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ASSESSMENT OF VIRGIN COCONUT OIL (VCO) WITH GATE-TO-GATE LIFE CYCLE ASSESSMENT ANALYSIS APPROACH

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Abstract
VCO or Virgin Coconut Oil is a high-quality crude oil extract formed from coconut without chemical compound addition or high-temperature heating. The differences between VCO and other coconut oil are commercial coconut oil produced from copra or dried coconut meat. Life Cycle Assessment (LCA) is a method used to assess a product based on its lifespan, starting from extracting raw materials for the product to the industrial manufacturing process to product distribution. This LCA aims to implement zero waste on VCO Production by using wasted coconut water in some products that has economic value. The existing condition of VCO production produces environmental impacts in the form of eutrophication of 38940.7 g N eq and global warming of 10672.5 g CO2 eq. We suggest a solution for coconut water waster with two alternatives, namely nata de coco production and coconut shell charcoal. The scenario with nata de coco can reduce the impact of eutrophication to 598,6002 g N eq and global warming by 0.00049 g CO2 eq. Meanwhile, the coconut charcoal scenario produces a eutrophication impact of 649 g N and global warming of 10.67 kg CO2, eq. Options to improve environmental quality were selected based on wastewater parameters and the resulting CO_2 equivalent.

Keywords: *Coconut, oil, environmental, LCIA, openLCA*

Abstrak
VCO atau *Virgin Coconut Oil* adalah ekstrak minyak kelapa mentah berkualitas tinggi yang dibentuk dari kelapa tanpa penambahan senyawa kimia atau pemanasan suhu tinggi. Perbedaan antara VCO dan minyak kelapa lainnya adalah minyak kelapa komersial dihasilkan dari kopra atau daging kelapa kering. *Life Cycle Assessment* (LCA) adalah metode yang digunakan untuk menilai suatu produk berdasarkan umurnya, mulai dari ekstraksi bahan baku untuk produk hingga proses manufaktur industri hingga distribusi produk. LCA ini bertujuan untuk menerapkan *zero waste* pada produksi VCO dengan memanfaatkan limbah air kelapa menjadi beberapa produk yang memiliki nilai ekonomis. Kondisi eksisting produksi VCO menghasilkan dampak lingkungan berupa *eutrophication* sebesar 38940.7 g N eq dan *global warming* sebesar 10672.5 g CO2 eq. Kami menyarankan solusi untuk limbah air kelapa dengan dua alternatif, yaitu produksi nata de coco dan arang tempurung kelapa. Sekenario dengan *nata de coco* dapat menurunkan dampak *eutrophication* menjadi 598.6002 g N eq dan *global warming* sebesar 0.00049 g CO_2 eq. Sedangkan dengan skenario arang kelapa menghasilkan dampak *eutrophication* 649 g N dan *global warming* 10.67 kg CO_2, eq. Alternatif untuk meningkatkan kualitas lingkungan dipilih berdasarkan parameter air limbah dan ekuivalen CO_2 yang dihasilkan.

Kata Kunci : Kelapa, minyak, lingkungan, LCIA, openLCA

INTRODUCTION

Virgin Coconut Oil (VCO) is a high-quality crude oil extract formed from coconut without chemical compound addition or high-temperature heating (Seneviratne et al., 2009). The differences between VCO and other coconut oil are commercial coconut oil produced from copra or dried coconut meat. This drying process can be done with smoking, sunbathing, or both, so these methods use high-temperature heating and make the color of the oil darker than VCO and have a less coconut-like aroma. The color of VCO is transparent with low viscosity characteristics, high content of vitamin E, and antioxidants (Satheeshan et al., 2020), which are suitable for preventing dandruff, counteracting free radicals, and moisturizing the skin (Gediya et al., 2011). Despite high demand in the market, most VCO production is made in the home-scale industry. Because it was more efficient to do so because the majority of coconut fields own individually, and no government will focus on derivative products of coconut (Al Miradz, 2018). The home-scale industry's characteristic is not too efficient in raw material and energy consumption with a high quantity of waste produced due to lack of technology, skilled human resources, and no waste treatment infrastructure.

The waste from VCO production is the shell, husk, and oil cake. Every output of one-liter VCO requires 12 to 16 grains of coconut or 3.6 to 4.8 kg of coconut flesh, so the yield produced 20% up to 27% from the weight of

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coconut flesh (Surdianto et al., 2006). So that means up to 80% of coconut potentially becomes a waste. An innovation to minimize waste generated in VCO production is needed.
Reducing environmental impact can be done by providing processing solutions or replacing product materials. The determination of this alternative is also seen from the results of the LCA research, which measures the largest environmental impact resulting from the process (Suryawan et al., 2021; Chairani et al., 2021; Iqbal et al., 2021). From the results of the processing, the VCO material section appears which have the greatest environmental impact. Therefore, lLCA can be implemented to analyze the environmental impact of every step of the VCO's life cycle.

METHOD

Life Cycle Assessment (LCA) is a method used to assess a product based on its lifespan, starting from extracting raw materials for the product to the industrial manufacturing process to product distribution. The product that has damage needs reparation to maintain the product's usage and quality. When the product isn't suitable for use, it will be transferred and disposed of in the landfill or recycled (Suryawan et al., 2021).

Goal and Scope

The purpose of this research needs to be explained to know the final results to be achieved. Besides, public targets and reasons for research need to be determined to avoid ambiguity. A process is defined, developed, and refined at system boundaries (Figure 1 and Table 1) to achieve the LCA's goals.

Life Cycle Inventory (LCI)

Life Cycle Inventory is the methodology steps to create an inventory of input and output flows of a product. LCI is used as LCA's data collection of entire production processes. The data of LCI consist of detailed tracking of inflow and the outflow of the VCO production, including the number of raw materials, water, wastewater, and solid waste.

Life Cycle Impact Assessment (LCIA)

The production of VCO impacts the environment from every process that is passed. Every impact of each process needs to be evaluated first of its potential environmental impacts. LCIA determination uses the open LCA data processing application to determine the impact of production activity and reduce the impact of improved production processing. OpenLCA is software to help analyze the stages of LCA research. In the openLCA software, the first thing to do is create Flows, which are the input and output of all products, materials, or energy in a development's production process. Besides, a database is needed to operate software that functions as data on various things related to the production process, such as energy, materials, and the flow of emissions from a component, process, or product.

Interpretation

The interpretation of this study uses the contribution analysis method. Contribution analysis presents the environmental impact of each process to see which function has the most significant impact. The company or the government can take more appropriate steps for improvement in the future.

RESULT AND DISCUSSION

Goal and Scope

The purpose of goal and scope definition in the LCA phase is to determine this project's focus. This LCA aims to implement zero waste on VCO Production by using wasted coconut water in some product that has economic value. This research aims to develop VCO production in the small home industry to be more environmentally with gate-to-gate system boundaries (Figure 1).

This boundary is chosen from table environmental with higher results of the specific process's cumulative score, the priority to fix the pollution also generated higher and vice versa. There are still more other factors from those processes that are still to be considered for implementing new or renewed steps to decrease the pollution and waste produced. Implementing a new method with simple technology and the minimum investment is essential since this VCO factory is a home industry. The Coconut heating process in this industry already uses low emission fuel from Liquified Petroleum Gas (LPG), so if they want to make the process cleaner, they will upgrade the energy to

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electricity, which needs to invest new equipment to boost the power of the electrical circuit. Same with the chilling process, it also needs to invest in recent equipment to make it more eco-friendly.

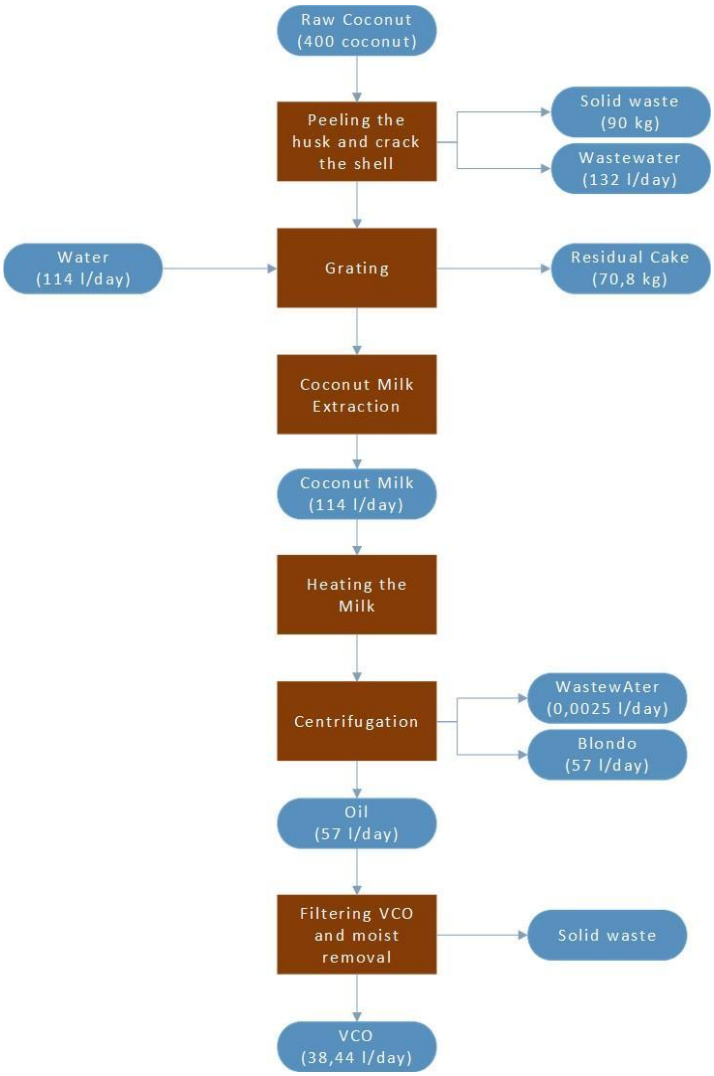

Figure 1. Workflow of VCO production

Besides that, due to this industry's scale being small and little capital, the method for pollution reduction must generate an additional income for the industry. So, dewatering the coconut step to clean the coconut step is the most feasible for upgrading the VCO-making process to be more eco-friendly, utilizing coconut water and shell wasted to new products and creating extra income.

Table 1. Table of scope definition

No	Parameter	Scope
1	Production	VCO
2	Production Rate	300-400 coconut/day
3	System Boundaries	Gate to Gate
4	Allocation and System Expansion	Turning waste coconut water into Nata de Coco
5	Data Requirements	Amount of coconut water used

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Life Cycle Inventory (LCI)

The inventory analysis stage is one of the steps that need to be passed in the LCA study. At this stage, the input and output materials are analyzed for inventory. In the VCO production process, the potential for improvement is in gate-to-gate system boundaries, namely in the coconut cleaning process.

Table 2. shows the input data from the production process. This system process 400 coconuts in a day. This process uses water 0.114 m^3 and a machine that works in 7-11 AM using electric power of 2.5 k for processing the raw materials. Table 3. shows the output of VCO processing. VCO processing output consists of grease, TN (Total Nitrogen), Phosphate, BOD, COD, coconut residual cake, CO_2 EqEq, and coconut shell.

Table 2. Inventory Analysis Input Data of VCO Production

No.	Input	Total	Unit
1	Raw Coconut	400	Coconut/day
2	Water	114	L

Table 3. Inventory Analysis Output Data of VCO Production

No.	Output	Total	Unit
1	Grease	76	mg
2	TN	13.75	kg
3	- PO4	92.4	mg
4	BOD	129.8	kg
5	COD	649	kg
6	Coconut Residual Cake	70.8	kg
7	CO_2 eqeq	0.7725	kg CO_2/kg
8	Coconut Shell	90	kg

Life Cycle Impact Assessment (LCIA)

VCO production has a significant impact on the water ecosystem and solid waste accumulation (Table 4), so we designed an advanced processing system of the waste with two production alternatives to determine the best to reduce environmental damage.

Table 4. Impact Analysis BEES method from initial Process in VCO Production

Environmental Impact	Unit	Value
Eutrophication	g N eq	38940.7
Global Warming	g CO2 eq	10672.5
Water Intake	liters	114

Since coconut water is relatively high, along with the incapability of waste treatment, to control the amount of coconut water wasted in streams, coconut water waste treatment is considered one of the main ways to optimize coconut. The coconut water itself has a lot of healthy nourishing stuff, leading to a potential due to the richness of the nutrients such as sugar, protein, fat, and relatively suitable for the growth of food processing bacteria products (Ariyanti et al., 2014). Therefore, we suggest a solution for the treatment of coconut water waster by utilizing the remaining coconut water into something widely known and consumed by most people and has an economic value. The remaining coconut water will be processed as a nata de coco by inoculating Acetobacter xylinum directly into the remaining coconut water as a medium of the bacteria growth that may lead to the following process: coconut water fermentation (Nugroho & Aji, 2015). Acetobacter xylinum is a bacterium that, once inoculated into a liquid medium, produces an enzyme compiled into a thousand chains of sugars or cellulose fibers. Much biomass will grow in the coconut water and eventually have a million solid white transparent cellulose (Nugroho & Aji, 2015).

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Nata de coco production includes several processes: filtering, boiling, placing it in a fermentation container, cooling, adding a starter, fermentation (curing) for seven days at room temperature, harvesting, cleaning the skin, and cutting (Ariyanti et al., 2014). In the manufacturing process of nata de coco, within a day of nata de coco production, it requires 400 liters of coconut water with a boiling frequency three times a day. While producing the nata de coco, each process may emit pollution into the environment since our primary focus is wastewater. Thus, the process stages that contribute the most to water pollution are the washing and cleansing processes of the nata de coco skin or surface. In comparison, solid waste is produced from the harvesting process. In contrast, solid waste is made in nata de coco, which fails to harvest from the nata de coco harvesting process due to unhygienic fermentation space or unhygienic workers causing fungal contamination in the coconut solution. Based on the statement by Ariyanti et al., it is known that within a year, there will be 1,261,715 liters of liquid waste produced from the nata de coco production process and solid waste with a potential of 129,475.5 kg (Ariyanti et al., 2014).

Every coconut has 35% husk and 12% coconut shell, so with 400 coconut processes each day, it will make 90 kg of solid waste/day (Herlina et al., 2014). To reduce the amount of solid waste in VCO production, charcoal from coconut shells is one method for the small-middle home industry. This process is possible for the industry due to simple steps and no significant investment. The furnace for a charcoal-making process can be made from brick, clay, or even used drums. The steps to make coconut shell charcoal are gradually burning coconut shell in a furnace until 400-450-degree Celsius (Tumbel et al., 2019). After that, every funnel is closed every 5 to 10 minutes to keep the flame on but not overburn it. Every kg of charcoal produced need 1,16 kg of solid coconut waste. With 90 kg solid waste in the factory every day, the charcoal generated from this process is around 77.59 kg. Based on Joseph et al., every 90 kg of coconut shell processed into charcoal will produce 28,42 kilograms on average (Joseph et al., 2016). However, this process has the consequence of adding more air emissions to the environment.

Interpretation

Based on the assessment carried out by the openLCA application for alternative use of coconut water into nata de coco, the alternative was chosen to improve environmental quality based on the parameters of wastewater generated in the industry. The parameter of sewage or water pollution was selected because the liquid waste in the form of coconut water is a liquid that contains high and complex organic matter. Hence, it has a very high potential to pollute the environment due to eutrophication in a water body adjacent to the factory and where the effluent is finally discharged. The content of BOD and COD is the main factor in considering why we chose this parameter. Besides, due to the cooling stages in the nata de coco production process, using a fridge for quite some time may also contribute to CO_2 emission towards the environment because electricity was provided by a natural resource known as coal. Coal is known for its contribution to global warming due to carbon dioxide, CO, SOx, NOx, etc. Thus, our group chose to add CO_2 eqeq as our parameter to be selected along with eutrophication.

In the making process of Nata de Coco, the amount of BOD and COD are reducing due to the utilization of coconut water being processed. On the other hand, while processing the nata de coco and putting it in the fridge for a while, the refrigerator will generate carbon emission to the environment within CO_2 eqeq 18.6 kg CO_2 eqeq with the initial generation by using electricity, the nata de coco process will generate 0.00049 g CO_2 eq. Since the BOD and COD level of the nata de coco process is higher than the carbon emission emitted to the environment, the possibility of eutrophication is elevated with an initial generation of eutrophication as many as 598.6002 g N eq (Table 5).

Table 5. Impact assessment BEES method using Open LCA for Nata de Coco

Environmental Impact	Unit	Value
Eutrophication	g N eq	598.2
Global Warming	g CO2 eq	0.00049
Water Intake	liters	0

Based on the openLCA application assessment, alternatives to improve environmental quality were selected based on wastewater parameters and the resulting CO_2 eq. This parameter was chosen because the wastewater from coconut water has a high potential for forming eutrophication in water bodies around the factory. BOD and high COD content are certainly a consideration in it. Meanwhile, CO_2 eq parameters were also selected for the two

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solution options to produce smoke from the combustion process of organic biomass material, which is not tiny. In making charcoal, the content of BOD, COD, and others does not experience a reduction in quantity because coconut water that contains these components is not processed. Meanwhile, the charcoal-making process will process solid waste in coconut shells, which are also not small in number. The charcoal-making process generates smoke and CO_2 eq every process until 10.67 kg CO_2 eq. So, the initial process of using electricity to extract the coconut meat will generate 10.67 kg CO_2, and eutrophication potential can still occur (Table 6).

Table 6. Impact assessment BEES method using Open LCA for Coconut Shell Charcoal

Environmental Impact	Unit	Value
Eutrophication	g N eq	649
Global Warming	g CO2 eq	10.6725
Water Intake	liters	114

CONCLUSIONS

From VCO production, it can be seen that a gate-to-gate life cycle assessment is required. In peeling the husk and cracking the shell, solid waste, and wastewater are produced. To reduce this waste, there are two alternatives, namely nata de coco production and coconut shell charcoal. Options to improve environmental quality were selected based on wastewater parameters and the resulting CO_2 eq.

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