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PRIMARY RESEARCH

Identification hotspot green house gases emission in supply Chain agroindustry potato chips

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Abstract

The supply chain of potato chips agroindustry products is very useful to be applied in various aspects, therefore it is necessary to continuously improve its performance. Factors that must be considered in the supply chain design of agricultural commodities and agro-industrial products in order to obtain a supply chain that is comprehensive, effective, efficient, responsive, fair and sustainable. Climate change is a major issue in sustainability, because it can cause dangerous temperature and sea level rise, drought, and others. Scientists throughout the world provide information that supports the fact that climate is changing and that this change is partly due to human activities through the release of Green House Gases (GHGs). However, lately, GHG emissions have increased, partly due to industrialization and changes in agriculture and land use. Based on this background, the authors conducted a study with the aim of analyzing the life cycle of the potato chip supply chain with carbon footprint methods in order to reduce environmental impact. In this research, carbon footprint models will be designed on potato chip agro-industry so that spots can be identified that have the potential to produce environmental impacts. Spot identification is done by analyzing the distribution and transportation of the potato supplier and the process of producing potato chips, so that the production process is environmentally friendly. The results of the design of the potato chip agro-industry carbon footprint model is that it can determine carbon emissions released along the supply chain of potato chips agroindustry and be measured quantitatively, so that stakeholders/actors involved in the supply chain can utilize them in the decision making process. So that it is expected to increase efficiency and reduce the environmental impact that occurs due to the production of potato chips and implement environmentally friendly and sustainable industries.

I. INTRODUCTION

Supply chain of potato commodities and agro-industry products is very useful to be applied to various aspects therefore need to be continuously improved its performance. Consequently, the supply chains of agricultural commodities and agro-industry products are more complex, probabilistic and dynamic. Components associated with the supply chain need to be handled more thoroughly. All these factors should be considered in the design of the supply chains of agricultural commodities and agro-industry products in order to obtain a comprehensive, effective, efficient, responsive, equitable and sustainable supply chain.

A more sustainable supply chain is better at identifying current and future environmental and social impacts and finding ways to reduce them. A company to grow, it is increasingly important to realize the economic, environmental, and social dimensions of its entire supply chain and proactively monitor and manage it, as supply chain operations are key to improving sustainability performance. Climate change is a major issue in sustainability, as it can lead to dangerous rises in temperatures and sea levels, drought, etc. [1]. Scientists around the world provide information that supports the fact that the climate is changing and that this change is partly due to human activities through the release of GHG. "Carbon" is often used as an abbreviation for greenhouse gases, because carbon dioxide is the main greenhouse gas

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emitted by human activities. According to the Intergovernmental Panel on Climate Change (IPCC), climate change refers to any climate change over time due to natural variability or as a result of human activities [2, 3]. The scientific community has accumulated substantial evidence that the climate is changing [4], as a result of increased concentrations of GHGs in the atmosphere, which are partly caused by human activity. However, lately, GHG emissions have increased, partly due to industrialization and changes in agriculture and land use. Carbon dioxide, for example, is emitted by the burning of fossil fuels such as coal, oil, and gas. Methane mainly comes from agriculture, livestock, and land supply [5]. Consequently, GHG emission measurement activities are often referred to as carbon footprints [6].

The carbon footprint may involve an organization, value chain, or product. Organizational carbon footprints contribute emissions from all activities throughout the organization (including the use of building energy, industrial processes, and company vehicles) [7, 8]. The carbon footprint of the value chain includes emissions outside of the organization's own operations (i.e., emissions from suppliers and consumers, including product use and end-of-life emissions). Finally, the product carbon footprint includes emissions during the entire life cycle of a particular product or service unit, from raw material and manufacturing extraction to its use and reuse, recycling, or final disposal. Ways to encourage or pressure companies to adopt more sustainable behaviors, both related to eliminating waste of both material, labor, and reducing emissions in distribution and transportation in the supply chain [9].

Potato chips agroindustry companies can find ways to reduce emissions and GHG costs by installing additional power units in their trucks as they begin to see the carbon footprint. Companies that seek to reduce their own emissions face two major challenges. First, it is practically impossible to convince me or even strictly estimate corporate responsibility for emissions associated with the final product or service. A typical product goes through many manufacturing and transportation activities, often shared by a number of companies in the supply chain. Secondly, the direct emissions that a company might face are usually a small part of the supply chain emissions. [10] reported that in all industries, the average direct emissions of firms alone account for 14% of their supply chain emissions prior to use and disposal. Therefore, the measurement of sustainability should take the perspective of the supply chain, to limit emissions and environmental impacts.

Pollution is a direct result of human activities. The pollution that occurs can be air pollution, water and land. Naturally nature can restore itself back to balance (homeostasis), but to go to the balance takes a very long time. By reducing direct impacts such as pollution due to human activities, human beings have tried to accelerate the natural balance. The existence of material and energy inputs such as fuel can cause pollution, one of which is greenhouse gas emissions. Currently, the Indonesian government has committed to reducing greenhouse gas emissions by 26% by own ventures and 41% with international assistance as written in Presidential Regulation No. 61 of 2011 on National Action Plan for Green House Gas Emission Reduction. To analyze the impacts and reduce pollution to the environment, a precise method is carbon footprint [11].

Carbon footprint is a cradle to grave based method used to determine the amount of energy, cost, and environmental impact caused by the life cycle of the product starting from the time the raw material is taken up to the finished product used by the consumer [12]. The environmental impacts generated at each stage of the potato chips production process can be analyzed using carbon footprint by calculating environmental loads based on the use of resources, energy, water, fuel, and other materials [13]. Furthermore, to reduce the environmental impact that may occur, it is necessary to re-analyze using several different alternatives to reduce the environmental impact that can be caused [14].

In the current world trade procedures, especially in developed countries, both goods and services require environmental performance as a selling power and promotional tool. Much research has been done on environmental issues such as sustainable consumption and production behavior and product competitiveness [15]. Carbon footprint is a method that is present to provide information on a product either goods or services in the form of how far the product is said to be environmentally friendly, how green or how sustainability is the quantitative claim of the product itself. Based on the above description, the development of carbon footprint model in potato agro-industry is needed to analyze the environmental impact of potato chips production process. The carbon footprint study conducted can be used to identify whether the production process is efficient and effective, so that it can produce environmentally friendly potato chips products that are not only beneficial to the company but also preserve the environment. In this research will be designed carbon footprint model on potato chips agroindustry so that can be identified spots that have the potential to produce environmental impact. Spot identification is done by analyzing the production process of potato chips, so that the production process is done to be

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environmentally friendly.

The design of this model is expected to improve efficiency and reduce the environmental impact caused by the production of potato chips. The results of carbon footprint model design of potato chips agroindustry can be measured quantitatively, so that stakeholders/actors involved in the supply chain can utilize it in the decision-making process. In addition, the results of this study can be used as a benchmark on studying carbon footprint of chips products and providing benefits for industry actors for environmental management and applying environmentally and sustainably sustainable industries.

Potato chips industry requires raw materials, auxiliary materials and energy to produce its products. Production process will produce emissions and waste that have an impact on the environment. Based on the above, carbon footprint method is used to find out the need of raw materials, additives and energy, emissions and waste generated, and to identify potential impacts on the environment in the production process of potato chips. The carbon footprint study used in this study is also expected to provide recommendations for improvements that can be done and be a solution in handling the problems that exist in the production process of potato chips. The analysis obtained can be used as consideration of the decision of product improvement or industrial production process in question, so it is expected that the process becomes more optimal and environmental damage can be inhibited or reduced.

Complete and deep calculation process needs to be done on the production process of potato chips. The calculation process is carried out so that in the production of potato chips can be known the impact caused after and before the activity can be identified and quantified properly. Because the implementation of activities that do not go through a good calculation is feared can cause a new impact for the environment. The carbon footprint method can be used as a tool in the overall and specific impact calculations. So that can be seen the impact of the implementation of potato chips production activities in order to reduce emissions. The carbon footprint function can be used to streamline energy and minimize waste in emissions reductions in accordance with government regulations. So it can make the profit increase for the company and the environment is maintained.

A. Scope of Research

The scope of this research is this research is limited from potato chips, transportation and potato chips production process.The observed products are potato chips. The environmental impact assessment under study is the impact of liquid, solid and air waste from the production cycle of potato chips. Category of environmental impact observed in the form of global warming.

II. MATERIAL AND METHODS

According to ISO 14040 standards, the LCA study has four phases, namely, (1) determination of goal and scope, (2) life cycle inventory analysis, (3) impact assessment and (4) interpretation [14].

A. Goal and Scope of the Study

Life Cycle Assessment (LCA) is a method for estimating the environmental impacts of a product or service in the entire supply chain [14]. In this study, the environmental impact of potato chips product is limited only to global warming which is carried out through the analysis of carbon footprint [7, 16]. At present, the analysis of carbon footprint has become one of the main indicators of environmental protection. Carbon footprint is defined as the total amount of greenhouse gas emissions, both directly and indirectly generated by all activities in a predetermined system boundary [6].

The goal of this study was to determine the carbon footprint and evaluate the impact of global warming caused by potato chips produced medium-scale semi-mechanical process of potato chips mills. The ISO 14040/44 guideline on Carbon Footprint Calculation for Products in accordance with the LCA methodology based on IPCC 2007 was used for the impact assessment.

B. Functional Unit and System Boundary

The calculation of carbon footprint is based on a functional unit, which is the measure of the system function that informs the reference unit related to the research inventory data. In this study, 100 kg of potato was the functional unit chosen. The system boundary of product life cycle is limited to production process potato from handling of raw materials, production precess until storage “gate to gate”. The process flow diagram of potato chips production is shown in Figure 1.

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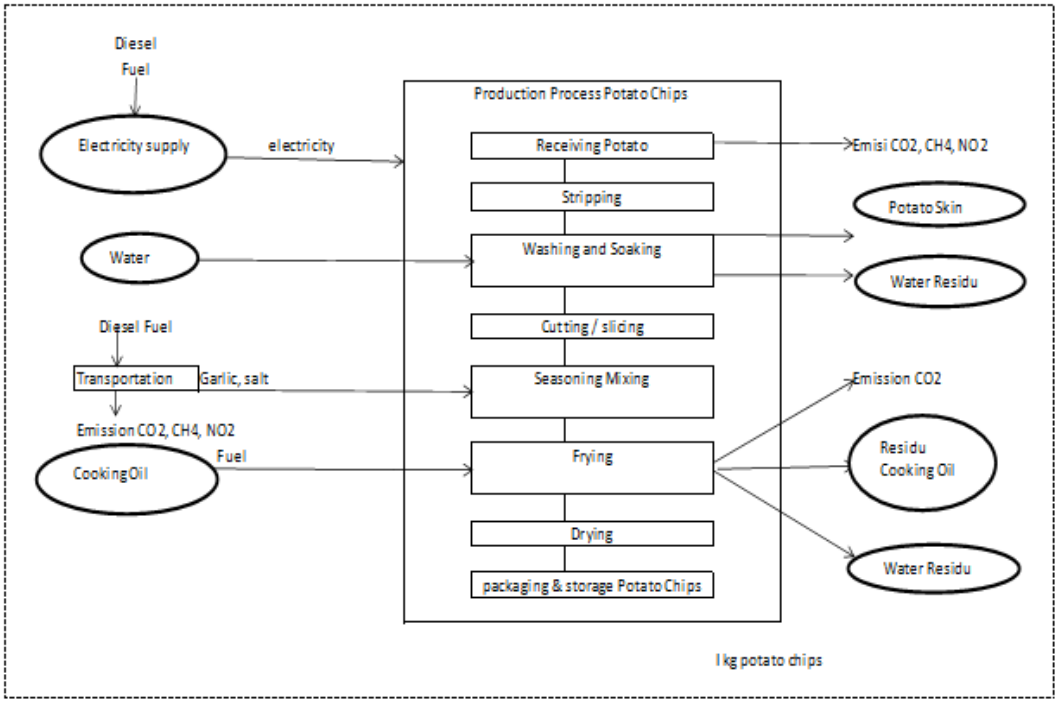

Fig. 1. Life cycle input-output supply chain agroindustry potato chips

C. GHG

form of fossil fuel has the potential to generate greenhouse gas emissions and participate in the occurrence of global warming. Three major greenhouse gases consisting of CO_2, CH_4, and N_2O are generated from burning fossil fuels, production process activities, catching/breeding activities, and waste handling and treatment. GHG emission calculations are performed using an emission calculation basis that has been recognized by the IPCC.

Greenhouse effect generated from CO_2 can be obtained from the use of fuel, such as: LPG, diesel, electricity usage. According to the [17] for the calculation of CO_2 emissions from fuel use is obtained through Equation 1.

$$CO_2 \ emissions \ (fuel) = QF \times NK \times FE \quad (1)$$

Information:
QF = Fuel consumption (l)
NK = Net calorific value (kcal/l)
FE = Emission factor (kg CO_2/TJ) (1)

Net calorific values and emission factors have different values depending on the type of fuel used. According to [17], the CO_2 emission calculation formulation of electricity usage is obtained through Equation 2).

$$CO_2 \ emissions \ (power) = QL \times FE \quad (2)$$

Information:
QL = Electricity consumption (kWh)
FE = Emission factor (0.485 t CO_2/MWh) (UNFCCC 2006) (2)

CH_4 emissions come from wastewater and diesel usage. Calculation of CH4 emissions derived from liquid waste can be done with calculations derived from the amount of COD produced. Based on [17] CH_4 emissions derived from wastewater are obtained through Equation 3).

$$CH_4 \ emission \ (wastewater) = VLC \times C \times FE \quad (3)$$

Information:
VLC = Volume of liquid waste (l)
C = COD value (mg/l)
FE = Emission factor (0.21 kg CH_4/kg COD) (3)

CH_4 emissions derived from the use of fuels can be obtained through Equation 4.

$$CH_4 \ (diesel) \ emissions = QF \times NK \times FE \quad (4)$$

Information:
QF = Fuel consumption (l)
NK = Net calorific value (9 063 kcal/l)
FE = Emission factor (10 kg CH_4/TJ) (4)

The calculation of nitrous oxide emissions (N_2O) from the use of diesel can be carried out by calculations derived from the amount of nitrogen content in an ingredient and the emission factor contained in IPCC (2006). N2O emissions derived from the use of diesel fuel according to [17] can be obtained through Equation 5.

$$N_2O \ (diesel) \ emissions = QF \times NK \times FE \quad (5)$$

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Information:
QF = Fuel consumption (l)
NK = Net calorific value (9 063 kcal/l)
FE = Emission factor (0.6 kg N_2O/TJ) (5)
According to [17] methane gas (CH_4) has a GWP (Global Warming Potential) value of 23 and nitrooxide gas N_2O) has a GWP value of 293. GWP is a value relatively equal to CO_2 then its conversion can be obtained through 1 kg CH_4 = 23 kg CO_2 Equation 1 kg N_2O = 293 kg CO_2 Equation 5

III. RESULT

A. *Scope System Supply Chain Potato Chips Agroindustry*

Scope of emission starts from storage raw material, to agroindustry potato chips then processed until become potato chips then distributed using vehicle to retailer. Scope 1 from potato supplier to potato chips agroindustry, scope 2 in production potato chips. Function unit per 1 Kg potato chips.
Boundary system starts from potato supplier then distributed by production process potato chips. Function unit per 1 kg potato chips.

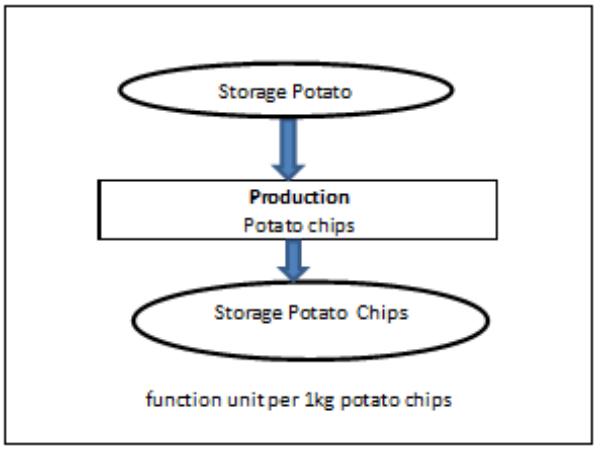

Fig. 2. Boundary system supply chain potato chips agroindustry

B. *Production Wastes Produced in Potato Chips Agroindustry*

In the process of making potato chips produced production waste in the form of gas, liquid or solid. The following solid and liquid wastes are generated.
Based on the above table can be known solid waste generated in the form of potato skin of 1.2 kg while for liquid limbag in the form of water and cooking oil total of 218.51 kg.

TABLE 1
WASTE GENERATED IN THE PRODUCTION PROCESS OF POTATO CHIPS

No	Process	Waste	Total
1	Receiving	-	-
2	Stripping	Potato skin	2 Kg
3	Washing	Water Residu	98 L
4	Mixing Seasoning	Water Residu	47.11 Kg
5	Frying	Residu Cooking Oil,	26.45 Kg
		Water	43.56 Kg
6	Drying	Residu Cooking Oil	3.55 Kg

C. *Carbon Footprint on Supply Chain of Potato Chips Agroindustry*

In the calculation of supply chain carbon footprint agroindustry potato chips stages are as follows:
1) Direct measurement: At this stage direct measurement is usually applied to the production site. Emission measurements are achieved by continuously measuring pollutants emitted into the atmosphere in the exhaust gases from combustion or industrial processes. Measuring exhaust gases in the transportation process from potato suppliers to potato chips agroindustry and transporting products to consumers.
At greenhouse gases are analyzed based on the content of CO_2 converted to CO_2-eq generated from burning fossil fuels, production process activities.
2) Energy-based calculations: In this calculation calculates the mass balance of the production process of potato chips. Here the mass balance of potato chips production process.
Based on the above table then the potato base 100 kg after going through the stages of the process until the product potato chips produced 70.89 kg. Then there is the waste gas production, solid and liquid.

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TABLE 2
MASS BALANCE POTATO CHIPS PRODUCTION PROCESS

Process	Unit	Mass Balance	
		Input	Output
Stripping + Cut			
Potato	Kg	100	
Peeled potatoes sliced	Kg		98
Potato skin solids	Kg		1.2
Potato skin water	Kg		0.8
Washing			
Peeled potatoes sliced	Kg	98	
Water	L	100	
Clean sliced potatoes solids	Kg		58.8
Clean sliced potatoes water	Kg		41.2
Residu Water	L		98
Mixing			
Clean sliced potatoes solids	Kg		58.8
Clean sliced potatoes water	Kg		41.2
Water	Kg	5	
Garlic	Kg	10	
Salt	Kg	3	
Potatoes sliced seasoning solids	Kg		70.89
Potatoes sliced seasoning water	Kg		47.11
Frying			
Potatoes sliced seasoning solids	Kg	70.89	
Potatoes sliced seasoning water	Kg	47.11	
Cooking oil	Kg	30	
Potato Chips	Kg		70.89
Potato Chips water	Kg		3.55
Potato Chips oil	Kg		3.55
Residu Cooking oil	Kg		26.45
Water	Kg		43.56
Drying			
Potato Chips	Kg	70.89	
Potato Chips water	Kg	3.55	
Potato Chips oil	Kg	3.55	
Water	Kg		3.55
Cooking oil	Kg		3.55
Potato Chips	Kg		70.89

3) Activity-based calculation: Here are energy-based activity calculations. Based on the above calculation it can be seen total emissions production process potato chips of 64,793.096 Kg CO_2eq/year.

TABLE 3
ACTIVITY BASED ENERGY CALCULATIONS

Activity	Use Energy (A)	Energi (MJ/Year) (B)	Emission Factor (C)	GHG Emission ($KgCO_2$eq/Year) (D)	Carbon Footorint ($KgCO_2$eq/kg potato chips)
	A	B	C	D = B x C	
Scope 1 (Production potato chips)					
Water supply	0.17	705.600	0.485	342.216	0.011
Stripping	0.75	22,500.000	0.485	10,912.500	0.513
Washing and soaking	1.25	36,750.000	0.485	17,823.750	0.838
Seasoning mixing	0.24	5,040.279	0.485	2,444.535	0.115
Frying	1.50	31,900.500	0.485	15,471.743	0.728
Drying	1.50	31,900.500	0.485	15,471.743	0.728
Material handling to storage potato chips	0.33	7,089.000	0.328	2,326.610	0.109
Carbon Footprint $kgCO_2$eq/kg potato chips (From production-storage)				64,793.096	3.042

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So carbon footprint generated for 3.042 Kg CO_2eq/kg potato chips. based on the graph, it can be seen that the biggest carbon footprint is in the process washing and soaking 0.838 Kg CO_2eq/kg potato chips. Then it needs to be improved in the process so that it can reduce emissions released in the process by doing energy efficiency, it can reduce the carbon footprint produced.

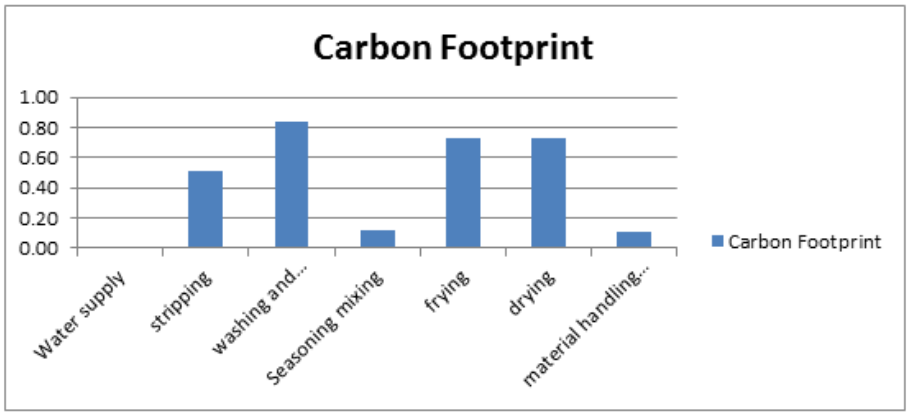

Fig. 3. Carbon footprint production process potato chips

IV. CONCLUSION AND RECOMENDATIONS

Based on the research done then the conclusion is as follows boundary system starts from storage raw material, production process until storage potato chips (Receiving, stripping, washing, cutting, mixing seasoning, frying, drying). Solid waste produced in the form of potato skin of 1.2 kg while for liquid limbag in the form of water and total cooking oil of 218.51 kg. Total emissions production process potato chips of 64,793.096 KgCO_2eq/year. So carbon footprint generated for 3.042 KgCO_2eq/kg potato chips. The highest carbon footprint is washing and soaking process. This carbon footprint research was conducted to support the green supply chain in the traceability system in potato chip agroindustry so that consumers are more selective in choosing foods that are safe for food safety and the environment.

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