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Energy and Land Conservation: Brown Sugar Processing with Appropriate Technology

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Abstract

Brown sugar is traditionally produced by rural communities and considered as the substitutefor crystal sugar and potential export commodity. The production of brown sugar from palm and cane could be developed by usingappropriate technology (AT) inmicro and small business scales. This study aims to examine the feasibility of brown sugar production by specifically looking at the efficiency of marginal land for sugarcane cultivation and the use of fuel in the production process. A case study in two groups of brown sugar producers was conducted in two different districts in South Sulawesi, Indonesia. Data analysis includes business feasibility, fuel efficiency, producers' potential incomes, and socio-economic and environmental impacts. The results show that the use of cooking stoves as AT has a great potency to increase the income of brown sugar producers through the improvement of energy efficiency and production capacity. Additionally, the cultivation of cane on marginal land for brown cane sugar can contribute to land conservation and rural community income source. The R/C-ratios are 3.34 for sugar canefarm, 1.82 for brown sugar can, and 1.22 for hybrid coconut brown sugar. The use of energy-efficient technology in the production of brown sugar can increase the efficient use of fuel, employment opportunities and income of rural communities and while encouraging forest preservation and agricultural land conservation

Keywords: *Brown Sugar, Sugar Cane, Hybrid Coconut, Marginal Land, Forest Preservation.*

1. Introduction

Brown sugar is one of Indonesia's traditional foods. It is consumed and used as sweetener and crystal sugar substitution[1]. The feature of brown sugar that distinguishes from crystal sugar is that it provides a softer texture for the food, natural flavor, as well as natural brown color[2]. Brown sugar is also used as a raw material in small industries both for food and beverages and promoted as healthy products[3]–[5].

In general, brown sugar is traditionally produced using a conventional method and utilizing woodfuel as an energy source in the cooking process. The sap as the raw material for brown sugar making is obtained from palm plant groups such as palm trees (*Arenga pinnata*), fan palm (*Borassus Flabellifr*), nipah (Nypa Fruticans), and hybrid coconut (*Cocos nucifera*)[6].

Sugar is one of the strategic commodities in the Indonesian economy because it is a basic need after rice, corn, and soybeans. Sugar is needed as an ingredient for the food and beverage industry and in other sectors[7].In 2017, the total national sugar consumption for industrial consumption and household consumption was 5.10 million tons, while domestic sugar production was only 2.44 million tons[8]. The shortage of sugar supply is met from imports and brown domestic sugar production. In fact, brown sugar could be an alternative to meet sugar demand in Indonesia[1], [9]

Brown sugar made from hybrid coconut and sugarcane has a great potential to be developed by small communities, especially by poor people in rural areas. Brown sugar production business can be initiated with a relatively small investment value by utilizing marginal land and

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appropriate technology (AT). In South Sulawesi, there are 14,438 ha of a hybrid plantation thatis not optimally managed [10]and a total of 342,094.53 ha marginal land area, of which 189,341.05 ha or 53.35 percent of the total marginal land[11]. The availability of marginal land can be utilized to cultivate hybrid coconut and sugar cane by poor people who have limited access to land[12]. In addition to the availability of land, brown sugar production can be supported by the use of appropriate technology (AT) in the form of energy-efficient cooking stoves. This technology can be used on all types of plants from either plant trees or sugar cane that produce sap to be processed into brown sugar. AT is a simple tool or method that is made locally with small investment which can improve the efficiency of energy use in the process of producing brown sugar and increase incomes of rural communities[13]–[17]. Traditionally, the production of brown sugar is considered not environmentally friendly for the forest or agricultural ecosystem. Cooking stoves used by brown sugar producers use wood fuel as the main energy source in the cooking process. The utilization of energy-efficient cooking stove that usesa small amount of fuel for brown sugar production encourages forest preservation while planting sugar cane on marginal land encourages conservation of agricultural land resources[18] The cultivation of palm and sugar cane plants have functioned as conservation crops which resistant to drought and suitable to be cultivated on marginal and sloping land[19]–[21]. Areas, where marginal lands are available, tend to have a poor population. Investment on brown sugar business that utilizes marginal land would be one solution to create employment opportunities, increase the income of rural communities, especially for the poor, as well as for the preservation of natural resources[14], [18], [22], [23].

Several kinds of research have been carried out related to the processing of brown sugar, both from palm trees and sugar cane. Studies related to the potential and prospects[1], [24],business feasibility [25], [26], as a source of income and prosperity for the community[27]and gender perspectives [28]. However, studies that focus on potential energy savings and utilization of marginal land for brown sugar production are still limited. The purpose of this research is to examine business feasibility, efficient use of fuel in brown sugar production from hybrid coconut, and utilization of marginal land-based to cultivate sugar cane, which both are used as raw materials for brown sugar production.

2. Method

Brown sugar from hybrid coconut and sugar cane were selected as the object of the study with the consideration that both types of brown sugar could be easily produced by poor or rural communities. The utilization of AT can be used as an example to showcase the production of brown sugar, which traditionally cultivated and uses wood fuel in the cooking process. This research was carried out in two villages that produced brown sugar from hybrid coconut and sugar cane on a small scale basis. The research method was a case study of households that produced brown sugar from hybrid coconut in Lawawoi Village, Sidrap Regency, and from sugar canein Toddopulia Village, Maros Regency. Both of these locations are in the South Sulawesi Province of Indonesia. Data was collected using the RRA (Rapid Rural Appraisal) method. Data collected during the field research include the value of an investment, level of fuel use, production, and market prices of brown sugar. Data were analyzed to examine business feasibility, level of fuel efficiency, household income of the producers, potential socio-economic, and environmental impacts.

3. Results and Discussions

3.1. Brown Sugar Production

Brown sugar is traditionally produced from palm and sugar cane plants. Brown sugar from palm trees is generally cultivated by poor people in the forest and less populated areas. Conversely, brown sugar from sugar cane is mostly cultivated in populated areas, which is an alternative business rather than selling sugar cane to crystal sugar factories. Palm is mostly

cultivated in Eastern Indonesia, whereas sugar cane is in the Western region, especially in Java. Arenga pinnata (aren) is one of the forest resources that has enormous potential as a source of income for people in rural areas in Indonesia[21], [24], [29]. However, Producers of brown sugar from palm are typically live in the forest area because they use wood as fuel in the cooking process. They usually leave their families from their home, devote large numbers of workers, use large amounts of wood fuel, and bear higher transportation costs to distribute products to markets, or collectors who buy at the production location at a low price [30]. This condition makes the value of production is low, compared to the production inputs used. It is not even feasible if all inputs used and opportunity costsare financially computed.

In addition to palm trees, fan palm can also be used as raw materials for brown sugar production. However, it is usually cultivated in a field with a limited number of plant populations and is challenged by a limited amount of fuel. This causes brown sugar from *Arenga Pingata*(Aren), and fan palm is not economical because the plant population in the area is limited or spread [31].

Besides *Aren* and fan palm, hybrid coconut is also raw material to produce brown sugar[31]. Hybrid coconut has been cultivated since the late 1980s in South Sulawesi. It has different characteristics with local coconut or tall coconut. It is very responsive to external input, and the fruit is not favored for household consumption as a vegetable coconut andoil manufacturing for cooking oil. This makes hybrid coconut is less attractive to the community to designate coconut production. In addition, demand for coconuts can be met from tall coconut production, which traditionally does not require intensive farming. Many hybrid coconuts are used for the production of brown sugar to meet domestic and export demand for brown sugar. America is one of the destinations for coconut sugar exports, where its demand continues to increase [32].

The advantage of hybrid coconut as a source of raw material for brown sugar that it has ashort stem, allowing it to be easily harvested. In addition, there is a large population in an area that can achieve economies of scale. Financially, owners of hybrid coconut plantations prefer to rent out or be cooperated with brown sugar producers. The owner of the coconut can get cash by selling to the market or coconut assembler,which is almost equivalent to the value of coconut plantation rent, without spending costs for coconut cultivation. On the other hand, brown sugar producers prefer to process brown sugar from hybrid coconuts because coconut is in a single area with a lot of plant populations. However, the producers need to transport wood as fuel for the cooking process from outside of their plantation. Therefore, the biggest cost component in processing brown sugar from coconut is firewood because it must be supplied from outside.

Sugar cane is one of the plants that are widely cultivated in tropical and sub-tropical countries, including Indonesia[33]. This plant isone of the raw materials to produce sugar, both for crystal and brown sugar. Processing sugar cane into brown sugar is well known in Indonesia and other countries[2]. Brown sugar processing uses energy-saving cooking technology. Sugar cane bagasse generated after the sugar cane pressed using a machine is used as fuel in the cooking process. The scale of sugar cane processing in East Java is considerably large, and sugar cane is cultivated on productive lands. Farmers have choices of selling their sugar cane to sugar factories or processing it into brown sugar[34]. This model was adapted in South Sulawesi with some adjustments, including smaller milling capacity (0.5 - 2.0 TCD - Ton Cane Day), sugar cane cultivation on marginal land, and integrating brown sugar processing units with sugar cane plantations, either individually or in groups. One processing unit can be supplied by 2-4 ha of cultivated marginal land. Through group facilities or partnerships between processing units and farmers. Especially for the area of fewer than 0.50 hectares of marginal land is affordable and can be cultivated by rural communities.

3.2. Characteristics of Palm for Brown Sugar Production

Research conducted on the three types of Arenga piñata and fan palm plants [24], [35], [36],and hybrid coconut [37]have a different sap but could be processed for brown sugar. Each palm plant has advantages and disadvantages in making brown sugar.As shown in Table 1, the productivity of aren and fan palm is considered high, but the plant population in one area is limited. Aren is mostly cultivated by the poor community because they live in the forest area.

The tree is short and supported by the availability of abundant wood fuel for brown sugar processing. On the contrary, fan palm trees are cultivated in the agricultural area. The tree is high and not supported by the availability of wood fuel. In contrast, hybrid coconut has low productivity, but large populations in one area and wood fuel used is supplied from outside of the processing unit.

Table 1. The Description of The Plant Caharacterstic as Raw Material for Brown Sugar Production.

Description	Arenga pinnata	Fan Palm	Hybrid coconut	Sugar cane
Brown sugar production	1-3 kg/tree/ Day	1-3 kg/tree/ Day	0.33 kg/tree/day	5-7 ton /ha
Harvesting time (day)	90-110 /panicle	90-120 / panicle	20-40 / panicle	240/year
Population	5-20 tree/ha	10-30/tree/ha	150 tree/ha	60-70 ton/ha
Age for harvesting (year)	5-8	8-10	3	1
Productive age (year)	20	30	20	5
Growing area	Forest	Garden	Garden	Garden
Acquisition system	Common property	Private	Private	Private
Main products	Brown sugar	Brown sugar	Coconut	Crystal sugar
Side products	Palm fiber Sugar palm fruits	Fan palm fruits	Brown sugar	Brown sugar
Other side products	Sago	Palm leaves formatting		Fuel, sugar drops
Business integration	Shifting cultivation	Permanent cultivation	Intercropping with coconut	Cattle

Brown sugar processing from palm supported by the use of AT energy-saving cooking stoves can generate many side products with economic value. In addition, it can also create additional jobs because labor flows for the manufacture of palm sugar are reduced and diverted to other businesses. For example, cultivating derivative products, such as 1) producing palm fruit, palm fiber, roof, and sago on palm plants; 2) utilizing fruit and leaves from palm trees, as well as cultivating secondary crops on plants; 3) cultivate crops in the area of coconut plantations.

3.3. Description of Appropriate Technology

Producers of brown sugar produced from sugar cane use one or two pans from each furnace that is not equipped with a chimney as a smoke disposal channel (Figure 1). Consumption of wood fuel as the main energy source is too much because the cooking process takes 6-8 hours. In addition, the large amount of smoke produced during the cooking would infect the eyes off fromthe producers, which causes pain that may be a problem for producers' healthiness. Therefore, simple cooking technology prevents the producers from increasing the scale of business, although it is supported by the availability of a large number of sap sources. This condition causes many brown sugar producers to leave their businesses if other jobs are available. In general, producers utilize 3-10 trees with a production capacity of 5-10 kg of brown sugar per day.

The traditional cooking stove used to produce brown sugar from palm

Sketch of cooking stove used to produce brown sugar from palm

Figure 1. The Traditional Cooking Stoves Used To Produce Brown Sugar Form Palm Plants.

Energy-saving cooking stoves are generally used by brown sugar producers in Java, especially in East Java Province. This stove consists of 7-12 pans that are installed in a row above the heat channel so that all the pans can receive heat from one heat/fire source. For the manufacture of AT in the study location, the cooking stove consists of 5-7 pans with a size of 25-33 inches each (Figure 2). This cooking stove is equipped with a chimney, so there is no smoke coming out of the stove that makes brown sugar producers and their families like to work because there is no smoke in the cooking place.

The working principle of AT is to use heat energy effectively and maximally so that it does not use a lot of fuel. Fuel can be a wood, husk, or other agricultural waste. The kiln is only at one point at the front and heats the pan in the back. The heat flows from the front of the kiln to the back, then continues to rise through the chimney. The heat that flows through the bottom of the pan is lined up, heating the pan before the heat comes out through the chimney. For more details, see the picture of the cooking furnace AT construction in Figure 2. This technology is expected to be adopted by brown sugar producers, both for those who use palm and sugar cane as raw materials.

Energy-efficient cooking stove

Sketch of energy-efficient cooking stove

Figure 2. Energy-Efficient Cooking Stovefor Brown Sugar

3.4. Financial Analysis of Brown Sugar

Brown sugar is produced in the area of a hybrid coconut plantation. The coconut plantation cannot be managed by the owner because it requires labor for cultivation and costs for production inputs. The gross production value produced is around IDR 15.0 million/ha/year, before deducting the costs of production for fertilizers, pesticides, labor for cultivation,and post-harvest.

There are two hybrid coconut payment schemes with a contract period of one year: 1) payment at the beginning of the year with a rental value of IDR 20 million / ha/year; 2) monthly payments with a rental value of IDR 10 thousand / tree/month paid at the end of each month. Production costs and plant maintenance are charged to the brown sugar producers. The productivity of hybrid coconuts is influenced by maintenance because hybrid coconut is very responsive to the use of fertilizers.

One unit of brown sugar processing from hybrid coconut is 0.5 ha, consisting of 125-150 coconut trees. This business unit is managed by one household with two laborers, husband, and wife. Investment value and operational costs for the first year are IDR 15.5 million/ha, and it can be obtained NPV 257.7 million and R / C Ratio 5.08 if labor costs are not taken into account. If labor cost is calculated as much as Rp. 2.75 million / month (equivalent to Minimum Regional Wage-UMR in South Sulawesi), NPV 27.86 with R/C ratio 1.22. The processing of hybrid coconut brown sugar only creates labor opportunities for the producers itself, and the investment spent is equivalent to a 10 percent interest rate. This makes the coconut owner is not interested in producing brown sugar. The obstacle faced in processing brown sugar is the labor required for harvesting because all trees need to be harvested (climbed) twice a day.

Brown sugar businesses that use sugar cane as raw materials can be run in two business models: 1) separate brown sugar processing business with sugar cane planting business, 2) integration sugar cane plantation, and brown sugar processing. Sugar cane is processed into brown sugar using a small-scale press machine. The AT of an energy-efficient cooking furnace uses sugar cane bagasse as fuel, which is waste produced from the process of sugar cane pressing. This results in a reduction of wood fuel and labor use. Planting sugar cane on marginal land is not only a source of income but also functions as a conservation crop for marginal land and environment [38]–[40].

The values of investment and operational costs in the first year of brown sugar production from sugar cane are IDR 17 million/ha with business feasibility achieved at a discount factor of 12% is R/C ratio 3.30, and NPV IDR 107.2 million. Processing sugar cane into brown sugar can be done using AT sugar cane press machine and energy-efficient cooking stove by utilizing sugar cane bagasse as the fuel[34]. AT pressing machines can be made by local workshops, and cooking stoves can be built by farmers at a relatively small cost.

Sugar cane processing has been carried out by Nurhijrah Farmer Group in Toddopulia Village, Maros District. The farmer group utilized marginal land and using a small press machine made by a local workshop in Makassar. Maros District is next to Makassar as the capital city of South Sulawesi Province. The distance between the processing unit of Nurhijrah Farmer Group and Makassar is around 40 km or approximately 40 minutes by car. The investment value of IDR 32.5 million with operational and maintenance costs of IDR 77.6 million for a year. Finally, the results achieved were NPV IDR 183.6 million and R/C Ratio 1.50.

Table 1. Financial Analysis of Brown Sugar for Sugar Cane And Coconut

No.	Description	Sugar cane farm	Brown sugar from sugar cane	Brown sugar from coconut
1	Land used (ha)	1.0	0.05	0.50
2	Investment (IDR Million)	24.0	32.5	15.5
3	Operation and Maintenance (IDR Million)	10.5	77.6	14.3
4.	Net Present Value (DF 12%) (IDR Million)	1001.22	283.12	257.74
5.	R/C Ration (DF 12%)	3.34	1.82	1.22

3.5. Potential Impacts of The Brown Sugar Business with Appropriate Technology

There are two categories of potential impacts resulting from the development of brown sugar from coconut and sugar cane, which are direct and indirect impacts. The resulting impact on the

processing of coconut-based brown sugar is an increase in productivity, economic scale, and product quality. In addition, reducing the use of wood fuel could be achieved by 70-80 percent and, at the same time utilizing agricultural waste as an energy source. Other impacts resulting from the processing of brown sugar from coconut is to encourage the development of *aren* and fan palm cultivation for brown sugar production, to protect forest because it does not use a lot of wood as fuel in the cooking process, to contribute as an export commodity, and at the same time producing various side products plan trees.

The resulting impact on the production of brown sugar from sugar cane is the use of marginal land and unproductive land, and at the same time, sugarcane plants function as conservation plants, create employment opportunities, etc. (Table 3). The direct impact resulting from the use of AT energy-efficient cooking stoves is to reduce production costs from the use of fuel, reduce labor on the cooking process, thus encouraging people to work, especially for rural people.

Table 3. Potential Impacts of Using AT on Brown Sugar Production

Brown sugar from coconut	Brown sugar from sugar cane
Direct Impacts	
Increase production/economic scale	The utilization of marginal land
Energy efficiency in wood fuel	New income source
Increase product quality	Create employment for the rural poor
The utilization of agricultural waste as an alternative energy source	Land conservation
Forest conservation	Raw sugar for crystal sugar
Organic sugar product	Organic sugar product
Indirect Impacts	
Extension of brown sugar production to *aren*to fan palm	Beef cattle integration
Encourage palm sugar export	Import substitute of crystal sugar
Support the economic scale on transportation and trading	Encourage brown sugarcane export
Create employment for the rural poor	Encourage other organic agriculture products
Enterprise diversification	

3.6. Potential for Brown Sugar Development in South Sulawesi

The potential for developing brown sugar business is large, both from coconut and sugar cane. Potential raw material sources for producing brown sugar are sugar cane, aren, fan palm, and hybrid coconut. The three types of palm plants are abundant in South Sulawesi. In addition, there is agricultural land which is very suitable for sugar cane without disturbing other agricultural commodities. This potential can be developed by facilitating the number of poor people in South Sulawesi with a total 779.64 thousand or around 8.89 percent of the population of South Sulawesi (8,771.97 thousand people). About 610.940 or 78.36 percent live in rural areas of the total poor population in South Sulawesi [10].

Demand for brown sugar continues to increase along with the increase in people's welfare. Brown sugar is very popular because it is considered healthy, natural, and does not use chemicals in the production process, as does the production of crystal sugar[5], [41]. Even brown sugar from aren and fan palm can be considered to be organic sugar[42]. All these conditions can encourage the utilization of agricultural resources to increase brown sugar production and, at the same time, preserve natural resources. Coconut productivity in South Sulawesi is very low when compared to its potential production oftall coconut productivity. It is only about 0.77 tons/ha or around 20 percent of the minimum potential of tall coconut for copraproduction (3 tons/ha) and 0.44 tons/ha or around 12.5 percent of the minimum potential of hybrid coconut copra production (3.5 tons /ha). The existence of tall coconut as a substitute for coconut and copra from hybrid

coconut encourages the owners of hybrid coconut plantations to prefer producing brown sugar. The availability of family labor or the existence of poor people who want to partner with the owners of hybrid coconut plantation can support the production of brown sugar. Job opportunities that can be created are two labors/ha from sugar cane, four labor/ha from hybrid coconut, and 0.2 labor/tree from aren and fan palm. The number of farmers involved in making palm sugar is around 8,162 households. If all the workforce involved increases their capacity to 20 kg ha/ day from *aren* and fan palm with 300 effective working days per year. The production of brown sugar that can be produced in South Sulawesi from the palm is around 224,000 tons per year.

Table 4. The potency for Brown Sugar Development Based on Different Raw Materials

Palm Tree	Farmers/ Enterprise	Main Products	Area (ha)	Production (ton)	Productivity (ton/ha)
Smallholder					
Tall coconut	88,467	Dried coconut	88,467	68,078	0.77
Hybrid coconut	13,838	Dried coconut	13,838	6,132	0.44
Aren	6,135	Brown sugar	6,135	4,383	0.71
Fan Palm	2,027	Brown sugar	2,027	710	0.35
Private Plantation					
High coconut	1	Dried coconut	806	149	0.18
Hybrid coconut	1	Dried coconut	600	3	0.005

If 50,000 ha or about 14.62 percent of marginal land in South Sulawesi is used, with an average potential sugar production of 60 tons/ha of sugar cane on marginal land with a 10 percent conversion factor of cane to brown sugar, brown sugar production can be reached around 300 thousand tons or around 12.5 percent of national sugar production. The potential of brown sugar from palm and sugar cane, which can be produced in South Sulawesi, is around 525 thousand tons per year.

Table 5. The Potency of Land for Sugar Cane Cultivation In South Sulawesi, Indonesia, 2018

No.	Land	Total (ha)	Percent (%)
I	**Agricultural Land 2018***	3,035, 289	100
1	Garden	501,918	16.54
2	Agricultural and Huma fields	107,759	3.55
3	Temporary unused land	105,753	3.48
4.	Other lands (plantation, social forestry, etc.)	2,319,859	76.43
5	*Marginal land 2016***	*189,345*	*12.48*
II	**Marginal Land****	**342,094**	**100**
1.	Marginal land of agriculture	189,341	55.35
2.	Marginal land in the forest and social forest	152,753	44.65

Source: * South Sulawesi in Figure 2019.
** South Sulawesi in Figure 2017.

Brown sugar business, both made from palm and sugar cane, is financially beneficial, especially for the rural poor. An attractive business of brown sugar is sought for the community if economies of scale can be improved and developed. Marketing margins can be reduced through increased productivity, the scale of production, and a number of processing units at one production center. Cost reduction occurs because the economies of production, efficient handling, marketing, and transportation can be achieved. This condition can be realized if supported by local government policies in encouraging the use of AT and the development of areas or centers for the development of brown sugar[43].

4. Conclusion

Brown sugar from hybrid coconut and sugar cane is financially, economically, and environmentally feasible to be developed if supported by the use of AT energy-saving cooking stoves. Energy from wood fuel can be saved 70-80 percent in the processing of brown sugar from coconut. Forest conservation can be done from the development of AT-based brown sugar from coconut. The production of brown sugar from sugar cane can also be done with the support of small-sugar cane pressing machines made locally. Sugar cane can be cultivated on marginal or unutilized land, thus creating employment opportunities as well as improving incomes of rural communities. The utilization of appropriate technology in a from the energy-efficient cooking stove for brown sugar production is suitable for rural poor. This expectation can be realized if it is supported by local government policy in encouraging the use of AT and the development of brown sugar production center.

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