LIFE CYCLE ASSESSMENT OF CANNED SWEET CORN IN CHIANG MAI

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Abstract:
Thailand is one of the world's largest exporters of agricultural products, with several agricultural crops that play a vital role in the global economy. One of the country's most renowned agricultural crops is sweet corn. Normally, sweet corn is brought to be processed into canned sweet corn, considered as a successful export product that generates massive profits for the country while meeting the demand of the global market. Sweet corn is an easily grown crop that offers high productivity and can be cultivated throughout the year. Therefore, the processing of sweet corn can add value to the newly processed product ready for the market expansion and export. In 2013, Thailand was ranked first for the exporter of canned sweet corn, with a total cultivation area of 247,138 rai generating a yield of 365,061 tons. Sweet corn is famously planted in the northern part of Thailand due to its appropriate weather condition. Chiang Mai is considered as the largest cultivation hub in the north, possessing more than 32 percent of market share of the total cultivation area in the region. In addition, there are several important production plants of canned sweet corn for exportation located in different areas in the country. This research aims to study the life cycle of canned sweet corn in Chiang Mai via the Life Cycle Assessment (LCA) for 3 production plants in the province, with more than 80 percent of export market share. The objective is also to assess the environmental impact of the product, which can be divided into 2 categories, including Carbon Footprint and Water Footprint. The assessment methods are designed to serve as guidelines for environmental sustainability and hinder the shortage of natural resources that may occur in the near future as well as eliminate redundant costs, processes and resources while enhancing competitiveness in the global market. According to the study, 1 can of 12-ounce canned sweet corn with net weight of 340 grams causes 399.51 grams of the carbon footprint (G CO_2-eq.)and 274.48 liters of the water footprint (L H_2O-eq.). The acquisition of raw materials with the carbon footprint and the water footprint is estimated at 70.77 percent and 97.96 percent, respectively. Meanwhile, the production process of both categories is equal to 29.23 percent and 2.04 percent, respectively.

Keywords: canned sweet corn, Life Cycle Assessment (LCA), carbon footprint, water footprint

1. INTRODUCTION

The problem of natural resources has currently become more critical and controversial in several countries due to the decreasing number of resources resulted from various environmental impacts as well as the global warming influenced by the greenhouse effect, which causes a number of natural disasters including flood, drought and freshwater shortage, in which only 2.5 percent has existed comparing to the total amount of water in the world while two of the three categories are maintained in a form of polar ice, remaining less than 1 percent of utilizable freshwater. The natural resource and environmental situation of Thailand has been caused by several changing factors varying in the climate change, increasing population size, economic and industrial expansion, trade and investment competition and consumption trend, which have all forced natural resources to be utilized in the wrong way, exceeding their potential basically supported by the ecosystem. The country has therefore established a strategic natural resource management and environmental sustainability specified in the National Economic and Social Development Plan No. 11 (B.E. 2555-2559) legislated by the Office of the National Economics and Social Development Board aiming to develop and promote the effective use of natural resources, ensuring cost efficiency and environmental quality. Guidelines for the carbon footprint and water footprint in manufacturing products and promoting services for both agricultural and industrial sectors have been developed, as part of the goal to ensure sustainable development as Thailand is renowned as one of the world's largest agricultural countries, with various types of processed agricultural products to be exported at very high volume each year. One of the most remarkable economic crops is sweet corn, which is famously processed as canned sweet corn to be exported to foreign countries. In 2013, Thailand was ranked first for the exporter of canned sweet corn with its export volume of 167,011 tons valued 5,400 million baht, where the Philippines, Taiwan, Japan, South Korea are major export markets while the Middle East is considered as an emerging market for Thailand's canned sweet corn business. Judging from the current trend, sweet corn is always an on-demand product that can consistently achieve strong growth in the global market, thanks to its potential, competitiveness and eco-friendly quality. Therefore, Life Cycle Assessment (LCA) is significant for manufacturers to understand the environmental status of their products in order to improve and promote the products' environmental value that leads to maximizing competitiveness for Thai business entrepreneurs to sparkle in the global market and gear up for sustainable development of Thailand's business industries.

2. THEORIES AND RELATED RESEARCHES

2.1. Carbon footprint assessment

The calculation of greenhouse gas emitted from each product throughout its life cycle including the acquisition of raw materials, transportation, production, utilization and waste management can be concluded as (CO_2-eq). Greenhouse gas includes Carbon Dioxide (CO_2), Methane (CH4), Nitrous Oxide (N_2O), Hydro Fluorocarbon (HFCs), Per Fluorocarbon (PFCs), Sulfur Hexafluoride (SF_6) and other gases with greenhouse properties. The global warming potential is calculated from the amount of each emitting greenhouse gas and converted into the form of equivalent Carbon Dioxide referring to the GWP 100 of the latest IPCC used as the criteria. For example, Methane is estimated to possess GWP 100 at 25 means Methane of 1 kilogram causes the global warming potential equivalent to Carbon Dioxide of 25 kilograms. Therefore, the emission of a 1-kilogram Methane can cause the global warming potential equivalent to Carbon Dioxide of 25 kilograms. The amount of greenhouse gas emission and absorbance of the organization is calculated in ton (kilogram) of each type of greenhouse gas and is also included in ton (kilogram) of the equivalent Carbon Dioxide.

2.2. Carbon footprint calculation

Primary and secondary data must be converted into the emitting amount of greenhouse gas in each activity. It is required to convert the amount of greenhouse gas into the form of equivalent Carbon Dioxide per product multiplied by the coefficient of the emission factor. The result should be displayed in the form of the equivalent Carbon Dioxide and is required to be summed up with the equivalent Carbon Dioxide received from all processes, with reference to the following equation (1).

$$CFP = \Sigma (A_i \times EF_i) \qquad (1)$$

CFP = Carbon Footprint or the equivalent Carbon Dioxide per product
A_i = Emitting amount of greenhouse gas in each activity i
EF_i = Coefficient of the emission factor in each activity i

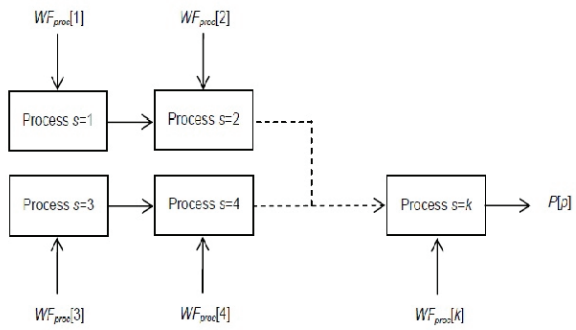
2.3. Water footprint assessment

This is used to calculate the direct and indirect utilization of water in developing the product. The calculation can be conducted in 2 approaches as follows:

Chain-Summation Approach

This approach is used when the production system is designed for the manufacturing of a single product, which can be calculated according to the following equation (2).

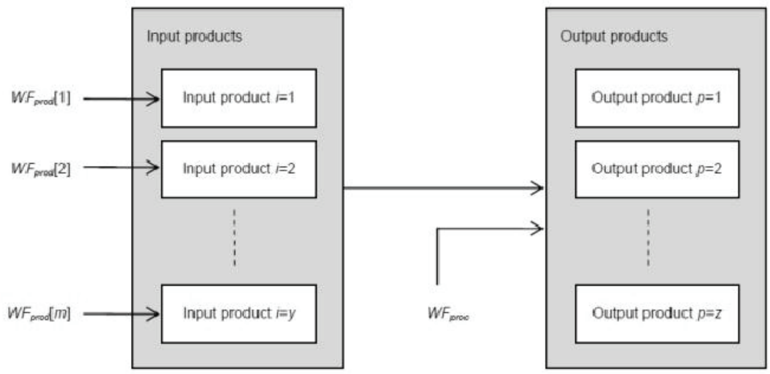
Figure 1: Chain-summation production system



$$WF_{prod}[p] = \frac{\sum_{s=1}^{k} WF_{proc}[s]}{P[p]} \tag{2}$$

WFprod [s]	=	Value of water footprint *s*
P[p]	=	Manufacturing amount of product

Figure 2: Step-wise accumulative production system



Step-Wise Accumulative Approach

This approach is used for the calculation of the water footprint of a product by combining the water footprint values of the raw materials and incoming products, considered as a significant process of the final stage of production according to Figure 2 and the calculation of equation (3)-(5) as follows.

$$WF_{prod}\,[p] = \left(WF_{proc}[p] + \sum_{i=1}^{y} \frac{WF_{prod}[i]}{f_p[p,i]}\right) \times f_v[p] \tag{3}$$

$$f_p[p,i] = \frac{w[p]}{w[i]} \tag{4}$$

$$f_v[p] = \frac{price[p] \times w[p]}{\sum_{p=1}^{z}(price[p] \times w[p])} \tag{5}$$

WFprod [p]	=	Water footprint value of the product (volume per weight)
WFprod[i]	=	Water footprint value of the incoming raw materials

WFproc[p]	=	Water footprint value of the processing of raw materials into the product
fp[p,i]	=	Productivity of the product
fv[p]	=	Productivity of the product's value
w[p]	=	Amount of the outgoing product
w[i]	=	Amount of the incoming product
price[p]	=	Price of the product

2.4. Water footprint of crop cultivation

This includes products with agriculture-based ingredients applied into fuel, food and cosmetics, mainly used in the production process of the agricultural sector. Therefore, agriculture-based products are directly related to the water footprint generated in the cultivation process varying in blue, green and grey displayed in the following equation.

WFproc = WFproc/green + WFproc/blue + WFproc/grey

WFproc	=	Overall water footprint used in the production process (cubic meter per ton)
WFproc/green	=	Green water footprint used in the production process (cubic meter per ton)
WFproc/blue	=	Blue water footprint used in the production process (cubic meter per ton)
WFproc/grey	=	Grey water footprint used in the production process (cubic meter per ton)

The green, blue and grey water footprint of the crop cultivation can be calculated according to the following equation.

$$WF_{proc,blue} = \frac{CWU_{blue}}{Y} \quad (6)$$

$$WF_{proc,green} = \frac{CWU_{green}}{Y} \quad (7)$$

$$WF_{proc,gray} = \frac{(\propto \times AR)/(C_{max} - C_{natural})}{Y} \quad (8)$$

When CWU is the amount of water used by a crop,

AR	=	Rate of chemicals used in cultivation area (kilogram per rai)
$\propto$	=	Washout ratio
C_{max}	=	Maximum acceptable concentration(kilogram per rai)
$C_{natural}$	=	Pollutant concentration (kilogram per rai)

The calculation of the value of the green and blue water footprint in crop cultivation commonly relies on the use of the CROPWAT program developed by FAO in 1988 in order to calculate the crop water requirement, moisture availability and irrigation requirement, with regard to the appropriate classification of soil layers referring to the calculation of climate, crop and soil. The CROPWAT program is calculated from ETa: actual evapotranspiration, ETm: potential Evapotranspiration, effective rainfall and crop water requirement. In addition, the CROPWAT program requires the input data as follows:

1. Weather data – includes temperature, humidity, sunlight, wind speed and rainfall.
2. Crop data – includes crop development stage, crop factors, rooting depth and yield response factors.
3. Soil data – includes water in soil, with different water level available different types of soil.

2.5. Literature review

Patcharee and friends (B.E. 2550) thoroughly studied on the experiment and development in the sweet corn production, with the comparison between the technological process of sweet corn production of the Chinat Field Crops Research Center and the agricultural process of sweet corn production used in the upper-northern provinces of Thailand totaling 3 methods varying in collecting soil for the assessment of nutrient amount, preparing land plots for sweet corn plantation and injecting fertilizer for productivity measurement and evaluation with regard to stem height, pod length, harvesting stem, harvesting pod, number of pods per stem, net weight of pod with shell, net weight of pod without shell, net weight of pod with shell per rai, net weight of pod without shell per rai and level of sweetness. It was required to make a record of meteorological data and analyze costs and returns. However, the results unveiled that the first method (grain-corn) using the agricultural process achieved greater productivity per rai comparing to the technological process provided by the Chinat Field Crops Research Center, where a cultivar known as Sugar # 75 offered the highest yield per rai, considered the highest level of grain-sweet corn cultivation.

Ingwersen (2012) studied on the life cycle assessment of pineapple in Costa Rica starting from its plantation in a farm to retail export to the US. The study focused on all possible impacts varying in the energy loss of the carbon footprint and the water footprint, soil erosion and toxicity to human health and ecosystem. The study result encouraged manufacturers to prevent the production that caused an impact to the environment as well as the selection of appropriate geography for cultivation, appropriate production, consideration on toxic or carbon-based products and efficient use of energy regarding the application of the life cycle assessment in controlling managing tropical fruits.

A.Y. Hoekstra (2005) studied on the water footprint in the US, revealing that the country used a large amount of water comparing to other countries across the world. According to the information in 1997-2001, the average water footprint of the US was estimated at 2,480 square meters per year comparing to China, the country of the world's highest population, generating only 700 square meters per year, where the world's average water footprint remained at 1,240 square meters per year, ranked third for the country with the highest footprint. The US's water footprint was mostly resulted from the water utilization, varying in 48 percent in agricultural products, 24.5 percent in industrial products, 8.7 percent in household use and 18.4 percent in water from outside the country (8).

Roos et al (2010) focused the study on the uncertainty of the carbon footprint in food products related to the King Edwards's potato case study. This research team had prepared detailed transactions according to the trend of global warming similar to Sweden. The study revealed that the carbon footprint of potato remained in the range between 0.10-0.16 kilogram. In addition, 95 percent of potato produced in the year was estimated to have Carbon Dioxide and Nitrous Oxide emitted from the soil, considered as the uncertainty of the carbon footprint emission. The lowest productivity during the period of uncertainty remained at 19 percent. Additionally, potato could fully be grown in the weather with the carbon footprint lower than 9 percent of annual productivity of 53 percent. According to the calculation of the carbon footprint for annual potato plantation, its value was estimated to vary between -17 to +30 of the certain average value. In preparing the uncertainty for analysis, labeling the carbon footprint notice on food products could ensure unbiased comparison.

3. RESEARCH METHODOLOGY

3.1. Scope of research

It is required to apply the life cycle assessment in evaluating the environmental impact divided into 2 categories. Firstly, the carbon footprint emitted from the acquisition of manufactured products. Secondly, the water footprint derived from the production of canned sweet corn weighed 340 grams provided by production plants in Chiang Mai. Obviously, the scope of research requires the Cradle-to-Gate assessment as the production plants used in this research are contract manufacturing companies.

3.2. Data collection

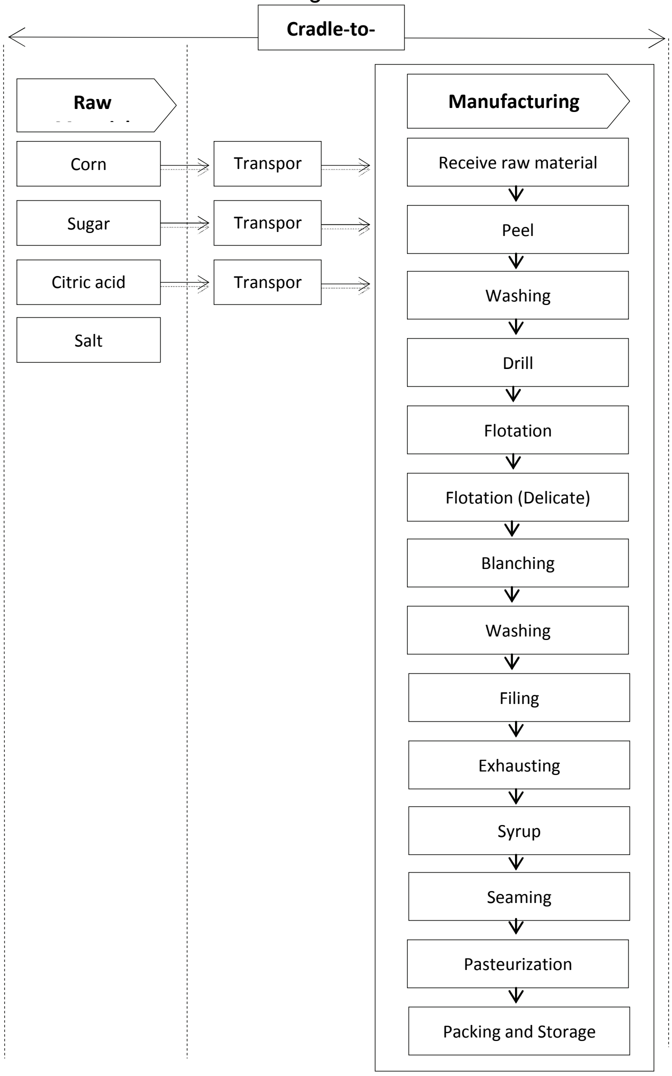
The collection of data requires information sharing and value measurement genuinely conducted at the sites. In addition, data collection is determined to rely mainly on representatives of the canned sweet corn production plants in Chiang Mai. It is required to study on theories and collect significant information from various sources from both local and international organizations. The secondary data also requires the coefficient of the emission factor according to the data provided by the greenhouse gas management organization, the coefficient of the water footprint using the Sigma Pro program based on the temperature data provided by the Meteorological Department, the cultivation data obtained from various organizations developed to calculate the evaporation of crops and the amount of rainfalls required for their growth using the CROPWAT program and the research data prepared by different educational institutions including Kasetsart University, Mahidol University, Chiang Mai University and other top universities in the country.

3.3. Research methodology

The implementation of the research requires the life cycle assessment applied to 3 production plants. According to the data collected over the past 1 year, the value obtained from the assessment is required to be used as the central data of this research, where procedures of the canned sweet corn's life cycle assessment can be described as follows:

The objective of this research is to assess the life cycle of canned sweet corn for consumption, considering 1 can weighed 340 grams. The scope, also known as system boundaries, of the Cradle-to-Gate (Business-to-Business: B2B) involves in the acquisition of raw materials and production shown in Figure 3 below.

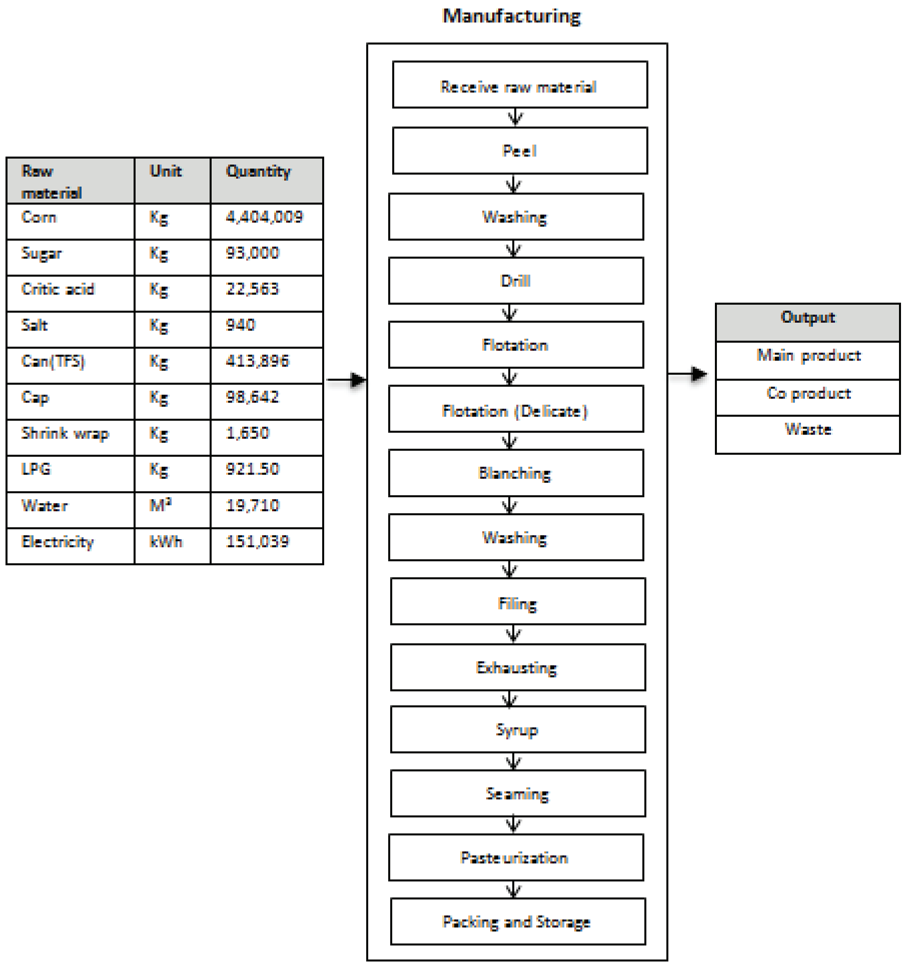
Figure 3: Life Cycle Assessment of canned sweet corn using B2B assessment



3.4. Inventory analysis

The environmental data requires both inputs and outputs of the acquisition of the product including the acquisition of raw materials, sweet corn cultivation, raw material transportation and production process, where the input also refers to raw materials, resources and energy as well as the supporting systems and materials for production. Meanwhile, the output engages in major products, minor products, wastes and environmental impacts shown in Figure 4. The utilization of resources for the production of canned sweet corn includes the preparation process prior to the actual production of minor water, cooling water, steaming water and wastewater treatment.

Figure 4: Life cycle impact (LCI)



This research requires the allocation, mass allocation, mass balance, law of mass conservation and energy balance. It is a fundamental principle of energy conservation law, saying that energy cannot be boosted and lost. Therefore, the total energy of any object must possess equal value at all existing positions.

This focuses on the assessment of the carbon footprint and the water footprint throughout the life cycle of canned sweet corn. According to the information engaged in the utilization of resources, energy and waste emission occurred to the product throughout its life cycle, it is calculated to assess the environmental impact received from the assessment process. The calculation exists in the form of the equivalent Carbon Dioxide and the water used in the acquisition of the product to ensure the preparation of data to be used in the interpretation of the environmental impacts of the product.

The interpretation of the environmental impacts discloses the facts of the carbon footprint and the water footprint in the production, which leads to the solutions of possible environmental impacts while maximizing production potential and cost efficiency.

4. STUDY RESULT

4.1. Study result of carbon footprint

The study result of the carbon footprint unveils that the acquisition of canned sweet corn, 1 can weighed 340 grams, possesses the greenhouse gas emission of 399.51 grams with the equivalent Carbon Dioxide (g CO2-eq.) shown in Table 1.

The process of the acquisition of raw materials with the carbon footprint equal to 282.72 or 70.77 percent is considered as the process that produces the highest emission rate of greenhouse gas. The major impact is caused the acquisition of canned sweet corn at 59 percent, with the carbon footprint in the production process of 116.79 grams.

Table 1: Carbon footprint result

Life Cycle	g CO_2-eg.	%
Raw material	282.72	70.77
Manufacturing	116.79	29.33
Total	399.51	100.00

4.2. Study result of water footprint

According to the study result of the water footprint, the acquisition of canned sweet corn, 1 can weighed 340 grams, possesses the utilization of water of 274 liters (L H_2O) throughout its entire life cycle shown in Table 2.

The water footprint of the acquisition of raw materials is equal to 268.868 liters, considered as 97.96 percent of the total water footprint. The major impact comes from the acquisition of corn pods equal to 87.50 percent while 5.613 percent is derived from the production process. Obviously, the majority of water is used in the sterilization process of 47.69 percent. In producing a can of sweet corn product, the study reveals that its production requires 181, 47.495 and 45.986 liters of the green, blue and grey water footprint, respectively.

Table 2: Water footprint result

L H_2O				%
Green water	Blue water	Gray water	Total	
180.9969	41.9089	45.9626	268.8684	97.96
0.0000	5.5857	0.0269	5.6126	2.04
180.9969	47.4945	45.9895	274.4810	100

5. SUMMARY

According to the life cycle assessment of canned sweet corn, entrepreneurs in the sweet corn industry can rely on the result and use it as the standard in operating the business. It is obvious that some processes are redundant for the production of canned sweet corn, which will result in several environmental impacts. If all production plants are able to seek effective solutions to tackle such problem, it will help benefit entrepreneurs in reducing the production costs, building an admirable image and possessing greater competitiveness in the global market.

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