Kajian "*Green Manufacturing*" pada UMKM Gula Kelapa Kristal Perdesaan

Study of "Green Manufacturing" on Rural Crystal Coconut Sugar SMEs

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ABSTRAK
Produksi gula kelapa kristal akan menghasilkan limbah yang akan berdampak terhadap pencemaran lingkungan. Limbah yang dihasilkan yaitu limbah cair dan limbah padat. Penanganan pengurangan limbah dapat diterapkan prinsip "*green manufacturing*". Tujuan penelitian adalah: (1) mengidentifikasi limbah yang dihasilkan, (2) menentukan peluang *green manufacturing*, (3) Menganalisis kelayakan terhadap peluang *green manufacturing*, dan (4) Menentukan prioritas penerapan *green manufacturing*. Tahap penelitian meliputi: (1) analisis *quick scan*, (2) identifikasi aliran material, energi, dan limbah, (3) alternatif peluang *green manufacturing*, (4) analisis kelayakan (finansial, teknis, dan lingkungan), dan (5) penentuan prioritas penerapan *green manufacturing*. Hasil penelitian menunjukkan produksi gula semut menghasilkan limbah berupa kotoran pada nira, abu sisa pembakaran, *loss energy*, inti kristal, dan ceceran gula. Alternatif *green manufacturing* yang layak secara teknis, lingkungan, dan finansial yaitu pemanfaatan abu menjadi pupuk anorganik, mengganti tungku pemasakan, modifikasi peralatan pengeringan, mengganti bahan proses, perbaikan dan modifikasi peralatan pengayakan, pengeringan, dan pengemasan. Prioritas penerapan alternatif *green manufacturing* menunjukkan alternatif utama untuk diimplementasikan yaitu perbaikan dan modifikasi peralatan pengayakan, pengeringan, dan pengemasan dinilai baik dalam kriteria kemampuan teknis dan teknologi, finansial, sumber daya manusia (SDM), dan lingkungan. Hasil ini menunjukkan bahwa "*Green Manufacturing*" pada UMKM gula kelapa kristal perdesaan untuk meningkatkan daya saing global "*Green Economy*".

ABSTRACT
Crystal coconut sugar production will produce waste which will have an impact on environmental pollution. Waste generated is liquid waste and solid waste. Waste reduction handling can be applied to "green manufacturing" principle. Research aims are: (1) identify waste generated, (2) determine green manufacturing opportunities, (3) green manufacturing opportunities analyze feasibility, and (4) green manufacturing implementation determine priority. Research phase includes: (1) quick scan analysis, (2) material, energy and waste flows identification, (3) alternative green manufacturing opportunities, (4) feasibility analysis (financial, technical and environmental), and (5) determination green manufacturing

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implementing priority. Results showed that ant sugar production produces waste in excrement on sap form, ashes from combustion, energy loss, crystal nuclei, and spilled sugar. Green manufacturing alternatives that are technically, environmentally and financially feasible are ash into inorganic fertilizers utilization, replacing cooking furnace, modifying drying equipment, replacing process materials, repairing and modifying screening, drying and packaging equipment. Implementing green manufacturing priority alternatives indicates that main alternatives to implemented are repairs and screening, drying and packaging equipment modifications which are considered technical and technological capabilities good in criteria, finance, human resources (HR), and environment. These results indicate that "Green Manufacturing" in rural SMEs crystal coconut sugar to increase global competitiveness "Green Economy".

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1. Introduction

Coconut sugar is the result of processing coconut sap which has a distinctive taste. Coconut sugar can be used as a sweetener and even to give chocolate color to food [1]. Coconut sugar can be used as a sweetener and even to give chocolate color to food [1]. Crystal coconut sugar is coconut sugar in the form of powder made from coconut sap, and is a solution of coconut molded sugar that has been re-melted with the addition of water at a certain concentration [2]; [3]. The quality of crystal coconut sugar is largely determined by the main raw material, namely coconut sap. The form of crystalline coconut sugar is in the form of powder or fine granules which causes the sugar to dissolve easily so it is practical in serving, easy to pack, carry, and has a long shelf life because it has a low water content [1]. The processing of crystal coconut sugar also produces various wastes that need to be managed properly. Color is one of the essential attributes as product quality criteria that determine the acceptance of a product by consumers. Granulated palm sugar is a crystalline form, which is hygroscopic [4].

Waste generated from processing coconut crystal sugar has an impact on environmental pollution. Waste that is usually generated from crystal coconut sugar SMEs is liquid waste and solid waste. Solid waste can be generated from crystalline coconut sugar that is scattered on the floor. Liquid waste can be generated from washing tools and machines [5], so there is a need for further handling to reduce the generation of waste in each process. Handling waste reduction can be applied to the principle of "green manufacturing".

Green manufacturing is a sustainable activity of an integrated environmental impact mitigation strategy whose implementation includes the production process, product handling to marketing to improve resource efficiency and reduce impacts on humans and the environment [6]. It is intended to reduce the environmental impact of industrial activities and is built on the 3P (pollution, prevention, pays) concept. Green manufacturing is directed to business, industry (processes and products) and services. The definition in the technical aspect is that the green manufacturing strategy is basically related to operations, environmental sustainability and maximizing waste reduction, recycling, and use at the company level, and within the scope of microeconomics [7].

According to [8] green manufacturing is a productive strategy to prevent/reduce the impact on the environment, more efficient use of resources, especially because of its potential to improve operational control and generate financial benefits for the company [9]. [10] stated, green manufacturing is about the use of energy and materials that are minimal but more efficient and the substitution of products that are more dangerous (for the environment and health) with less harm to health and the environment. According to [6] the purpose of implementing green manufacturing is to increase productivity by providing a better level of efficiency in the use of raw materials, energy and water, in order to encourage better environmental performance through reducing waste and emission generating sources as well as reducing the environmental impact of product life cycle with an environmentally friendly yet cost effective design.

Green manufacturing is an environmental management strategy that is preventive in nature and integrated so that it can be applied to the entire production cycle. Green manufacturing aims to increase productivity by providing better efficiency levels in the use of raw materials, energy and water, encouraging better environmental performance through waste and emission generating sources and reducing the impact of products on the environment through environmentally friendly, yet effective designs, in terms of costs [11]. In addition, according to [12], [13], [14], and [15] stated that institutional pressure is the main motivator for companies/industry players to find innovations in environmentally friendly processes and products. According to [16], hierarchy is defined as a representation of a complex problem in a multi-level structure, where the first level is the goal, followed by the level of factors, criteria, sub-criteria and so on down to the last level of alternatives.

The production process of coconut crystal coconut sugar has the opportunity to be applied to green manufacturing as various processes improvement. The application of green manufacturing is carried out to increase efficiency, reduce pollutants and wasted energy to get better profits. This can be done by eliminating waste, recycling waste, or utilizing waste for process improvement. The resulting design will be subjected to a feasibility analysis, especially from a financial perspective, to determine whether the new design is feasible to implement. The waste management alternative in the Wulan Coffee Agroindustry were coffee pulp waste processing i.e., cascara tea, briquettes, and animal feed, also the waste water of coffee processing as biogas. The cleaner production applied in the Wulan Coffee Agroindustry had an alternative of cascara tea [17]. The study of "green manufacturing" on rural crystal coconut sugar SMEs to increase the global competitiveness of the "green economy" is very important to be developed. Thus, strengthening food MSMEs based on green manufacturing will strengthen the nation's economy towards global competitiveness in the era as a form of commitment in the green economy era.

2. Materials and Methods

2.1. Materials and Tools

The materials used in this study were sap, sodium bisulfite, water, firewood, LPG, quicklime, and plastic packaging. The equipment used are juice containers, cooking stoves, cooking pans, rotating rack dryers, packaging, thermometers, scales, and power meter.

2.2. Research Variables

Research variables in this study include: mass and energy. The mass includes the sap mass, cooking mass, wet crystalline coconut sugar mass, dry crystalline coconut sugar, and packaged coconut sugar mass. Energy includes juice extraction energy, cooking energy, crystallization energy, drying energy, and packaging energy.

a. Energy Extraction

The energy extraction process typically involves converting a form of energy into a more useful form, such as converting the chemical energy in fuel into electrical energy. The steps involved in this process can vary depending on the specific technology and system being used. Here are some general steps that may be involved: (1) Fuel preparation: This step involves preparing the fuel by processing, refining, and/or treating it to make it suitable for energy extraction. (2) Combustion or reaction: The fuel is burned or otherwise reacted to release its energy in the form of heat. (3) Heat transfer: The heat generated in step 2 is transferred to a fluid or other material, such as steam or a gas. (4) Energy conversion: The transferred heat is used to drive a turbine or other mechanical device, which converts the heat energy into mechanical energy. (5) Electrical generation: The mechanical energy is then converted into electrical energy using a generator.

To measure the efficiency of this process, various metrics can be used, such as: (1) Energy conversion efficiency: This is the ratio of the useful energy output to the energy input. It measures how well the system converts the

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energy in the fuel into useful electrical energy. (2) Heat rate: This is the amount of fuel energy required to generate one unit of electrical energy. It is a measure of the system's efficiency in converting fuel energy into electrical energy. (3) Emissions: The amount and type of emissions produced during the energy extraction process can also be measured to assess the environmental impact of the process.

b. Cooking Energy

The process of cooking palm sugar involves converting the sap of palm trees into a thick syrup by boiling it down. The energy required for this process can be calculated and measured using the following steps: (1) Determine the amount of palm sap: The first step is to determine the amount of palm sap that will be processed. This can be measured by volume or weight. (2) Calculate the energy required for boiling: The energy required to boil the palm sap can be calculated using the following formula:

Energy = (mass or volume of sap) x (specific heat of sap) x (temperature increase)

$$E_c = m_s\, C_p\, \Delta t \qquad (1)$$

Where:

E_c : cooking energy (J)

m_s : mass of sap (kg)

Δt : temperature increase (°C)

The specific heat of palm sap is approximately 1.44 J/g°C, and the temperature increase will depend on the desired consistency of the syrup.

c. Crystallization Energy

The process of crystallizing palm sugar involves cooling and agitating the boiled sap to promote the growth of sugar crystals. The energy required for this process can be calculated and measured using the following steps: (1) Determine the amount of palm sugar syrup: The first step is to determine the amount of palm sugar syrup that will be crystallized. This can be measured by volume or weight. (2) Calculate the energy required for cooling: The energy required to cool the palm sugar syrup can be calculated using the following formula:

$$E_{cr} = m_s\, C_p\, \Delta t \qquad (2)$$

Where:

E_{cr} : crystallization energy (J)

m_s : mass of sap (kg)

Δt : temperature increase (°C)

The specific heat of palm sugar syrup is approximately 1.34 J/g°C, and the temperature decrease will depend on the desired crystallization temperature.

d. Drying Energy

The process of drying palm sugar involves removing moisture from the sugar crystals to achieve the desired moisture content. The energy required for this process can be calculated and measured using the following steps: (1) Determine the amount of palm sugar crystals: The first step is to determine the amount of palm sugar crystals that will be dried. This can be measured by weight or volume. (2) Calculate the energy required for moisture removal: The energy required to remove moisture from the palm sugar crystals can be calculated using the following formula:

$$E_d = m_p\, C_p\, \Delta t \qquad (3)$$

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Where:
E_d : dyring energy (J)
m_p : mass of product (kg)
Δt : temperature increase (°C)
The specific heat of palm sugar crystals is approximately 0.71 J/g°C, and the latent heat of vaporization of water is 2,260 kJ/kg at atmospheric pressure. The moisture reduction will depend on the desired moisture content of the final product.

e. Packaging Energy

The process of packaging palm sugar involves putting the dried and crystallized sugar into appropriate packaging material to preserve and protect it for transport and sale. The energy required for this process can be calculated and measured using the following steps: (1) Determine the amount of palm sugar: The first step is to determine the amount of palm sugar that will be packaged. This can be measured by weight or volume. (2) Calculate the energy required for packaging: The energy required to package the palm sugar can be calculated using the following formula:

$$E_p = m_s\ C_p\ \Delta t \qquad (4)$$

Where:
E_p : packaging energy (J)
m_s : mass of sugar (kg)
Δt : temperature increase (°C)
The specific energy consumption of the packaging equipment will depend on the type of equipment used, such as manual or automated, and the packaging material used, such as plastic or paper.

2.3. Research Stage

This research was conducted in several stages which is shown in **Figure 1**. These stages include: (1) quick scan analysis, (2) identification of material, energy, and waste flows, (3) alternative green manufacturing opportunities, (4) feasibility analysis (financial, technical, and environmental), and (5) prioritizing the implementation of green manufacturing.

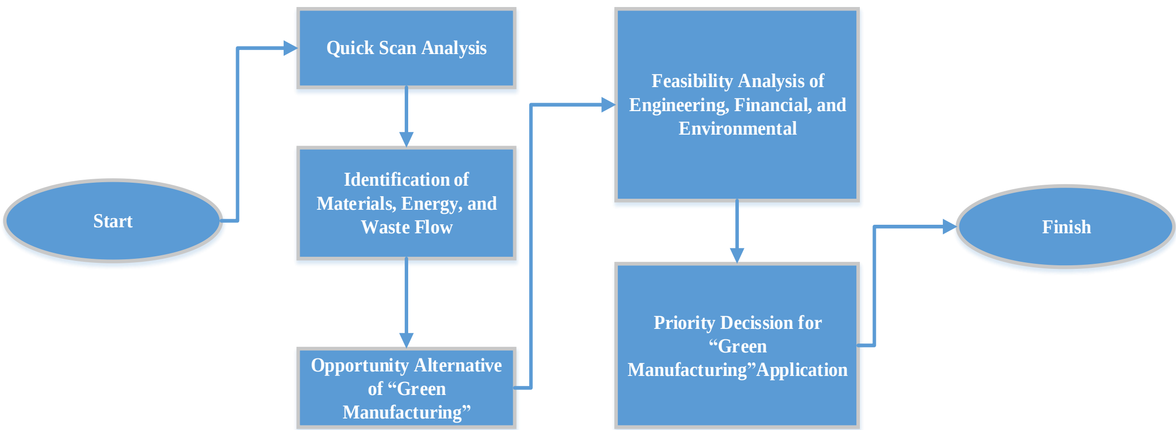

Figure 1. Flowchart of research

2.4. Research Procedure

2.4.1. Quick Scan

Quick Scan is an initial study of the production process of a company followed by a brief analysis and becomes an indicator of the potential application of green manufacturing [8]. In the quick scan analysis, environmental risk identification and

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analysis of waste formation are carried out quickly to provide a basis for determining the activities obtained to be applied as green manufacturing activities in coconut sugar MSEs in Banyumas Regency, Central Java.

Quick scan analysis is a tool used in green manufacturing to identify opportunities for improving environmental performance and reducing resource use in manufacturing processes. Mapping and sampling are two key steps in the quick scan analysis process. Mapping involves creating a visual representation of the production process, including inputs, outputs, and material flows. This allows for a better understanding of the different stages of the process and where potential opportunities for improvement may lie. The map can also help identify potential sources of waste, emissions, and energy use. Sampling involves taking measurements of different inputs and outputs at different stages of the production process. This can include measuring the number of raw materials used, energy consumption, and emissions generated. Sampling can also involve collecting data on the efficiency of specific pieces of equipment or processes. The information gathered through mapping and sampling can be used to identify areas where improvements can be made, such as reducing waste or energy use, or improving the efficiency of certain processes. This information can also be used to develop a plan for implementing changes and tracking progress over time. Overall, mapping and sampling are important tools in the quick scan analysis process as they provide a clear understanding of the production process and identify opportunities for improving environmental performance and reducing resource use.

To determine if a quick scan analysis is needed, we need to assess the variation in the cases. If the variation is high, it indicates that there may be significant differences in environmental performance and resource use between different production processes, and a quick scan analysis can help identify opportunities for improvement. One way to assess the variation is by calculating the coefficient of variation (CV), which is the ratio of the standard deviation to the mean, expressed as a percentage. A high CV indicates a high degree of variation in the data.

2.4.2. Determination of Alternative Green Manufacturing Opportunities

Determination of green manufacturing opportunities is carried out based on the waste and loss formed during the processing of crystalline coconut sugar at the level of craftsmen (SMEs), collectors, and industries. Green manufacturing activities are activities carried out to minimize waste and losses are formed through: good house-keeping, changes in input materials, changes in technology, changes in products, on-site reuse. Determination of green manufacturing alternatives based on literature search.

2.4.3. Feasibility Analysis

One of the problems that arise in planning the improvement of a production business is analyzing the feasibility aspect. It is important to conduct a feasibility analysis to provide a solid foundation for whether the activity industry is worth continuing or carrying out. Feasibility analysis consists of technical, environmental, and economic. Technical analysis can be done based on literature review and interviews with related parties. Environmental analysis aims to determine whether the determination of green manufacturing opportunities is able to reduce the impact of pollution in an industry, is able to minimize waste, and is able to support the concept of environmental protection. Financial analysis aims to estimate the costs and possible savings and benefits that can be obtained by implementing green manufacturing.

$$NetB/C = \frac{\sum_{i=1}^{n} N\overline{B}_i(+)}{\sum_{i=1}^{n} N\overline{B}_i(-)} \quad (5)$$

2.4.4. Priority Selection Analysis with MPE Method

The selection of alternative priorities for green manufacturing in this case study uses the Exponential Comparison Method (MPE). Exponential Comparison Method (MPE) is one method to determine the priority order of decision alternatives with multiple criteria.

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The MPE (Material-Product-Environment) method is a systematic approach used to analyze the environmental impact of products and processes. In the development of the MPE method, researchers have identified a priority scale for the variables used in the analysis. The priority scale is used to determine the relative importance of different variables and guide the analysis process. The order of the priority scale is as follows:

1. Material consumption: Material consumption refers to the number of raw materials used in the production process. It is considered the most important variable as it directly affects the depletion of natural resources.
2. Energy consumption: Energy consumption refers to the amount of energy used in the production process. It is the second most important variable as it contributes to the depletion of natural resources and can result in emissions and other environmental impacts.
3. Emissions: Emissions refer to the release of pollutants and other harmful substances into the environment during the production process. Emissions are the third most important variable as they can have a significant impact on air and water quality, and human health.
4. Waste: Waste refers to the amount of material or products that are discarded during the production process. Waste is the fourth most important variable as it can contribute to pollution and environmental degradation.
5. Water consumption: Water consumption refers to the amount of water used in the production process. It is the least important variable as it is less directly linked to environmental impact compared to the other variables.

2.5. Data Analysis

The data were analyzed using the AHP method consisting of several steps: (1) Compiling a hierarchy of problems encountered in the factory, (2) Determining the priority of elements by making pairwise comparisons, filling in the matrix, and synthesizing.

2.6. Method of Interpretation and Conclusion of Research Results

Processing data in this study using Microsoft Excel 2013 and SPSS 16 for Windows. The result data were analyzed descriptively AND mathematically based on measurements and field data. The formulation of the opportunity strategy for implementing green manufacturing is made by analyzing the 5M elements (man, materials, methods, money, machines) in each factory. The strategy formulation is formulated with the aim of making it easier for factory owners if these options/alternatives are implemented.

3. Results and Discussion

3.1 Crystal Coconut Sugar Production Process

The production process of crystal coconut sugar starts from the collector's level (SMEs) which consists of crystal coconut sugar craftsmen. The processing process at the level of crystal coconut sugar craftsmen includes tapping the juice, filtering the juice, heating and stirring, stirring without heat, drying, stirring and grinding, and sifting. Tapping of sap is carried out twice a day, in the morning and in the evening in the coconut groves of each craftsman. The tapped nira will immediately undergo a screening and cooking process of the sap. Tapped nira should not be left for long because it will affect the freshness of the sap. This is in accordance with [18] which state that the wiretapping process is carried out twice a day, namely in the morning and evening. Each sapling has 2 bunches that can be tapped. The process of tapping and storing the sap can affect the freshness of the sap because the sugar contained in the sap is very easy to ferment. Furthermore, the sap is separated from the impurities through a filtering process. The dirt found in coconut juice is in the form of insects and young flowers (manggar). The clean nira is carried out cooking using furnace heat. The furnace used by craftsmen is a traditional furnace made of clay. In the cooking process, coconut oil is added as much as 1 spoon. The addition of coconut oil in the process of cooking sap aims to control the formation of foam so that it does not spill.

Furthermore, the coconut juice that has begun to thicken will be lifted from the furnace and then stirred until it is slightly dry. In the stirring process, a crystal nucleus or brondol is added which aims to facilitate the crystallization of crystalline coconut sugar. The addition of crystal nuclei will provoke the formation of sugar crystals [19]. The crystallization process is the process of evaporating water contained in viscous juice and forming sugar crystals with a diameter according to standards by suppressing sugar loss. The sugar formed will then be dried by allowing it to stand and forming lumps. The sugar lumps are then stirred and grinded to make them smaller in size to be further filtered with a 16-mesh sieve. In addition, crystalline coconut sugar must have quality standards regulated in the Indonesian National Standard (SNI) 3743-2021 [20] in **Table 1** as follows.

Table 1. Quality requirements of crystalline coconut sugar in accordance with SNI 3743-2021

No.	Criteria Test	Unit	Requirements
1	Circumstances		
	Color	-	Normal (light brown to dark brown)
	Smell	-	Normal (typical of palm sugar)
	Taste	-	Normal (typical of palm sugar)
2	Particle size	mm	Maximum 1.41
3	Water insoluble material	%	Maximum 1.0
4	Ash content	%	Maximum 2.5
5	Moisture content	%	Maximum 3.0
6	Reducing sugar	%	Maximum 3.0
7	Sugar (calculated as saccharose)	%	80 - 93
8	Heavy metal contamination		
	Lead (Pb)	mg/kg	Maximum 0.25
	Cadmium (Cd)	mg/kg	Maximum 0.20
	Tin (Sn)	mg/kg	Maximum 40
	Mercury (Hg)	mg/kg	Maximum 0.03
	Arsenic (As)	mg/kg	Maximum 1.0

Source: [20]

The mass balance of the process of processing crystalline coconut sugar at the level of the crystal coconut sugar craftsman can be seen in the **Figure 2**.

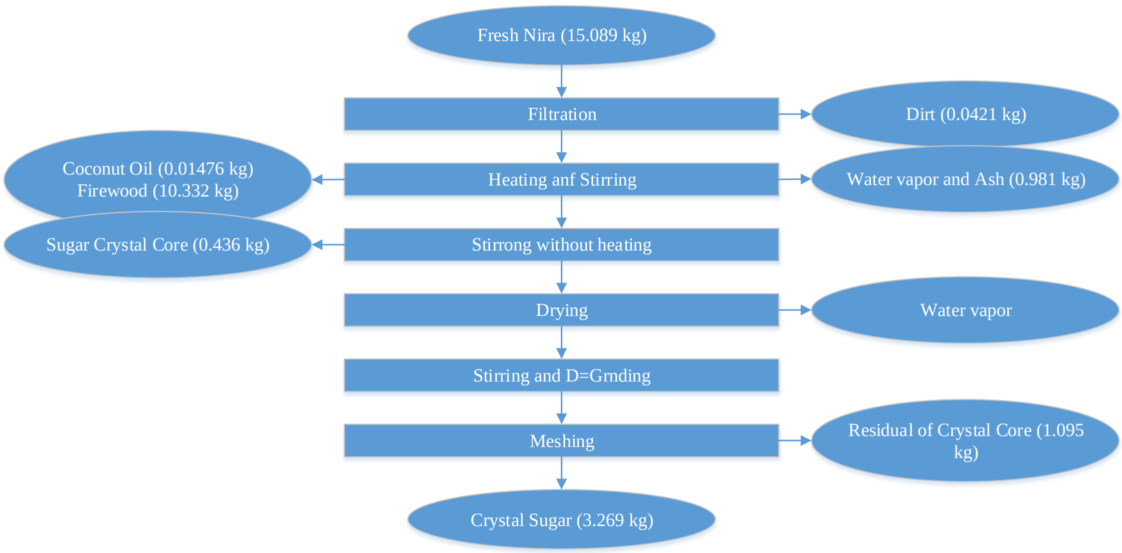

Figure 2. Mass balance of the crystal coconut sugar production process at the level of crystal coconut sugar craftsmen

a. Tapping Coconut Nira

Nira tapping is an activity to take sap which is used as raw material for making crystal coconut sugar. Tapping coconut sap which is done manually by craftsmen. Tapping sap is done every day, namely in the morning and evening. Tapping

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the sap is done when the coconut tree is 8 years old. The steps that need to be done before tapping coconut sap are determining bunches to be tapped and cutting bunches [18].

b. Filtering

Filtering is done with a regular filter made of plastic (HDPE Orange Plastic Wire Mesh Safety Fence) and cloth. Filtering aims to separate the sap from impurities such as insects. The presence of dirt in the sap is caused because the roof or the sap container is not covered. The sap that has been filtered will immediately carry out the cooking process. The average amount of waste obtained by the craftsmen for each tapped sap is 0.0421 kg from 15,089 kg of fresh sap from the tapping. The mass balance of the filtering process is shown in the **Figure 3** below.

Figure 3. Mass balance at the sugar craftsman level filtering process crystal coconut

c. Heating and Stirring

The sap cooking is done immediately after the filtering process using a traditional wood-fueled stove. The furnace used by the craftsmen is a furnace made of clay. The average firewood used is 10.332 kg. The heating and stirring time of the juice takes approximately 2 hours-3 hours (reach the sugar crystallization phase). In the heating process, the sap needs to be added with coconut oil. The average coconut oil added by the craftsmen is 0.01478 kg. This process produces waste in the form of ash from combustion of 0.981 kg each time of production. In addition, it also loses water vapor which causes the sap which has a liquid phase to thicken. The mass balance of the heating and stirring process is shown in the **Figure 4.**

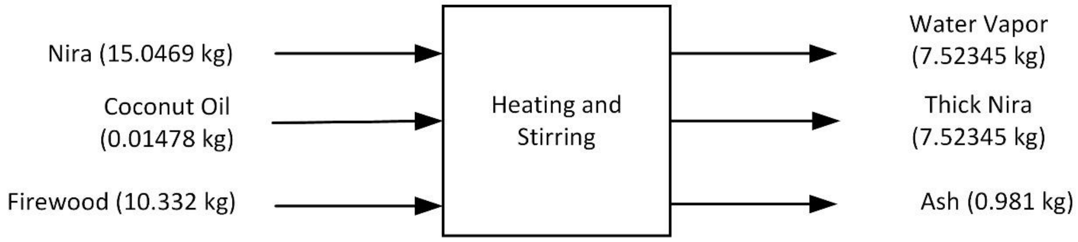

Figure 4. Mass balance in the heating and stirring process crystal coconut sugar craftsman level

d. Stirring without Heat

Once the sugar begins to thicken, it is removed from the stove and placed elsewhere. The sugar that has started to thicken is stirred until the texture becomes thicker. The speed of thickening depends on the water content in the sugar. The higher the water content, the longer the sugar will curdle. In this process, a crystal core/brondol is added. The addition of a crystal core aims to speed up the crystallization process. This is in accordance with the opinion of [19] which states that the addition of sugar will provoke the formation of sugar crystals. The average crystal nucleus added was 0.436 kg. The mass balance of the heat-free stirring process is shown in the **Figure 5.**

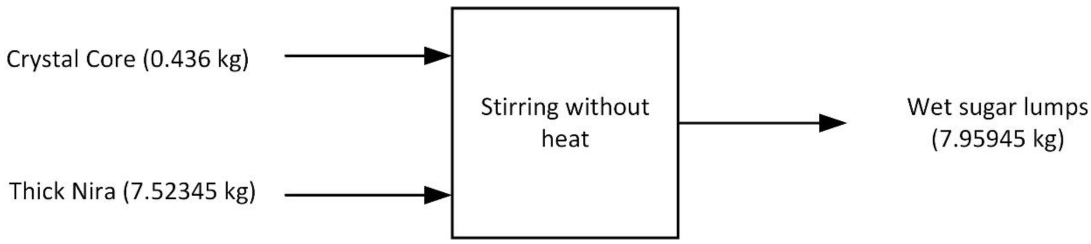

Figure 5. Mass balance in the heat-free stirring process crystal coconut sugar craftsman level

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e. Drying

After the addition of crystal nuclei and the stirring process, the sugar is dried. This drying aims to make it easier for the sugar to be stirred and ground. Drying is done only by standing still. Drying takes 5-10 minutes. The mass balance of the drying process is shown in the **Figure 6.**

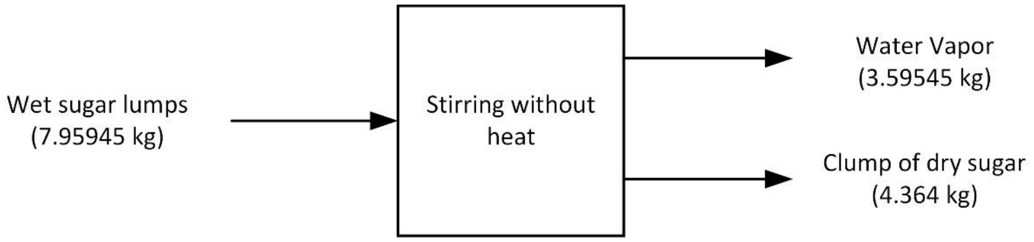

Figure 6. Mass balance in the drying process at the level of sugar craftsmen crystal coconut

f. Stirring and Grinding

After the sugar lumps have started to dry a little, the stirring and grinding process is immediately carried out. Grinding is done manually with the help of coconut shells. The purpose of this stirring and grinding is to make the sugar lumps into crystal sugar or in the form of finer granules and so that it can be sifted. Losses in stirring and grinding are very small, so it is assumed to be zero and it's shown in **Figure 7**.

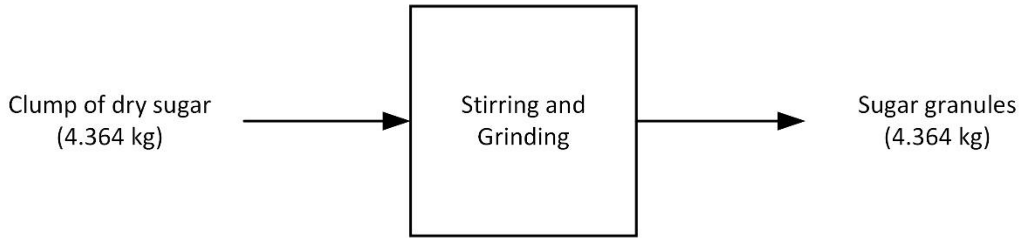

Figure 7. Mass balance in the process of stirring and grinding at the level of crystal coconut sugar craftsmen

g. Sifting

Sieving aims to produce a product, namely coconut sugar crystals with a size that has been determined by the industry. Crystal coconut sugar sieved with 16 mesh sieve size. According to [21] sifting in crystalline coconut sugar aims to separate refined sugar granules and large sugar granules. Each sifting process will produce coconut sugar crystals with a predetermined size and the remaining crystal core / loose fruit. The average brondol that comes out is 1.095 kg. The mass balance of the sieving process is shown in the **Figure 8.**

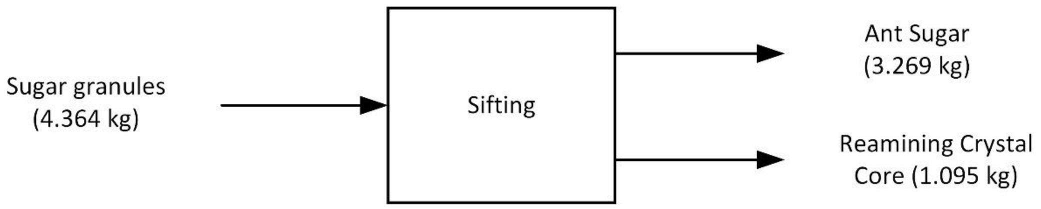

Figure 8. Mass balance in the sieving process at the level of crystal coconut sugar craftsmen

3.3 Energy Use

The production process of crystal coconut sugar at the Sari Manggar UMKM, Sunyalangu Village, Karanglewas District, Banyumas Regency, Central Java uses several tools and machines whose power source comes from electricity such as scales, sieves, ovens, and metal detectors. Sari Manggar SMEs use electricity from the State Electricity Company (PLN). Electricity needs for collectors also come from PLN with a total consumption of 6,182 kWh-8,932 kWh per day. Sari

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Manggar SMEs also use gas fuel (LPG) for the drying process with an oven of 24 kg a day. Calculations regarding the energy use of crystalline coconut sugar can be seen in **Table 2.**

Table 2. Energy consumption of crystal coconut sugar production equipment

Process	Tool	Power (Watts)	Power (MJ)
Receive Raw Material	Scales	3.00	0.01
Sifting	Sieve	3,300.00	11.88
Drying	Oven	250.00	0.90
Sifting	Sieve	3,300.00	11.88
Metal	Metal Detection		
Packaging	Scales	3.00	0.01
Total		**6,856.00**	**24.68**

3.4 Net Production Alternatives

Alternative green manufacturing applied to the production process of crystalline coconut sugar is adjusted to the problems that occur in each crystal coconut sugar production process. The production alternatives made and obtained are the result of joint discussions with MSMEs sari Manggar.

Based on the technical feasibility of its application, green manufacturing alternatives that can be carried out by SMEs sari Manggar are (1) the use of ash into inorganic fertilizers which aims to utilize the waste formed during the sap cooking process, (2) replace cooking furnaces that aim to save firewood and to reduce the formation of ash waste, (3) modification of craftsman-level drying equipment aims to make it easier for craftsmen to drying crystal coconut sugar and producing crystalline coconut sugar which has a low moisture content, (4) providing a grinding machine aimed at grinding brondol / crystal nuclei to become crystalline coconut sugar, and (5) repairing and modifying metal sifting, drying, and sifting equipment in the main factory aimed at reducing the presence of sugar splatter on the floor. Net production alternatives are shown in the following **Table 3.**

Table 3. Clean product alternative

Process	Waste	Clean product alternatives
Cooking Nira	Ash obtained from the rest of the wood burning results	Utilization of ash into inorganic fertilizer
Cooking Nira	Loss Energy	Replacing the cooking furnace
Drying	Brondol Due to the high moisture content in sugar ants	Modifications of drying equipment

3.4.1 Utilization of Ash into Inorganic Fertilizer

Based on research, in the process of cooking craftsmen-level sap, ash is produced from the rest of the wood burning. The resulting ash has not been utilized by craftsmen. Based on [22] stated that ash derived from plants such as firewood, copra, coconut husk, rice straw, and husk is an essential nutrient for plants grown on nutrient-deficient soils. With this, it is necessary to have a handling that can take advantage of the ash produced. An alternative that can be applied in this problem is the use of ash into inorganic fertilizers.

Fertilizer is a material needed for soil and plants in order to increase fertility and growth for cultivated plants [23]. The application of ash fertilizer can increase the growth of plants grown on nutrient-deficient soils [22]. Based on the results of wood ash analysis, there is a phosphorus content of 0.49%, potassium 1.45%, calcium 0.09%, magnesium 0.02%, and neralization power 53.93%. The application of wood ash fertilizer can improve chemical properties, namely increasing alkaline saturation and increasing nutrients, as well as improving biological properties, namely to stimulate the activity of

microorganisms so that it will accelerate the decomposition of organic matter. Wood ash can supply nutrients such as Ca and Mg needed by plants. Wood ash is also alkaline so that it can increase pH or reduce soil acidification [23].
The application of this alternative to green manufacturing can provide benefits for craftsmen. In the application of this alternative craftsmen require or invest sacks. Sacks aim to cool ash and ash storage. The advantage that will be received by craftsmen if they apply this alternative is inorganic fertilizer obtained in one day 196.2 grams, which will provide a profit of Rp. 1,165,435.44 in one year. In addition, the calculation of the B /C Ratio is 98.11. The B/C Ratio value in the calculation obtained by more than 1 indicates that this net production alternative is feasible to implement and get a Payback Period rate of return for 0.0102 years.

3.4.2 Replacing the Cooking Furnace

Based on research, the process of cooking sap requires firewood as a fuel medium. Firewood is a renewable energy source that has an important role for communities, especially rural areas [24]. In general, the wood used as firewood is wood located above the branching of the main trunk [25]. The use of firewood will result in producing waste in the form of wood ash. The more wood burned, the more ash will be formed. In addition, the furnace can affect the consumption of firewood. Craftsmen still use simple furnace technology, which results in air pollution because the smoke and gas output are still high [26]. An alternative that can be applied is to replace furnace materials with other materials that withstand high heat.
The furnace is a device designed as a place of combustion with the help of fuel. Artisans assisted by Sari Manggar SMEs in producing crystal coconut sugar still use traditional stoves. With the use of traditional stoves, the craftsmen need 9-11 kg of firewood in a day. An alternative that can be done is to replace traditional furnace materials with cement-cast concrete furnace materials. Based on research [26] to produce complete combustion, it is necessary to design the walls of the combustion chamber using high heat resistant materials. The results of the tests carried out [26] namely the modification of the furnace with walls made of cement cast is still higher in efficiency than the traditional furnace. The efficiency of the cement cast furnace is 16-20% while the traditional furnace is only 13%. With this statement it can be concluded that concrete stoves require 80% of wood from 100% of wood while traditional stoves require 87% of 100% wood. The advantage of applying this alternative is that craftsmen can save wood. If it is assumed that each process of making crystal coconut sugar only requires 1 bunch of firewood. 1 bunch of firewood weighs 7 kg. When using a traditional stove, craftsmen need 6,090 kg. Meanwhile, using a cast-cement concrete furnace only requires 5.6. So the craftsmen will save 1.4 kg of wood each process. The advantages obtained in the use of a cement cast concrete furnace are Rp 1,433,998.56 annually. In addition, the calculation of the B/C Ratio is 239.99. The value of the B/C Ratio in the calculation is found to be more than 1 indicating that this alternative to green manufacturing is feasible and will get a payback period of 0.0418 years.

3.4.3 Drying Equipment Modification

The drying process is a process of transferring heat and water vapor simultaneously which requires heat energy to evaporate the water content transferred from the surface of the material being dried by drying media such as air and heat. Drying is also known as hydration or partial and complete removal of moisture from a material. The main purpose of drying is for preservation. In addition, drying also aims to reduce packaging costs, reduce transportation weight, improve the taste of ingredients, and maintain the nutritional content of ingredients [27]. With this, drying in the production of crystalline coconut sugar is very important.
Based on the observations made on the crystal coconut sugar production process, the craftsmen did not do the final drying. The problem that often occurs in craftsmen when not drying is that crystal coconut sugar can have a high-water content, which is above 25% or is included in grade C and will be returned. Given this problem, the need for an alternative that aims to reduce the water content of the crystal coconut sugar by modifying the drying equipment by providing a pan that is useful as a container of crystal coconut sugar that can be used for drying on the stove with heat from the rest of the combustion. The application of this green manufacturing alternative can provide benefits for craftsmen. In the application of this alternative, craftsmen require or invest in a baking sheet. The financial benefits obtained in implementing this alternative are Rp 12,510,028.6 annually. In addition, the calculation of the B/C Ratio is 21.726. The value of the B/C Ratio

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in the calculation is more than 1, indicating that this alternative to green manufacturing is feasible and has a payback period of 0.324 years.

3.5 Priority Selection of Green manufacturing Opportunities

The selection of green manufacturing alternatives aims to provide an assessment of the recommended alternatives. The selection of this green manufacturing priority uses the Exponential Comparison Method (MPE) with several criteria, namely technical and technological capabilities, finance, human resources (HR), and the environment. Based on the results of the analysis, there are seven alternatives to green manufacturing, namely the use of ash into inorganic fertilizer, replacing the cooking furnace, modifying drying equipment, changing process materials, providing crystal core grinding machines, repairing and modifying sieving, drying, and packaging equipment. The results of the calculation of the financial analysis of net production opportunities can be seen in **Table 4** below.

Table 4. Value of alternative financial feasibility test for green manufacturing

Green manufacturing opportunities	PBP (year)	B/C Ratio	Investment (Rp)	Profit (Rp/year)
Utilization of ash into inorganic fertilizer	0.010	98.11	12.00	1,165,435.00
Replacing the cooking stove	0.042	240.00	60.00	1,433,998.00
Drying equipment modification	0.320	21.73	4,225,000.00	12,510,028.00
process material substance	0.026	38.48	336.00	12,595,200.00
Provide crystal core grinding machine	0.094	36.00	10,000,000.00	105,316,951.00
Repair and modification of screening, drying and packaging equipment	0.072	66.40	1,025,000.00	14,102,679.00

The assessment of net production opportunities in this case study uses three experts, namely two experts from SMEs Sari Manggar and one expert from academia. The results of the calculation with MPE with the first to seventh priority levels are shown in **Table 5** below.

Table 5. Results of prioritizing net production with MPE

Green manufacturing Opportunities	Score	Priority Level
Utilization of ash into organic fertilizer	3326	5
Replacing the cooking stove	4677	3
Drying equipment modification	6929	2
Changing process materials	4037	4
Provide Crystal core Grinding machine	1862	6
Repair and modification of sieving, Drying and Packaging equipment	7448	1

The priority of implementing green manufacturing alternatives based on the assessment shows that the first alternative that can be implemented is repair and modification of sieving, drying, and packaging equipment which is assessed both in terms of technical and technological capabilities, financial, human resources (HR), and environmental criteria. Repair and modification of equipment is considered both in terms of technical and technological capabilities because the means in procuring for repair and modification of equipment are considered easy to procure. Equipment repairs and modifications are considered good in financial criteria because SMEs are able to meet their cost needs. In terms of human resources (HR), it is considered a good criterion because the human resources (HR) owned by SMEs have a good level of ability to implement them. Environmental criteria are considered good because they have a positive influence on the production

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process, especially the impact on the environment. The company can implement green manufacturing based on the priority level that has been assessed or can apply all of the green manufacturing opportunities.

4. Conclusion

The production process of ant sugar produces loss or waste in the form of dirt on the sap, combustion ash, loss of energy, loose fruit or crystal cores, dirt in the form of grated coconut dregs, and sugar spills on the floor. Green manufacturing alternatives that are technically, environmentally and financially feasible are the use of ash into inorganic fertilizers, replacing cooking stoves, modifying drying equipment, changing process materials, repairing and modifying sieving, drying, and packaging equipment. The priority of implementing green manufacturing alternatives based on the assessment shows that the first alternative that can be implemented is repair and modification of sieving, drying, and packaging equipment which is assessed both in terms of technical and technological capabilities, financial, human resources (HR), and environmental criteria. These results indicate that "Green Manufacturing" in rural crystal coconut sugar SMEs to increase global competitiveness "Green Economy".

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