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Preliminary Life Cycle Analysis of Greenhouse Gas Emissions at Transportation Phase of a Beverage Drink for Green Logistics

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Abstract. As the transportation sector is one of the main emitters of large quantities of pollutions to the atmosphere, industries have been trying to cope with this issue and launch many campaigns or projects to reduce air pollutions. In any industries around the world, an electric vehicle is a part of alternative transportation mode which has recently experienced considerable growth. The paper aims to evaluate energy consumption and greenhouse gas (GHG) emissions of the food sector for the entire life cycle and particularly focusing on green road transportation. The focus of the analysis covers the mango powder drink mix transportation, distribution, and disposal aspects, especially for road transportation. The observed results showed that the electric vehicles have emissions reduction potential and consequently showed low impacts in Global Warming Potential (GWP) impact category. The environmental impact assessment identified that the primary source of energy use and GHG emissions was the transportation process from Hong Keaw plantation to King Mongkut's Institute of Technology Ladkrabang (KMITL) (0.025 kgCO_2eq).

1 Introduction

Environmental changes influence all global communities and can impact companies in many different ways. In terms of GHG emissions, each tonne of GHG emitted mostly is the carbon dioxide (CO_2) contributing to further climate change [1].

Within the food and beverage sector in which it plays a fundamental role in daily life, transportation is increasingly perceived as a dominant contributor to the carbon footprint contributing toward global warning. This is mainly because food is often shipped long distances [2].

As the new era of technology, logistics has been starting to play the crucial role for any industries in ensuring the success of the industry [3,4]. To move towards sustainability, one way of doing so is to be successfully implemented in green logistics. There are five key options, which include (1) green packaging, (2) green storage, (3) green technology, (4) green transportation and (5) reverse logistics [5]. As diesel vehicles are well known to have negative effects to human health, there is a significant push to reduce using these vehicles by switching to green transportation system [6].

In food industry, green transportation is an important transportation option especially for the ones needed to be transported over long distances. As a result, this study investigated the green transportation implementation to reduce the carbon footprint by attempting to model the electric vehicles over the full life cycle of mango powder drink mix. This study is a gate-to-gate study focusing mainly on the use phase of road vehicles for the food transportation.

According to Anderson, 2000 [7], several papers have been recently published in which Life Cycle Assessment (LCA) was used to evaluate the environmental impacts due to food productions, a variety of fruits were evaluated [8–16]. A few of them focused on green transportation. Consequently, this study aims to investigate the impact of replacing the diesel vehicles with electric vehicles.

The focus of the analysis covers the mango powder drink mix transportation, distribution, and disposal aspects. The modelled estimations of life cycle emissions and energy used generated in this study will be beneficial and will fill the research gap.

2 Methodology: LCA study of road transportation of mango powder drink

2.1 Goal and scope definition

The aim of this section is to evaluate GHG environmental impact of road transportation of Nam Dok Mai mango powder drink with freeze dry process. Hong Kaew garden in Nakhon Ratchasima and food laboratory at the department of Food Engineering, KMITL, Bangkok, Thailand were used as cultivation and production phases, respectively.

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The GHG results are specific to Thailand and US using the LCA, an environmental assessment tool, which provides information on the environmental effects of the process or product. This helps to improve understanding of the environmental implications in the consumption of mango powder drink.

2.1.1 Functional unit

As the functional unit is a key component of LCA, this unit is useful for constructing a flow model and is the main unit that can have a vast impact on the LCA results.

The functional unit selected in this study is a round trip (per 50g sachet). Even though running fuel is computed differently during on and off-peak times, this study assumed that the average electricity consumption rate is constant at any period of time.

2.1.2 System boundaries

This study is a gate-to-gate study that takes into account electricity consumption through the road vehicle use over the full life cycle of an instant Nam Dok Mai mango powder drink. The electric vehicle system boundaries include production and usage of electricity from battery.

As the product was produced locally, transported to US and consumed in US, the sources of data are from five main areas, which include (1) transportation from Hong Keaw to KMITL, (2) transportation from KMITL to Laem Chabang port, (3) transportation from Port of Long Beach (US) to resellers, and (4) transportation from resellers to disposal.

2.2 Life cycle inventory-data quality, sources, and assumptions

In this study, the Life Cycle Inventory (LCI) data came mostly from vehicle transportation systems from Thailand and US as well as Ecoinvent. The majority of the data were specific to Bangkok/Thailand and California/US. Nevertheless, information was taken from some other sources to cope with the absence of data.

2.3 LCA modelling

The approach of calculating all the transportation processes of mango was adopted and then transferred to the software GaBi 8, which is a software product of PE International, Germany.

In this study, Center of Environmental Science of Leiden University (CML), is used to characterize and evaluate the GHG impacts of the related processes taken into account in this study. CML is the life cycle impact assessment (LCIA) method.

2.3.1 Description of mango powder drink

Though the life cycle of mango powder drink has been divided in six main stages: cropping, transportation, processing for mango powder drink, distribution and transportation, human consumption, and disposal, this study only took the stages related to road transportation into account. All the related stages are briefly described as follows:

2.3.1.1 Transportation from Hong Kaew plantation to KMITL

Transportation is an important contributor towards GHG impacts [17], and different transportation modes lead to different environmental impacts.

In this study, the mangoes were transported at an ambient temperature from Hong Kaew plantation to KMITL by truck, with 100% load capacity outbound and 0 % on the return trip.

The input parameters for transportation calculation include the type of vehicle, type of fuel, total distance, and work load, as shown in Table 1.

Table 1. The input parameters for transportation between Hong Kaew plantation and KMITL.

Parameter	Value	Unit	Reference
Type of vehicle	TOYOTA VIGO 2.5 G.CAP 4 wheel	-	
Type of fuel	Diesel	-	
Distance	750	km/round	
Driving behavior	-	-	Cautious
Type of road	-	-	City
Slope of the road	-	-	Flat
Acceleration	0	m/s^2	
Total weight (kg)	3720		[18]; Experts' estimate
Rolling friction of the tires	0.02	-	[19]
Temperature at time of the travel	35	c	Expert's estimate
Density of air at 35 °C	1.15	$kg.m^{-3}$	[20]
Aerodynamic c drag coefficient	0.394		[18]
Frontal area of the vehicle	3.1592	m × m	[21]
Velocity	16.7	m/s	Expert's estimate

2.3.1.2 Distribution and transportation from KMITL to resellers in the US

The mango powder drink mix was transported from KMITL's laboratory to Laem Chabang port by truck (96.7 km), then transported by ferry to (13,135 km) and distributed within the U.S. In terms of distribution in the US, an average road transport distance of 500 km was adopted [22]. However, energy use due to ferry transportation and transport home by consumers will not be taken into account. The detail information for transportation and distribution is shown in Table 2 and 3, respectively.

Table 2. The input parameters for transportation from KMITL to Laem Chabang port.

Parameter	Value	Unit	Reference
Type of vehicle	Isuzu NKR	-	
Type of fuel	Diesel	-	
Distance	96.7*2	km/round	Google Map
Driving behavior	-	-	Cautious
Type of road	-	-	City
Slope of the road	-	-	Flat
Acceleration	0	m/s^2	
Total weight	8036	kg	[23]; Experts' estimate
Rolling friction of the tires	0.02	-	[19]
Temperature at time of the travel	35	c	Expert's estimate
Density of air at 35 °C	1.15	$kg.m^{-3}$	[20]
Aerodynamic drag coefficient	0.5696		[24]
Frontal area of the vehicle	3.6696	m^2	[23]
Velocity	16.7	m/s	Expert's estimate

Table 3. The input parameters for distribution from Port of Long Beach (US) to resellers.

Parameter	Value	Unit	Reference
Type of vehicle	MAN model 19.314 19.403 19.430	-	
Type of fuel	Diesel	-	
Distance	500	km/round	Google Map
Driving behavior	-	-	Cautious
Type of road	-	-	City
Slope of the road	-	-	Flat
Acceleration	0	m/s^2	
Total weight	22750	kg	[25]; Expert's estimate
Rolling friction of the tires	0.02	-	[19]
Temperature at time of the travel	18	c	Expert's estimate
Density of air at 35 °C	1.225	$kg.m^{-3}$	[26]
Aerodynamic drag coefficient	0.5696		[24]
Frontal area of the vehicle	4.7916	m^2	[27]
Velocity	24.58	m/s	Expert's estimate

2.3.1.3 Disposal

The aluminium foil packaging in this study is assumed to be disposed to landfill in US on an average road transport distance of 500 km after its ended use [28]. The landfilling data was taken from the Ecoinvent database. The detail information for disposal to landfill is shown in Table 4.

Table 4. The input parameters for disposal to landfill in US.

Parameter	Value	Unit	Reference
Type of vehicle	Garbage truck	-	

Type of fuel	Diesel	-	
Distance	500	km/round	[28]
Driving behavior	-	-	Cautious
Type of road	-	-	City
Slope of the road	-	-	Flat
Acceleration	0	m/s^2	
Total weight (kg)	24700		
Rolling friction of the tires	0.02	-	[19]
Temperature at time of the travel	18	c	Expert's estimate
Density of air at 35 °C	1.225	$kg.m^{-3}$	[19, 26]
Aerodynamic drag coefficient	0.6		[29]
Frontal area of the vehicle	8.06	m^2	[30]
Velocity	24.58	m/s	Expert's estimate

3 Results

The GHG results below are generated based on the CML2001 methodology to characterize and evaluate the environmental impacts of these processes. According to CML2001, the total GWP of all road transportation through the use of electric vehicles over the life cycle of mango powder drink is 0.032 CO_2eq.

The results clearly show that the primary source of energy use and GHG impacts are due to the transportation process from Hong Keaw plantation to KMITL, which accounted for 0.025 kgCO_2eq (78.62% of the total emissions), followed by transportation from Port of Long Beach (US) to resellers, which accounted for 9.85E-07 kgCO_2eq (18.81%), and, then, from resellers to disposal (1.5%) and from KMITL to Laem Chabang port (1.05%), respectively. In terms of 1 km travelled, GHG impacts from Hong Keaw plantation to KMITL, from Port of Long Beach (US) to resellers, from KMITL to Laem Chabang port, and from resellers to disposal were 6.85E-05, 1.23E-05, 3.55E-06, 9.85E-07 kgCO_2eq, respectively.

The study showed that transportation by trucks from Hong Keaw plantation to KMITL are more polluted than others. This shows that the high GWP could be attributed to the weightness of the mango. However, transportation consumption will vary based on variables such as load, car model, climate, etc. [31].

It is noteworthy to mention that avoiding energy usage, in the entire road transportation life cycle stage is important for all drink product supply chains.

4 Conclusion

In recent years, there has been increased environmental impact of foods and beverages transportation as well as a growing pressure in limiting GWP as a result of companies' activities causing increased concentrations of GHG emissions. Given the link between transportation and GHG emissions, companies are expected to use green logistics to help mitigate GHG emissions. As a result, early action is necessary to reduce GHG emissions at reasonable levels in an attempt to mitigate the future global warming.

The benefits of green logistics have been touted in many previous studies; however, few studies have examined the benefits of green logistics in food industry. As transportation is considered as one of the main contributors to CO_2 emissions which contributes to GHG emissions and has posed a serious impact to natural systems, the aim of this study is to evaluate the GHG impacts related to a mango powder drink mix to see which transportation process has the most emissions reduction potential.

The results showed that transportation process between Hong Keaw plantation and KMITL consumed more energy than others, which led to greater number of GHG impact. However, electricity consumption for transport depends on many factors, including load, car model, and climate [31]. Future improvement can be done by including other environmental impacts using LCA study.

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