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Development of Arrowroot (*Maranta arundinacea* L.) as Functional Food Based of Local Resource

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Abstract. The development of functional food is one of the government's programs to improve food security in Indonesia. Increasing cases of degenerative diseases such as obesity, diabetes, hypertension, and cancer have triggered people to look for functional food ingredients, especially local resource-based food sources in each region to explore the benefits and nutritional content of health. Arrowroot (*Maranta arundinacea* L.) is an alternative crop-source of carbohydrate with enormous potential to be developed. Flour products from arrowroot plant have special features, which are easy to digest because the content of the glycemic index (IG) is low so it is very good for health. This plant is generally propagated by vegetation, so it has a narrow genetic diversity. Various efforts have been made to improve the genetic diversity of arrowroot plants, in order to obtain superior types of arrowroot plants with high productivity. This study aims to understand and explore the primacy of arrowroot plants from the benefits, origin, spread, multiplication, and utilization of plants by the community. Based on the results of this study we have not discovered any superior arrowroot plant model with high productivity and wide genetic diversity.

1. Introduction

The food diversification program that was launched by the Indonesian government in 1980 has been closely associated with a national food security program. It has been a concern that Indonesia's dependence on rice as a staple food will have to be managed since Indonesia is abundant with carbohydrate-rich products [1]. This condition is caused by rapid annual increase of population with the rice production keeps lagging behind, the global climate change has affected food production and availability. Diversification of food through the utilization of location-specific food commodities needs to be started now. The dependence on a single type and imported food are proven to cause food vulnerability. Food security can be achieved if public consume various food sources, especially specific commodities as local food sources [2]. As one of the largest agricultural countries in the world, Indonesia should be able to meet its own food needs. However, a high rate of population growth and agricultural land conversion has enforced Indonesia to import primary food from other countries. Many studies to find other sources of carbohydrate as well as functional food have been conducted in national research institutes. An alternative plant that fits the bill to be developed is arrowroot (*Maranta arundinacea* L.).

This plant can be found in various regions of Indonesia with different local names such as sago banban (Batak Karo), sago rare (Minangkabau), sago andrawa (Nias), sago (Palembang), Patat (Sunda), arut/jelarut / irut / larut/ arrowroot (East Java), labia walanta (Gorontalo), and hudasula (Ternate)[3]. Food diversification has to be implemented to strengthen food self-sufficiency and food



security. Arrowroot has the priority from the government of Indonesia to be developed and cultivated in Indonesia and it has the potential to substitute wheat flour [4]. The arrowroot produced quality starch which it can be used for reducing dependence on primary food [5]. The arrowroot starch has high economic and health value since the tubers are rich in fiber which good for the digestive system [6]. The arrowroot starch is expected to reduce the import of wheat flour of more than 3 million tons per year [7]. Base on the literature [8], the effect of starch addition on the properties of citric acid-bonded particle board made from bamboo found that *Maranta* and *Canna* starches provided high mechanical properties than corn starch. Result of *Maranta* starch characterization showed that the starch could be used as a raw material in the food industry interested in starch which can form a gel by cooling [9]. Moreover, the addition of arrowroot starch to cassava and sweet potato starches seemed to be improved gel stability in commercial food products [10].

The arrowroot can be planted in the marginal land and or under plant stands as an intercropping plant. As such, the dry and marginal lands in parts of Indonesia should be suitable e.g. West Java Province (219,369 ha) of fields or huma, and 66% of the area (144,754 ha) is in southern West Java (West Java in Figures, 2015). Arrowroot plants can grow in poor lighting conditions and can also grow on infertile land, therefore these characteristics mean that they can be planted in a shaded place [11]. Arrowroot plants can be used in vacant lots under tall trees without interfering with the growth and production of the main crops. According to the literature [12], arrowroot under the light intensity 7400 lux (27% full light) the number of leaves and tillers were not much different than under full light, although the plant would grow taller otherwise. In addition, arrowroot intercropped with coconut can be profitable. Higher rhizome yield can be obtained by the application of farm yard manure of 15 ton ha⁻¹ and biofertilizers [13].

Arrowroot is monocot plants with vegetative propagation. The plant's measuring 0.5 meter to 1 meter in height, with green leaves, fine fur on the lower side, and funnel-shaped with pointy ends. Compound and white arrowroot flowers [14]. Arrowroot plants have fiber roots. At an early growth stage, the rod-shaped rhizome is above the ground, then penetrates into the ground, and swells into a fleshy organ. The rhizome has a distinctive characteristic, which is curved like an arrow, white, fleshy, and wrapped in overlapping scales. The length is around 20-40 cm with a diameter of 2-5 cm [15]. According to the literature [16], the plant spacing of 30x50 cm can yield higher plant height, length, and tuber weight of arrowroot per plant compared to the distance of 30x30 cm or 30x40 cm. The 20 cm planting depth resulted in the higher yield of tubers per plant and tuber weight per plot compared to 10 cm plant depth treatment. Based on the literature [17], 2 seeds per planting hole would result in better growth and yield of arrowroot however, the organic fertilizer did not give a significant result to the growth and yield of the arrowroot, the 5 ton/ha dose tends to give higher yield on tuber number, weight, and diameter of Arrowroot. The crossing between genotypes can occur because arrowroot plants produce the flowers, even though the arrowroot propagation is vegetative. Crossing can increase the genetic and morphological diversity. Diversity can occur due to mutations and environmental influences [18]. The characterization of morphological properties of arrowroot species in Indonesia needs to be done so that they can be described and utilized as genetic sources for future development programs and improvement in the quality of arrowroot plants.

This paper discusses important parts relating to the latest developments in arrowroot plants as one of the functional food sources in Indonesia.



Figure 1. *Maranta arundinacea* plant

2. Materials and Method

This paper is based on several previous studies on cultivation, propagation, breeding and utilization of arrowroot plant that have been carried out before. The amount of research on arrowroot is still very limited, both nationally and internationally. Several studies related to propagation techniques both conventional and *in vitro* methods have also been carried out, as well as the utilization of arrowroot tubers as an alternative food source. Researches related to the benefits of arrowroot plants for health have also begun to be carried out regularly, but has not provided satisfactory results. Research related to the propagation and initiation of arrowroot plants to obtain superior arrowroot farming has yet to yield results, Research Center for LIPI Biotechnology has carried out breeding and expansion of diversity of arrowroot plants by mutation induction using gamma rays radiation. The research has reached the fourth generation and it has been dubbed as the candidates for superior plants with better morphology and production of arrowroot plants.

3. Results and Discussion

3.1 Diversity

The original arrowroot plant from America is known as Arrowroot, meaning plants that have rhizome roots (tubers) shaped like arrows. In the Caribbean language, this plant is called Ararute, which is a starchy root. The scientific name of arrowroot is *Maranta arundinacea* Linn. Marantaceae family [19]. Arrowroot tubers are one of the plants that are included in tropical plants, mostly in South America, Brazil, Ecuador, Costa Rica, Mexico, and Venezuela, then spread to India, Sri Lanka, the Philippines, and Indonesia, now widely planted in the Philippines and India [20]. Several factors might influence the variations on the plant, such as genetic mutation, cross-pollination, geographical isolation, and morphological changes associated with heteroblastic development related with temperature and the irradiation period [21]. Furthermore, the adaptability of the plant is mainly determined by its ability to complete its life cycle in many different environments. A study on genetic variability of the 37 accession numbers of arrowroot plant collection at Germplasm Garden of Research Center Cibinong has been done [22]. The amplification of OPW-05 primer of those 37 arrowroot samples resulted in 6 band patterns with the size of 500-4000 bp, and the only one polymorphic pattern (16.66%). However, OPF-07 primer (400-10000 bp) resulted in 3 polymorphic patterns (37.5%) (Figure.1A-1B).

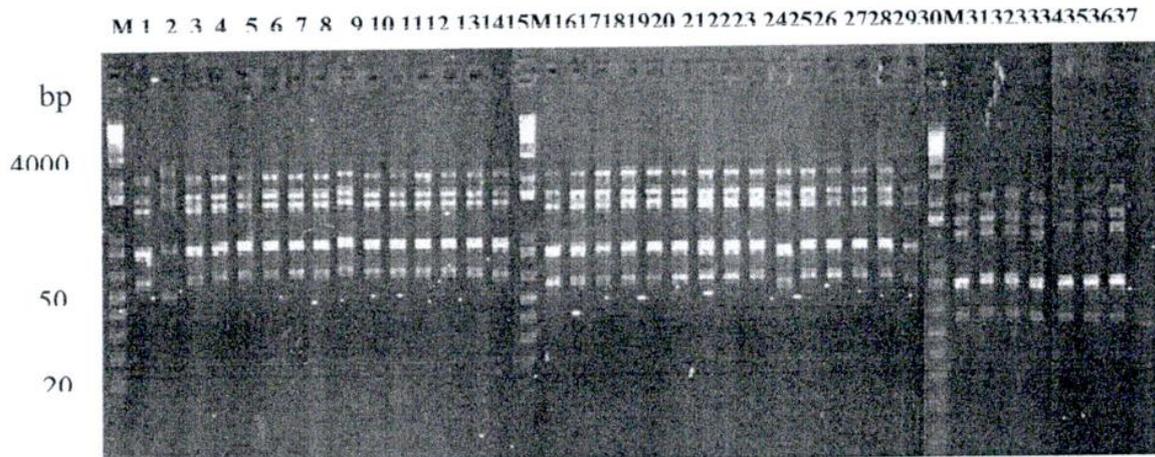


Figure 2A. Electrophoresis of OPW-05 primer amplification of 37 samples of arrowroot plant collection of Germplasm Garden, RC for Biotechnology-LIPI (Source: Deswina et. al (2016))

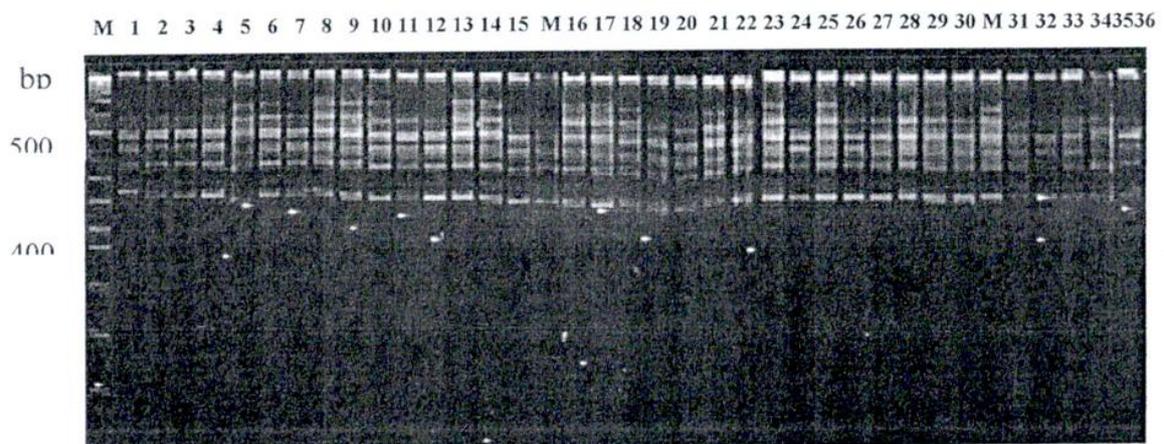


Figure 2B. Electrophoresis of OPF-07 primer amplification of 37 samples of arrowroot plant collection of Germplasm Garden, RC for Biotechnology-LIPI (Source: Deswina, P. et. al (2016))

Based on the genetic analysis, it concluded that the coefficient of similarity of those 37 arrowroot plant accession number was high (0.94) or has low genetic variability [23]. The result can be seen in Figure 2 and Figure 3.

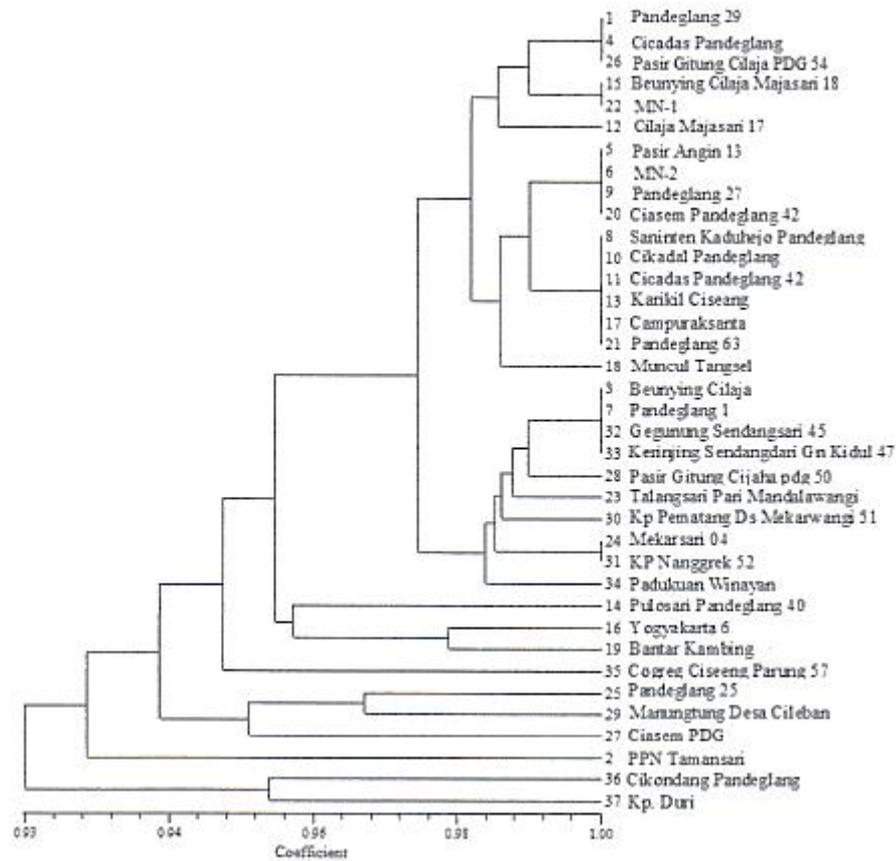


Figure 3 Phylogenetic tree of arrowroot

Furthermore, the gamma-ray radiation could affect the morphological characteristics of plants such as leaves, number of shoots, plant height, and tubers production [24]. The result can be seen in Table 1.

Table 1. The effect gamma ray radiation on growth of *Maranta arundinacea* (F1)

Gamma ray radiation (gray)	Leaf length (cm)	Leaf width (cm)	Age of flower (day)	Total rhizomes	Rhizome length (cm)	Rhizome diameter (cm)	Total biomass (g)	Rhizome fresh weight (g)	Rhizome dry weight (g)	Plant height (cm)	Total shoots	Total shoots /node
0	29.2	10.3	205.1	13.1	19.4	17.7	3600.0	596.7	543.1	114.2	13.2	5.2
10	30.7	10.5	252.0	15.1	17.3	18.5	3240.0	500.4	450.8	109.2	14.8	4.8
20	30.1	10.3	238.7	14.6	17.3	18.6	3075.0*	591.8	522.7	106.9	12.9	5.8
30	28.2	10.2	206.9	13.5	16.0*	16.7	3320.0	412.4	370.7	99.3*	17.1*	4.6
40	27.4	10.0	196.0	12.6	17.7	15.8	3177.8	517.1	466.1	96.6*	12.9	4.4
50	27.0	9.7	244.0	11.1	17.3	13.2	2420.0*	285.9*	253.2*	83.0*	13.1	3.2*

Mean indicated by * are significantly different ($p < 0.05$)

Source: Deswina et. al. (2019)

3.2. Distribution and origin

Maranta arundinacea L. is not native from Indonesia, this plant originated from tropical America, or precisely from West Indians, and spread to tropical regions where these plants would grow and adapt. From the area of origin, arrowroot plants are distributed to western India, South Africa, Australia, Philippines and Southeast Asia, including Indonesia. This plant can grow and develop easily in even less fertile soil types [3].

Arrowroot, including the *Marantaceae* family, is an herbaceous plant, perennials have a height of 60-80 cm. In general, the stems of plants are slender, finely hairy and tumid at the joints. The leaves are alternate with long leafy hairy lanceolate sheaths and slightly hairy underneath. The plant has a perennial fibrous starchy rhizome producing numerous fusiform fleshy, scaly tubers from its crown. The fleshy, white and cylindrical rhizome is covered with regular scale leaves and grows approximately 2.5 to 5.0 cm thick and 20-45 cm in height. It is used for the extraction of a very fine easily digestible starch known as the arrowroot starch. Yields of rhizomes normally average about 12 to 31 t ha⁻¹ depend on the land condition and the normal commercial yield of starch is 8-16 % [25]. Tubers develop side shoots, forming a large mass of tubers that can be 60cm in diameter and weigh over 20 kg. Fleshy stalks, up to 1 m long, shoot from eyes on the rhizome, and large, lush bright green leaves, 30-90 cm long unfurl on thick stalks. If planted in rich soil and given regular watering, this plant will grow vigorously, producing lush leaves and stalks and high yields of edible tubers. However, arrowroot will also perform well in poor soils, and dry conditions, and for this reason, we should consider it as a versatile survival food [26].

Still, in the same altitude range, the genus of *Maranta* was found in three species known as, *Maranta arundinacea*, *M. amplicolia*, and *M. linearis*. However, among these three species, *Maranta arundinacea* is the most abundant. Moreover, *Maranta arundinacea* is mostly distributed in the low land ranging 100 – 300 m [27]. The shades tolerance is the important characteristics of this species to make them fitted in the shaded condition of the agro-forestry system. Distribution of arrowroot in Java Island can still be found at an altitude of 100 - 500 m above sea level, under the shade of large plants thus increasing the ability of these plants to adapt under stands [25]. When the plant is erect, perennial and shallow rooted with rhizomes penetrating into the soil.

Arrowroot does not seem to suffer from serious diseases or pests even though under poor drainage conditions. It requires rainfall of 50-300 mm/year with a humidity of 50-85%. The plants would grow well in sandy and fertile clay-textured soils with pH 5 - 6.5 on poor soils, arrowroot may produce so-called "cigar roots" (long thin fibrous rhizomes, containing little starch) this can be prevented by applying more fertilizer. The leaf blight disease, caused by *Pellicularia filamentosa*, the arrowroot leaf roller (*Calpodes ethlius*) sometimes infects the crop and also causes defoliation and consequently starch losses, spraying with Bordeaux mixture is effective [20].

The arrowroot is native to Mexico, Central America, the West Indies, and South America. It is widely cultivated in many warm countries and is considered naturalized in countries like Jamaica, Bahamas, Bermuda, the Netherlands, India, Sri Lanka, China, Mauritius, Equatorial Guinea, Gabon, Florida, Cambodia, Indonesia, and the Philippines. In Indonesia, arrowroot plants are evenly spread in Yogya especially in four districts, namely Bantul (Subdistrict Sedayu and Pajangan), Kulon Progo (Subdistrict Sentolo, Lendah, and Pengasih), Sleman (Prambanan sub-district), and Gunung Kidul (Subdistrict Semin). The plant covers 6,301-17,847 ha and productivity is estimated to be 15-17 ton ha⁻¹. In Central Java, arrowroot plants were developed in Sragen Regency, such as in Gesi, Mondokan, Sukodono, and Miri Districts. The area ranges of development of arrowroot plants in this district are 7.828 ha. In Central Java, arrowroot plants were developed in Sragen Regency, such as in Gesi, Mondokan, Sukodono, and Miri Districts. The area of development of arrowroot plantations in this district is 7.828 ha [22]. Arrowroot plants are also spread in several districts in West Java, including Ciamis, Sumedang, Garut, Tasikmalaya, Cianjur, and Bogor. In Malang, Blitar and Sampang, East Java, arrowroot cultivation has been carried out massively on 18.000 ha of land with average productivity of 20 ton ha⁻¹. However, a survey result of the Direktorat Budidaya Tanaman Kacang-kacangan dan Umbi-umbian showed that arrowroot plants had not been cultivated intensively in West Sumatra, South Kalimantan, South Sulawesi, West Sulawesi, and Maluku [23]. An extremely hardy perennial to 2 meters tall, shooting from a large purple/red, round rhizome/tuber that can be larger than a clasped fist. It's been encouraged that every garden to grow arrowroot, for an all year around food source. Arrow root prefers a sunny place to grow but will also perform well in shade. According to literature [24], the plant thrives best in well-drained loamy or sandy soil under partial shade.

3.3. Propagation

The arrowroot can be propagated both conventionally by its tuber cuttings and tissue culture technique (*in vitro*). However, large quantities and uniform seeds can be produced by tissue culture technique.

3.3.1. Conventional propagation. Several studies on arrowroot propagation using tubers cuttings have been done to obtain the best and most efficient method to increase tuber production and starch quality. A study in the literature [25], the best part of arrowroot tubers for propagation in producing the highest rhizomes, was using 3 rhizome segments. The growth of the plant with shading was better than without shading. The highest fresh weight is produced from plants with 30% shade in ogor. In addition, the research of the application of several doses of green manures on the growth of Arrowroot under *P. falcataria* stands resulted in the highest plant, stem, diameter, and leaf number [26]. Another study using a combination of light intensity and fertilizer application had found that the arrowroot seed growing in 50% light intensity and two times application of the goat manure resulted in the best arrowroot growth (98.6 cm plant height, 100 leaf sheets, and 8 clumps) [27]. While a-three segments rhizome seed was the efficient plant tuber and resulted in the best growth and production of arrowroot. A research in Bogor had found that arrowroot tubers planted under shading would result in higher plant and tuber fresh weight compared to those planted without shading.

According to the literature [28], the arrowroot vegetative growth was affected by the application of fertilizer to the plant. It showed that the end parts of the rhizomes containing four nodes produced the highest survival percentage and growth rate. The end of the rhizome part produced 240 g of rhizomes (47.19 g starches), the base parts produced 324.04 g rhizome (52.51 g starch) and the middle part produced 326.46 g rhizome (61.25 g starch) per clump. A base and middle part of 3-nodes rhizome are the most efficient for the seed of arrowroot due to the highest starch content of 23.18 and 23.72 g respectively. While the highest starch production of 3-nodes base and the middle part was 70.38 and 72.41 g. It found that the plant spacing (30 x 40 cm), fertilizer application (SP36 and KCl 300 kg ha⁻¹), and their interactions have a significant result to increase the number of tillers and rhizome diameter [29].

3.3.2. *In vitro* Propagation. In addition to conventional propagation, arrowroot plants can also be propagated through *in vitro* techniques or tissue culture to obtain seeds in large quantities and uniformly. The importance of *in vitro* techniques or tissue culture has been carried out on several commodities of horticultural plants such as bananas, taro, and so forth. Several studies were carried out to accelerate mass seed production. One of the issues faced in propagating through tissue culture is the costs required. This technique must be further developed to shorten the time it takes in supplying the seeds in large quantities. According to the literature [33], the use of BAP (6-benzylaminopurine) directly on arrowroot rhizome which was soaked in BAP for 15 minutes before planting on sterile sand media showed that the growth of intact rhizomes was lower (5.6 – 12.5%) compared to the cut rhizomes. The highest growth (86.1%) and the highest growth rate (4.6 shoots/week) is produced by pieces of rhizomes soaked with 4 mg / 1 mg BAP-1. The highest leaf growth rate (3.9 strands/week) is produced by rhizomes which are cut and soaked first with a solution of 4 mg / 1 BAP but not significantly different from plant height. For shoot multiplication, solid MS media have been used with the addition of BAP and NAA with various concentrations. Most shoots (1.6 shoots/plantlets) are produced from rhizome buds cultured on MS media added 2 mg / 1 BAP and 0.5 mg / 1 NAA, but 1 mg / 1 NAA is the best concentration to accelerate the growth of shoots. The highest number of roots (3.2 / plantlets) was obtained from MS media containing 1 mg / 1 IBA. The results of acclimatization showed that the best medium for plant growth was sand media using plantlets added with Root one F. produce shoot height of an average of 4.6 cm and the number of roots 6.4 with a life success of 90%. Research on molecular technology or genetic engineering in the development of arrowroot plants is still very limited. Further research is needed for the development of plants, because of the great benefits of plants as a functional food.

3.4. Utilization

Arrowroot plant is an important starch yielding tuber crop plant which in the early days of human civilization was treated not only as food but also as a medicine. The leaves of the plant can be makeshift packaging while the fibrous material remaining after the extraction of starch can be used as cattle feed or manure [31].

The arrowroot tuber contains plenty of starch and other compounds which contain alternative sources of carbohydrate. The starch has a high digestibility, in addition, this plant tastes bland, making it a suitable choice for neutral diets, especially for people who are feeling nauseous [20]. This plant may need further research to be considered a good source of starch as well as a medicinal plant.

3.4.1. Food. The composition of arrowroot tuber is dominated by carbohydrates, especially starch. Freshly harvested fresh Arrowroot contains about 16-18% starch with an excessive amount of water content. The tuber can be consumed directly or processed into semi-finished form of arrowroot flour. Furthermore, the starch content of arrowroot tuber is around 12-15% of dry weight. The starch powder is white, odorless and is used as a thickening agent in the food industry [32].

Arrowroot is beneficial for health because it is low in calories compared to the other tubers such as potatoes, yams, cassava, and so forth. Arrowroot starches contain amylopectin (80%) and amylose (20%) [33].

Arrowroot is used externally as well as internally because the starch contains alternative sources of carbohydrate, it is widely used as a stabilizing agent in food, condiments, soup, candy, pudding and ice cream. Arrowroot also contains more protein compared to other tropical food sources such as the sweet potatoes, potatoes, cassava, bananas, and so forth. The other advantage of arrowroot tubers is that they're gluten-free as in other roots and tubers. Gluten-free starch is used for patients with celiac disease [34].

3.4.2. Medicine. One of the protection against disease can be achieved with the provision of antioxidants compounds that can inhibit reactive oxygen species/reactive nitrogen species (ROS/RNS) as well as free radicals. Moreover, the natural antioxidant compounds of polyphenols can be

found in arrowroot tubers that are used to make starch and contains high carbohydrates [33]. Methanolic extract of arrowroot at 200 and 400 mg kg⁻¹ doses in rats and brine shrimp showed anti diarrheal activity but have slight cytotoxic effect [35]. The ethanolic extract of arrowroot tubers was able to reduce the concentration of SGPT and SGOT. The most effective dose of the ethanolic extract of arrowroot tubers to reduce the concentration of SGPT and SGOT was 500 mg kg⁻¹ [33].

The arrowroot bulbs can also be used to treat ulcer peptic. It is also reported to treat diarrhea, pain and as antioxidant. The tuber has the properties of anti-cholesterol and anti-ulcer since they have 32 glycemic index (IG) which belongs to the food category with low glycemic index. The arrowroot plants also have phenolic, flavonoid, alkaloids and saponin compound that are potential as antioxidants. According to the literature [36], the antioxidant activity of fresh tuber extract (1.78 µg mL⁻¹) is higher than fresh leaf extract (0.27 µg mL⁻¹).

The use of modified arrowroot starch resulted in the increase of amylose content, total dietary fiber content, and resistant starch content of cookies. It could also reduce starch digestibility of cookies. The glycemic index of cookies from modified arrowroot starch was 31, a much lower glycemic index of cookies from wheat which was 44. This was because of higher amylose content, total dietary fiber content, and resistant starch content and lower starch digestibility of cookies from modified arrowroot starch than cookies from wheat [37]. The Starchy carbohydrates together with beta-carotene, niacin and thiamine are present in the mature rhizomes of arrowroot, so that when they are peeled and cooked they become very digestible and nutritious food [38]. Besides being friendly to the gluten-sensitive individuals, arrowroot flour can also help to keep glucose and lipids within normal limits. Therefore it can be used as a functional food, especially in people who have difficulties in managing glucose and lipid profiles [39].

4. Conclusion

The prospects for arrowroot are promising because of its high yield potential, high-quality starch and multiple benefits such as for people with autism, diabetes, or digestive disorders. Arrowroot starch flour is potential for food diversification into another food product, to survive competition with other starch-producing crops, the efficiency of starch extraction should be improved and the utilization of debris should be optimized. In South-East Asia, the feasibility of large-scale production in areas with a short dry season should be investigated. This research needs to be conducted for evolving high yielding varieties in this crop using *in vitro* technique or other breeding strategies.

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