0.14). Interestingly, it exhibits a weak positive correlation with field dry starch yield (%) (r = 0.31). This implies that sections yielding more starch in kilograms also tend to have a somewhat higher percentage of starch. It also shows a weak negative correlation with length of stem (m) (r = -0.26), suggesting that sections from longer stems might yield slightly less dry starch in absolute terms, though this relationship is not strong at the section level.

Field dry starch yield (%) (starch concentration) shows a weak positive correlation with dry field starch (Kg) (r = 0.31), as mentioned above. It shows a weak negative correlation with total disc weight (Kg) (r = -0.32) and a very weak negative correlation with disc pith weight (Kg) (r = -0.11). Negative correlation was found in length of stem (m) (r = -0.20). This indicates a slight tendency for sections from longer stems to have a lower starch percentage. This exhibits a moderate negative correlation with disc skin weight (Kg) (r = -0.44), and noteworthy finding, suggesting that a heavier disc skin (relative to other factors) is associated with a lower percentage of starch yield. This could imply that a higher proportion of skin might reduce the overall starch concentration.

Disc pith weight (kg) and total disc weight (Kg) have a strong positive correlation (r = 0.85). This is expected, as pith weight is a major component of the total disc weight. Disc skin weight (Kg) and total disc weight (Kg) also show a strong positive correlation (r = 0.76), as skin weight also contributes significantly to the total weight. Length of stem (m) shows weak to moderate positive correlations with disc pith weight (r = 0.29), disc skin weight (r = 0.36), and total disc weight (r = 0.41) at the section level. This suggests that longer stems tend to have heavier disc sections overall.

The correlation analysis provides initial insights into the relationships between various parameters and sago quality indicators based on the provided dataset. Parameters like disc pith weight and total disc weight appear to be positively associated with the quantity of starch. Disc skin weight shows a negative association with starch concentration, suggesting it might be an important factor to consider for sago quality. The length of the stem showed some negative trends with yield, but these were not very strong and warrant further investigation.

The physical and chemical analysis as industrial indicators

Physical and chemical parameters such as ash content, fiber, and fineness play a crucial role in determining the suitability of sago starch for industrial applications. A study by Sumardiono et al. (2021) indicates that starch with a fineness greater than 90%, ash content below 1%, and fiber content below 0.5% is ideal for the production of noodles, gluten-free bread, and pharmaceutical excipients. In this research, only a few cultivars, such as Kurai and Widoi, consistently meet these parameters.

The high ash content (>2%) in the Makubong and Dami cultivars is a particular concern, as excess ash in starch can lower the gelatinization point and increase the risk of browning reactions during heating, according to Haryanti et al. (2014). Therefore, these cultivars should not be prioritized for food products; however, they may be explored for technical applications such as bioplastics.

Based on a color perspective, sago starch that is white or light grey (such as that from the Amiri, Kurai, and Widoi cultivars) is aesthetically preferred and indicates a higher level of purity. This adds value to the food industry, which prioritizes product visualization.

Industry implications and development recommendations

The high production of sago starch in Wooi-Woinap (41 tonnes dry per year) and the robust regenerative structure in Wanampompi present significant opportunities for the development of sago agribusiness. Sago starch from local varieties can be developed into bioethanol, bioplastics, and even as carrier material for probiotics in functional products (Kartika et al. 2024).

However, the selection of appropriate cultivars is of paramount importance. Cultivars such as Kurai, Huworu, and Woru may be prioritized for the food industry, while cultivars with moderate yields but unique chemical characteristics (such as Dami or Makubong) can be directed towards non-food industries. This aligns with the strategy of diversifying industries based on local commodities. In addition, strengthening local institutions, providing training in post-harvest processing, and conducting agroclimatic mapping are essential steps in supporting the sago value chain. The successful development of the sago industry in Eastern Indonesia must be accompanied by an efficient logistics and trading system.

In conclusion, research on the quality of sago starch from various cultivars in Yapen Islands District has yielded several important findings that have implications for the development of the sago industry in the region. Yapen Islands District boasts a high diversity of sago cultivars with differing physicochemical characteristics, reflecting a rich gene pool and the ecological adaptation of plants to local conditions. Based on the analysis results, there are significant differences in production potential among cultivars, with Noyn and Huworu demonstrating the highest productivity at 630 kg per tree and 264 kg per tree of dry starch, respectively. The stand structure of sago in various villages exhibits high regeneration rates, with an average of 3,168 young shoots per hectare; however, the number of mature trees is relatively low (43 trees per hectare), indicating suboptimal management. The physicochemical characteristics of starch vary among cultivars, with important parameters such as moisture content (1.66-4.78%), fineness (88.98-95.12%), and ash content (0.91-1.39%) determining its suitability for industrial applications. Cultivars Kurai, Woru, and Huworu possess starch qualities that are suitable for the food industry, while cultivars with high ash content, such as Makubong, are more promising for non-food applications such as bioplastics. The total production of sago starch in the Wooi-Woinap area reaches 41 tons dry per year, demonstrating substantial economic potential if managed sustainably. The development of further research is also necessary to explore the potential modification of sago starch for various industrial applications, as well as to conduct in-depth analyses of the nutritional content and bioactive compounds of different sago cultivars in Yapen Islands District.

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