

REDUCTION IN GREENHOUSE GAS EMISSIONS FROM COCONUT MILK PRODUCTION PLANTS IN THAILAND

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Abstract

This research aimed to study how to reduce the amount of greenhouse gas generated during the production process of UHT coconut milk in Thailand. The system boundary was defined from cradle to gate, starting from whole coconut until coconut milk production by using life cycle assessment methodology based on ISO 14040. The study was divided into three groups: 1) greenhouse gas emission from the baseline process, 2) greenhouse gas emission from the co-product development process, and 3) greenhouse gas emission from biogas wastewater treatment systems used for electricity generation. For the baseline case, it was found that during the production of 1 kg of UHT coconut milk, the highest GHG emissions came from raw material procurement (78.55%) followed by the production process (18.54%). Electric power consumption included electricity consumption in the production process (0.59%) and the support system (41%). In addition, the electrical energy consumption for baseline processing and the co-product model from biogas was decreased and directly led to a decrease in greenhouse gas emissions and a reduction in carbon for the production process.

Keywords: Carbon footprint; carbon reduction; coconut milk; coconut; greenhouse gas

Introduction

Global warming affects the environment in many ways, such as rising sea levels, increasing ocean acidity, and forcing organisms to adapt to survive (Yiamsungnoen, 2018). Most scientists believe this is mainly due to rising levels of greenhouse gases in the atmosphere and a link to climate change that could lead to global change (Franchetti and Apul,

2013). Carbon dioxide emissions (CO₂) from energy use in the first six months of 2021 were 125.1 million tons of CO₂, an increase of 0.8 percent and included an increase from industry (Energy Policy and Planning Office, 2021).

Coconut milk is essential in many Thai foods, savoury foods, and desserts. But getting coconut

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milk to cook is complex, including the procurement of materials and equipment, and it takes a long time to cook. Thus, the Thai food industry produces a lot of ultra-high temperature (UHT) coconut milk for easy cooking and exportation. Coconut milk can be manufactured by separating the coconut flesh from the coconut fibre and shell. A belt press crushes coconut flesh to obtain coconut milk, as shown in Figure 1 (Sangdee, 2018).

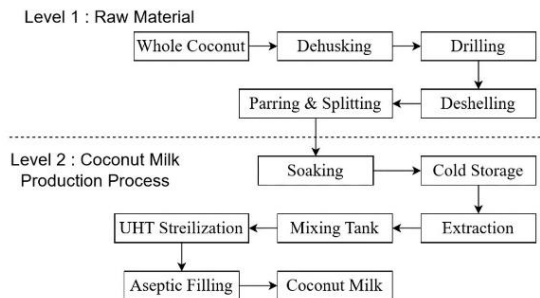


Figure 1. Shows UHT coconut milk production process

The coconut fibre and shell are waste materials that can be used as bio-fuels for other production processes. Thus, the process of preparing UHT coconut milk may cause greenhouse gas (GHG) emissions, including carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and chlorofluorocarbons (CFCs) (Ozlu and Kumar, 2018). An increase in GHG, such as carbon dioxide, causes climate change and global warming (Wang *et al.*, 2020). To reduce these impacts, the world trade market and consumers try to mitigate climate change caused by production processes.

The Carbon Footprint (CFP) is the total amount of carbon dioxide and other greenhouse gases, such as methane, laughter, etc., released by a product or service (according to ISO 14040) over its life cycle. It is a tool for assessing greenhouse gas

emissions to stimulate their reduction. The CFP has gained high interest from several countries, especially for its application in food products which aim to promote the declaration of carbon footprint information via a carbon label. A product's carbon footprint is an assessment of the amount of greenhouse gas emission of a product over its entire life cycle, from start to finish including the acquisition of raw materials, the processing of raw materials, the manufacturing processes, its distribution (transport of the product to retail outlets), its use or consumption and its disposal as waste after use or consumption (Mungkung *et al.*, 2010). The sources of such gases come from using electricity, which may include using fossil fuels in industry, agriculture, etc. The CFP is a tool to evaluate GHG emissions throughout a product's life cycle, including raw material extraction, production, distribution, use, and disposal. In addition, CFP is used to stimulate the manufacturing sector to reduce GHG emissions and increase the efficiency of production in many countries (Pattara *et al.*, 2017; Malik *et al.*, 2018).

However, GHG emissions for Thai UHT coconut milk have not been reported. Quantifying GHG emissions from the production of UHT coconut milk helps consumers, researchers, and policymakers understand and manage these emissions. Thus, this study aims to investigate the energy consumption and GHG emission in Thai UHT coconut milk as a guideline for reducing GHG emissions and establish more beneficial and suitable energy consumption methods that could potentially be applied in the UHT coconut milk production process.

Materials and Methods

LCA is a methodology for estimating the environmental impact related to the selected product

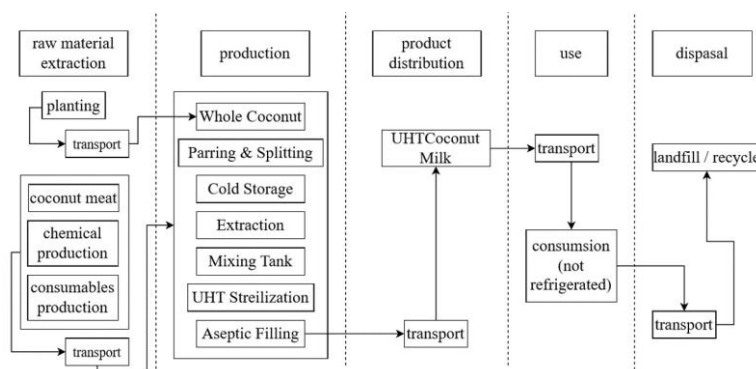


Figure 1. Shows life cycle inventory of UHT coconut milk

or service. Carbon footprint is based on an LCA methodology, which is defined as the total amount of greenhouse gas emissions, both directly and indirectly, emitted from the production process within a selected system boundary.

Life Cycle Inventory

The life cycle inventory collects environmental information about raw material extraction, production, product distribution, use, and disposal in Figure 2 (Sangdee, 2018). This information will assess the environmental impact based on carbon dioxide emissions.

The Calculation of Greenhouse Gas Emissions

GHG emissions were calculated from 1 kg of UHT coconut milk and recorded in terms of CFP or carbon dioxide equivalent per unit of product (kg CO₂e/kg of product) as shown in Equation (1) (TGO, 2022).

$$X = A \times E \quad (1)$$

where X is CFP or CO₂ emission, A is Activity data, and E is Emission factor.

GHG emissions were calculated for the baseline scenario, the co-product allocation scenario, the biogas utilization scenario, and the co-product and biogas utilization scenario.

For the baseline scenario, this method looked at the whole process without considering the allocation from different parts to study greenhouse gas emissions from the production process of UHT coconut milk.

For the co-product allocation scenario, the GHG emissions were investigated as a significant co-product of coconut milk production. This method considered the allocation, which was divided into three parts (Models 1, 2, and 3). Model 1 investigated GHG emissions as a significant co-product of coconut milk production for discarded coconut flesh, skin peels and residues. Model 2 studied GHG emissions as a substantial co-product of coconut milk production for discarded coconut flesh, skin peels, residues and coconut water. Model 3 studied GHG emissions as a significant co-product

of coconut milk production for discarded coconut flesh, skin peels, residues, coconut water and coconut pulp.

For the biogas utilization scenario, the biogas from the wastewater treatment system for electrical production was evaluated for its GHG emission.

For the co-product and biogas utilization scenario, GHG emissions were investigated as a major co-product of coconut milk production and as a biogas from the wastewater treatment system for electrical production. This method also considers allocation.

Estimating the Electrical Energy Consumption

Electrical energy consumption was studied for raw material extraction, production, product distribution, use, and disposal from baseline processing of 1 kg of UHT coconut milk. In addition, electrical energy consumption was studied for raw material extraction, production, product distribution, use, and disposal from baseline processing and as a co-product of using biogas as a fuel. Divided into 1) data on electricity usage from sub distribution board (SDB) and main distribution board (MDB) 2) measure the electrical energy consumption of machinery with a power quality meter (Hioki PQ3100), and 3) from the energy yearly audit report.

Results and Discussion

All data in this research were obtained from the collection of production and raw material procurement data of the Ampol Foods Group.

CFP from Baseline Processing

GHG emissions for baseline processing of UHT coconut milk (Table 1) are calculated using raw materials and the energy associated with the entire production process for UHT coconut milk. The unit of grams of carbon dioxide equivalent represents GHG. The total GHG emission, which includes raw material extraction, production, product distribution, use, and disposal for the baseline processing of 1 kg of UHT coconut milk, is 1,464.90 g of carbon dioxide equivalent.

Table 1. The amount of GHG emission of baseline processing for UHT coconut milk

Life cycle inventory	GHG emissions (gCO ₂ e./kg)		Total
	acquisition and utilization	transportation	
raw material extraction	1,072.80	78.3	1,151.10
production	271.7	0	271.7
product distribution	-	14.5	14.5
use	-	-	-
disposal	27.4	0.2	27.6
total	1,371.90	93	1,464.90

The highest emission came from the raw material extraction process (1,151.1 g of carbon dioxide equivalent, 78.58%), followed by the production process (271.7 g of carbon dioxide equivalent, 18.55%), the disposal process (27.6 g of carbon dioxide equivalent, 1.88%) and product distribution (14.5 g of carbon dioxide equivalent, 0.99%) respectively. This result agrees with the report of Jassim *et al.* (2016) which indicated that the highest GHG emissions come from producing and transporting raw materials in the raw material extraction process. Therefore, the optimum raw material extraction process will reduce GHG emissions which cause the most significant environmental problems.

CFP from co-product allocation scenario

The GHG emissions of co-product processing are lower than for primary production because co-product processing includes allocating resources and materials for producing other products. The results of the current study follow those of Hansupalak *et al.* (2016) which indicated that most GHG emissions were caused by the use of raw materials in the main product. Moreover, it is higher than for co-products production.

The total GHG emission of model 1 (major co-product of coconut milk production with discarded coconut flesh, coconut skin peels and residues), including raw material extraction, production, product distribution, use, and disposal from co-product processing of UHT coconut milk (1 kg) is 1,065.38 g of carbon dioxide equivalent. The highest emission came from the raw material extraction process (800.75 g of carbon dioxide equivalent, 75.16%), followed by the production

process (221.95 g of carbon dioxide equivalent, 20.83%), disposal process (27.68 g of carbon dioxide equivalent, 2.60%) and product distribution (15 g of carbon dioxide equivalent, 1.41%) respectively. In addition, the GHG emission of co-product processing is lower than that for significant production by about 27% (compared with baseline processing) (Table 2).

The total GHG emission for model 2 (major co-product of coconut milk production including discarded coconut flesh, coconut skin peels, residues and coconut water), including raw material extraction, production, product distribution, use, and disposal from co-product processing of UHT coconut milk (1 kg) is 950.47 g of carbon dioxide equivalent. The highest emission came from the raw material extraction process (706.20 g of carbon dioxide equivalent, 74.30%), followed by the production process (201.59 g of carbon dioxide equivalent, 21.21%), disposal process (27.68 g of carbon dioxide equivalent, 2.91%) and product distribution (15 g of carbon dioxide equivalent, 1.58%) respectively. In addition, the GHG emission of co-product processing is lower than that of major production by about 35% (compared with baseline processing) (Table 3).

Total GHG emission of model 3 (major and co-product of coconut milk production including discarded coconut flesh, coconut skin peels, residues, coconut water and coconut pulp), including raw material extraction, production, product distribution, use, and disposal from co-product processing of UHT coconut milk (1 kg) is 948.13 g of carbon dioxide equivalent. The highest emission came from the raw material extraction process (704.28 g of carbon dioxide equivalent, 74.28%), followed by

Table 2. The amount of GHG emissions in the UHT coconut milk production process (Co-Product: Model 1)

Life cycle inventory	GHG emissions (gCO ₂ eq./kg)		
	acquisition and utilization	transportation	Total
raw material extraction	752.34	48.4	800.75
production	221.93	0.02	221.95
product distribution	-	15	15
use	-	-	-
disposal	27.4	0.28	27.68
Total	1,001.67	63.7	1,065.38

Table 3. The amount of GHG emissions in the UHT coconut milk production process (Co-Product: Model 2)

Life cycle inventory	GHG emissions (gCO ₂ eq./kg)		
	acquisition and utilization	transportation	Total
raw material extraction	668.4	37.8	706.2
production	201.57	0.02	201.59
product distribution	-	15	15
use	-	-	-
disposal	27.4	0.28	27.68
Total	897.37	53.1	950.47

the production process (201.17 g of carbon dioxide equivalent, 21.22%), disposal process (27.68 g of carbon dioxide equivalent, 2.92%) and product distribution (15 g of carbon dioxide equivalent, 1.58%) respectively. In addition, the GHG emission of co-product processing is lower than major production by about 35% (compared with baseline processing) (Table 4).

CFP from Biogas Utilization Scenario

The biogas from the wastewater treatment system for electrical production was evaluated for GHG emission. The total GHG emission of the biogas utilization scenario, including raw material extraction, production, product distribution, use, and disposal from co-product processing of UHT coconut milk (1 kg), is 1,377.4 g of carbon dioxide equivalent. The highest emission came from the raw material extraction process (1,150.8 g of carbon dioxide equivalent, 83.51%) followed by the production process (184.5 g of carbon dioxide equivalent, 13.40%), disposal process (27.60 g of carbon dioxide equivalent, 2.01%) and product distribution (14.5 g of carbon dioxide equivalent, 1.09%) respectively (Table 5). In addition, the GHG emission of the biogas utilization scenario is lower than significant production by about 5.97%

(compared with baseline processing). Moreover, we found that the GHG emission in production decreased by about 32%. This result indicates that biogas could reduce GHG emissions or the carbon footprint of UHT coconut milk production. This result is consistent with the research of Hansupalak *et al.* (2016) which indicated that biogas could reduce the carbon footprint of the Thai cassava starch industry.

CFP from Co-product and Biogas Utilization Scenario

The total GHG emission of co-product and biogas utilization scenario model 1 (major and co-product of coconut milk production of falling coconut flesh, coconut skin peels and residues), including raw material extraction, production, product distribution, use, and disposal from co-product processing of UHT coconut milk (1 kg) is 1,015.76 g of carbon dioxide equivalent. The highest emission came from the raw material extraction process (800.43 g of carbon dioxide equivalent, 78.80%), followed by the production process (175.65 g of carbon dioxide equivalent, 17.00%), disposal process (27.68 g of carbon dioxide equivalent, 2.73%) and product distribution (15 g of carbon dioxide equivalent, 1.48%)

Table 4. The amount of GHG emissions in the UHT coconut milk production process (Co-Product: Model 3)

Life cycle inventory	GHG emissions (gCO ₂ eq./kg)		
	acquisition and utilization	transportation	Total
raw material extraction	666.7	37.58	704.28
production	201.15	0.02	201.17
product distribution	-	15	15
use	-	-	-
disposal	27.4	0.28	27.68
Total	895.25	52.88	948.13

Table 5. The amount of GHG emissions in the UHT coconut milk production process (Biogas)

Life cycle inventory	GHG emissions (gCO ₂ eq./kg)		
	acquisition and utilization	transportation	Total
raw material extraction	1.0725	0.0783	1,150.80
production	0.1845	0	184.5
product distribution	-	0.0145	14.5
use	-	-	-
disposal	0.0274	0.0002	27.6
Total	1.2844	0.093	1,377.40

Table 6. The amount of GHG emissions in the UHT coconut milk production process (Biogas: Model 1)

Life cycle inventory	GHG emissions (gCO ₂ eq./kg)		
	acquisition and utilization	transportation	Total
raw material extraction	752.03	48.4	800.43
production	172.63	0.02	172.65
product distribution	-	15	15
use	-	-	-
disposal	27.4	0.28	27.68
total	952.06	63.7	1,015.76

respectively. In addition, the GHG emission of the co-product and the biogas utilization scenario for model 1 is lower than for primary production by about 31% (compared with baseline processing) (Table 6).

Total GHG emission of co-product and biogas utilization scenario model 2 (major and co-product of coconut milk production of falling coconut flesh, coconut skin peels, residues and coconut water) including raw material extraction, production, product distribution, use, and disposal from co-product processing of UHT coconut milk (1 kg) is 918.09 g of carbon dioxide equivalent. The highest emission came from the raw material extraction process (705.88 g of carbon dioxide equivalent, 76.89%), followed by the production process (169.53 g of carbon dioxide equivalent, 18.47%), disposal process (27.68 g of carbon dioxide equivalent, 3.02%) and product distribution (15 g of carbon dioxide equivalent, 1.63%) respectively. In addition, the GHG emission of co-product and biogas utilization scenario for model 2 is lower than major production by about 37% (compared with baseline processing) (Table 7).

Total GHG emission of co-product and biogas utilization scenario model 3 (major and co-product of coconut milk production of falling coconut flesh, coconut skin peels, residues, coconut water and coconut pulp) including raw material extraction, production, product distribution, use, and disposal from the co-product processing of UHT coconut milk (1 kg) is 916.10 g of carbon dioxide equivalent. The highest emission came from the raw material extraction process (703.96 g of carbon dioxide equivalent, 76.84%), followed by the production process (169.46 g of carbon dioxide equivalent,

18.50%), disposal process (27.68 g of carbon dioxide equivalent, 3.02%) and product distribution (15 g of carbon dioxide equivalent, 1.64%) respectively. In addition, the GHG emissions for the co-product and biogas utilization scenario model 3 are lower than major production by about 37% (compared with baseline processing) (Table 8).

Electrical Energy Consumption in UHT Coconut Milk

The electrical energy consumption in 1 kg of UHT coconut milk is divided into two parts: (1) electrical consumption for direct production such as machinery for production, light, and supporting electricity within the production area; and (2) electrical consumption for the support of production such as wastewater and the use of stream water, cold water, compressed air and raw water.

The total electrical energy consumption for 1 kg of UHT coconut milk is 0.1548 kWh. Direct production used about 0.0920 kWh (59%) of electrical energy. The supporting production used about 0.0628 kWh (41%) of electrical energy.

The total electrical energy consumption for 1 kg of UHT coconut milk products and the development of co-products, including Group 1, Group 2, and Group 3, showed greenhouse gas emissions of 1,466, 1,065, 950, and 948 gCO₂eq, respectively. When we used biogas from the wastewater treatment system as fuel for electrical production, the electrical energy consumption decreased for baseline processing and co-product models 1, models 2, and models 3. The total greenhouse gas emissions of 1,377 gCO₂eq and co-product development including Group 1, Group 2, and Group 3, showed greenhouse gas emissions of

Table 7. The amount of GHG emissions in the UHT coconut milk production process (Biogas: Model 2)

Life cycle inventory	GHG emissions (gCO ₂ eq./kg)		
	acquisition and utilization	Transportation	Total
raw material extraction	668.08	37.8	705.88
production	169.51	0.02	169.53
product distribution	-	15	15
use	-	-	-
disposal	27.4	0.28	27.68
total	864.99	53.1	918.09

Table 8. The amount of GHG emissions in the UHT coconut milk production process (Biogas: Model 3)

Life cycle inventory	GHG emissions (gCO ₂ eq./kg)		
	acquisition and utilization	transportation	Total
raw material extraction	666.38	37.58	703.96
production	169.45	0.02	169.46
product distribution	-	15	15
use	-	-	-
disposal	27.4	0.28	27.68
total	863.23	52.88	916.1

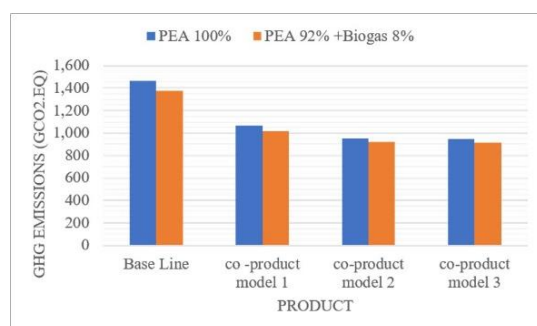


Figure 3. Shows a Comparison of GHG gas content from 100% PE production process with PEA 92%

1,016, 918, and 916 gCO₂e, respectively. Total greenhouse gas emissions and co-product development, including Group 1, Group 2, and Group 3 from biogas, showed decreases of 6%, 30.7%, 37.4%, and 37.5% per year compared to the baseline case, as shown in Figure 3.

This result indicates that the baseline process, without using biogas, leads to higher GHG emissions and a larger carbon footprint than when biogas was used as electric energy because the baseline process released methane into the atmosphere (Hansupalak *et al.*, 2016).

Conclusions

Using biogas from the wastewater treatment system as fuel for electrical production, which was used in both the production of baseline processing and the co-product model, decreased electrical energy consumption and reduced the number of greenhouse gases in the production process of UHT coconut milk.

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