The Potential of Nipah (*Nypa Fruticans* Wurmb) as Bioenergy Resources

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Abstract—Renewable energy opens up prospects for answer the problem and an eco-friendly solution directed to energy security. Indonesia as a rich country of biodiversity resources, has a high potential for developing new and renewable energy derivatives from plants. One of those biodiversity resources that had been investigated is nipah (*Nypa fruticans* Wurmb). Nipah belongs to family Palmae or Arecaceae. Commonly known as the nipa palm, is a species of palm considered adapted to the mangrove ecosystem. Nipah naturally distributes in Sumatera, Kalimantan, Java, Sulawesi, and New Guinea. Nipah produces high amount of sap that can be converted into bioethanol. Nipah sap was produced by fruit stalks that can be harvested twice a day. One stalk can produce about 0.5 to 2 l sap per day. This nipah sap generates 8.98-14% of ethanol that resulting varied amount of bioethanol from 3,587.92-22,374.54 l per ha per year. Nipah also contains high amount of lignocellulose that can be converted into bioethanol. Nipah has cellulose and hemicellulose content that ranges from 28.9-45.6 wt% and 21.8-26.4 wt%, respectively. This lignocellulose component can be converted into bioethanol and yielded around 1,169.22 kg per ha. Charcoal production is also potentially made from some parts of nipah tree, such as fruit bunch, fruit shell, leaf midrib, and leaves. Nipah has productivity around 2,858.89 kg per ha to produce charcoal. The nipah charcoal has characteristics close to charcoal characteristics produced from other palm trees.

Keywords—bioethanol; nipah; charcoal; green-industry; mangrove

I. INTRODUCTION

In this decade the uses of unrenewable energy, such as fossil energy have been increased. The increase of unrenewable energy uses occurs every year. It correlates with increased human population and due to rapid growth of industrialization, urbanization, technology, and modern agricultural development [1, 2]. The world faces the energy scarcity due to most of energy resources is un-renewable. Therefore, it is needed to find new sources of renewable energy.

The Renewable energy opened up prospects for answer the problem and an eco-friendly solution which directed to energy security [4]. Renewable energy doesn't have a negative impact on the environment. It doesn't emit exhaust gasses which contains sulfur. Sulfur is one of the

elements that can accumulate and cause acid rain. In addition, it also can reduce the effect of greenhouse gasses (GHG) [3].

There are some alternatives of renewable energy resources, such as solar energy, geothermal energy, ocean thermal energy conversion (OTEC), hydroelectric energy, and biomass energy. Biomass energy is one of the future energy that has potential to be developed in this century. Biomass energy can be produced from all kinds of living things, such as algae, fungi, and lignocellulosic materials [5–10]. Industrial waste, such as agriculture, plantation, forestry, and other sources of nonwood lignocellulosic materials is a potential raw material for biomass energy resources. Therefore, the premises have the opportunity and great potential for the development of biomass energy.

Nipah (*Nypa fruticans* Wurmb) is a non-wood lignocellulosic material. It has potency to be developed as bioenergy resources in Indonesia. Nipah is one of palm in mangrove ecosystem, widely distributed and used in Southeast Asia. The mangrove area in Indonesia is about 3.24 million ha and from it area, 973,205.54 ha is nipah vegetations [11]. It's distributed in Sumatera, Kalimantan, Java, Sulawesi, and New Guinea. Nipah can be producing high amount of sap, which can be converted into ethanol. It can produce 6,480-10,224 L ethanol in 1 ha per year [12]. Nipah sap is a potential material to convert into bioethanol. Its chemical composition is 19.5 wt% consisting of sucrose, glucose, and fructose [13]. It shows that nipah has a chance and potency to be developed as next-generation fuel.

This review is trying to evaluate nipah as bioenergy resources in Indonesia, includes: (1) botany of nipah, (2) the distribution of nipah resources, (3) nipah productivity for bioenergy resources.

II. Nipah (*Nypa fruticans* Wurmb)

A. Botany of Nipah

Nipah belongs to family Palmae or Arecaceae [14, 15]. Commonly known as the nipah palm, is a species of palm considered adapted to the mangrove ecosystem. This species is the only member of the genus *Nypa* and the subfamily Nypoideae [16].

Unlike most palms, nipah is structurally unique, lacking an upright trunk and instead having a horizontal stem with dichotomous branching that grows underground [17]. Leaf of nipah can produce an inflorescence consisting of monopodial axis, the male and female reproductive parts are found in separate flowers on the same plant [18].

B. Distribution of Nipah Resources

Nipah is an ecologically important species forests Mangrove Nature Reserve East Coast and important economically for the community around the nature reserved area. Nipah is one of species in mangrove forest (about 30% of total area). Based on satellite image data, mangrove area in Indonesia about 3,244,018.46 ha, so from that data nipah area was about 973,205.54 ha [11]. In Indonesia, nipah was distributed from Sumatera, Kalimantan, Java, Maluku, Sulawesi, and New Guinea Island.

III. Utilization of Nipah as Bioenergy Resources

A. Nipah Sap

Bioethanol is a next-generation fuel that is manufactured from renewable materials, such as algae, lignocellulosic, carbohydrate, and sugar materials [5–8]. Nipah can be used to produce a raw material of bioethanol [19]. Nipah produce sugary material in the sap that can be converted into bioethanol [5]. Nipah sap contains carbohydrates 89.61%, protein 5.98%, and Ca 44.58 mg per kg [19]. The conversion of materials which contained 68–85% carbohydrate is resulting 5.8% ethanol [20]. For further processing, nipah sap generating 8.98–14% of ethanol, result in bioethanol ranging from 3,587.92–22,374.54 L per ha per year [21]. It shows that nipah sap has a potency to convert into ethanol.

Natural potency of nipah sap which produced by a single fruit stalk in a day with twice harvesting time (morning and afternoon) about 0.5–2 L per day [12, 22, 23]. The number of sap producing days and fruit stalk length were found to be highly correlated with sap yield [24]. In addition to growing nipah for its bioethanol, there are other advantages of growing nipah. Continuous productivity of nipah means no displaced labour, which is one of major problem of sugarcane plantation. Production of nipah is not interrupted by replanting and rotation. Based on this development pattern, then it is expected that deforestation and land degradation that occurred in mangrove forest ecosystem, as a habitat of nipah, can be minimized.

B. Lignocellulose of Nipah

1) Ethanol

Nipah also contains lignocellulose which can be converted into bioethanol [6, 9, 10]. Reference [25] was shows nipah have the content of cellulose and hemicellulose were 28.9–45.6 wt% and 21.8–26.4 wt%, respectively. The greater content of cellulose and hemicellulose in a material shows that materials were more potential to be converted into bioethanol [7, 9, 26]. The highest lignin content in nipah was found in the leaf [25]. The higher lignin content in the materials affected the conversion process into bioethanol [7]. The step of converting lignocellulosic materials into bioethanol can be done in several stages, including (1) pre-treatment, (2) hydrolysis, (3) fermentation, and (4) distillation (Fig. 1) [9].

In most cases, WIS was produce by pretreatment process [27]. It contains cellulose and lignin, and a liquid fraction composed of hemicellulose [9]. The hemicellulose intact is more depending on the pre-treatment when hydrolyzed to monosaccharide, it proceeds to fermentation. When not completely hydrolyzed, it requires further hydrolysis before fermentation. Cellulose is hydrolyzed by celluloses enzyme and converted to glucose, which is fermented. When hydrolysis of cellulose and fermentation occurs separately it called SHF [2, 28]. When the pentose part is fermented together with the hexose part after a separate hydrolysis it is designated as SHCF. When hydrolysis is performed in simultaneous with fermentation it's named SSF [29], when SSF includes the co-fermentation of glucose and xylose it's called SSCF. When the enzymes are produced also during process, hydrolysis, and fermentation of all sugar performed in one step it's called CBP [9].

Fig 1. Lignocellulosic ethanol bioprocesses. Water-insoluble solids (WIS), separate hydrolysis and fermentation (SHF), separate hydrolysis and co-fermentation (SHCF) simultaneous saccharification and fermentation (SSF), simultaneous saccharification and co-fermentation (SSCF), consolidated bioprocessing (CBP).

The calculation shows that nipah fruit waste has productivity around 361.65 kg per ha to produce ethanol [19, 33]. From the frond and empty fruit bunch nipah have productivity of 57.50 and 750.06 kg per ha respectively [19, 26, 30–34]. The total productivity of nipah for ethanol production is 1,169.22 kg per ha per year.

2) Charcoal

Charcoal production is a process to improve the quality of fuels derived from biomass [35]. Charcoal made with carbonization process [36]. Nipah have the large content of lignocellulose in the trunk, kernel shell, leaf, empty fruit bunch, and the leaf midrib. The lignocellulose in nipah can be used to produce charcoal. Nipah charcoal has similarity characteristics of other palm species (Table I) [37].

TABLE I. Characteristic charcoal from oil palm frond (OPF), palm kernel shell (PKS), and empty fruit bunch (EFB)

Feedstock proximate analysis (%)	OPF	PKS	EFB
Moisture	6	8.44	5.18
Volatile matter	76	71.81	82.58
Fixed carbon	17	26.96	3.45
Ash	1	1.23	8.79
Feedstock ultimate analysis (%)	OPF	PKS	EFB
Carbon	42.88	50.42	42.08
Hydrogen	7.06	9.74	7
Nitrogen	0.52	0.52	0.99
Oxygen	49.54	39.32	49.93
Biocharcoal ultimate analysis (%)	OPF	PKS	EFB
Carbon	91	81	75
Hydrogen	1	1	2
Nitrogen	2	3	2
Oxygen	6	15	21

The carbon content affects the charcoal energy and It shows the quality of charcoal [37]. The higher carbon content in charcoal produces more energy than the charcoal with the lower carbon content [38]. Carbonization process palm fruit produce charcoal fibers by 71% [39]. It shows that nipah has a potency to produce charcoal as bioenergy resources.

Charcoal productivity from frond, fruit waste, and empty fruit bunch of nipah is 958.39 kg per ha, 1,307.85 kg per ha, and 1,900.5 kg per ha, respectively [19, 26, 30, 34, 41, 40]. The total productivity nipah to produce charcoal is 4,166.74 kg per ha per year.

IV CONCLUSION

Nipah is a potential renewable material for bioenergy resources in Indonesia. It can be converted into bioethanol as primary product and charcoal as side product. Nipah has productivity around 3,587.92-22,374.54 L per ha per year and 1,169.22 kg per ha to produce bioethanol from sap and lignocellulosic conversion, respectively. Charcoal productivity as an alternative product from nipah is 2,858.89 kg per ha per year.

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