Life Cycle Assessment of Heaven Mushroom Product

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Abstract. Climate change affects all regions around the world, so efforts to minimize the environmental impacts of climate change have high importance. The aim of this study is to evaluate the environmental impacts on the production of heaven mushroom product at the Ban Tai Khod community in Rayong, Thailand. In this study, cradle to gate was selected as the system boundary and functional unit from the life cycle assessment method. The results found that the process of building a mushroom house has the highest greenhouse gas emissions of 1,496.609 $kgCO_{2eq}$. The mushroom cubes mixing process has the highest energy consumption throughout the production process, requiring an energy consumption of 5.595 kWh. The greenhouse gas is released amount 3,588.362 $kgCO_{2eq}$. throughout this process. Additionally, the payback period of the heaven mushroom product is 0.92 years.

1 Introduction

The release of greenhouse gases (GHG) and their increasing concentration in the atmosphere is leading to climate change. The increase of greenhouse gas emissions is related to energy demand and economic growth which is affecting human health and the environment [1]. Average temperatures in Southeast Asia have risen every decade since 1960. According to the Global Climate Risk Index (Germanwatch), Thailand is one of 10 countries in the world that have been most affected by climate change over the past 20 years [2]. Climate change policy in Thailand is well defined and follows the UNFCCC's goal to reduce greenhouse gas emissions. This reflects strong engagement with international policy discourse which will continue to be a main policy driver for national climate change actions. The Eastern Economic Corridor (EEC) is the most effective area to reduce GHG emission because of the highest CO_2 emission from the industrial and agricultural sectors [3]. In particular, Rayong has many agricultural areas and high-value agricultural products, so the government set the agricultural action plan with the aim of increasing the potential of farmers and encouraging agricultural products.

The Ban Tai Khod community, a learning center of the sufficiency economy philosophy, was selected as a case study. The community is an example of a sustainable self-reliant community. Most of the people in the community work at a rubber plantation and gain additional income from growing organic vegetables, making compost, and cultivating mushrooms [4]. The oyster mushrooms are easy to cultivate and get high yields, in addition, they can sell through various distribution channels [5]. In the past, the cultivation of mushrooms within the community did not take into account the energy and environmental impacts. A life cycle assessment (LCA) is needed in order to understand energy consumption, energy loss and environmental impacts in all of the processes. LCA is used to assess the process from the preparation of raw materials through to agricultural product processing.

Several studies in the past decade have concentrated on reducing GHG emissions and other environmental impacts from agricultural products using LCA as a tool. They found that the batch process of making raw material, transportation and maintenance are the most environmentally friendly. Ukaew and Bunsung [6] evaluated the GHG emissions of two types of fresh rice noodles, wide rice noodles and rice stick noodles, in Phitsanulok Province. The outcomes shown that rice cultivation contributed the highest amount of emissions. Moreover, the study offered potential means to decrease GHG emissions with making production and energy efficiency improvements. Meanwhile, Piamdee et al. [7] quantified the environmental impacts of smoked fish sausages weighing 250 grams, and found that fish meat cutting contributes to total CO_2 emissions 0.49 $kgCO_{2eq}$. Suesa-ard and Sachakamol [8] studied the environmental impact of melon in syrup in Chanthaburi by using LCA as a tool, mainly in terms of their water footprint. The product disclosed that one unit of 2,000 grams of melon in syrup required 688.86 liters of water. Phanchandee and Sachakamol [9] sought to raise environmental awareness of agriculture products by focusing on mango and mangoesteen production in Thailand by introducing the LCA. The study found that fertilizing process contributes the highest amount of emissions. Mangoesteen required water resources and emitted CO_2 more than mango. Chiramakara et al. [10] studied the environmental impact of CO_2 emissions from Bana grass cultivation for elephants to consume in Surin. It found that Bana grass planting produced 20 tons per rai and the total CO_2 emissions from the cultivation of Bana grass was

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2,006.3132 $kgCO_{2eq}$. Cabral et al. [11] performed LCA of goat milk and goat cheese production. The study revealed that the environmental impacts relate to the main ingredient of goat feed for example goat milk production and soybean. For environmental impact reduction, hay and grass partially instead of soybean for goat feed. Naderi et al. [12] evaluated the energy flow and environmental impacts of bell pepper production in greenhouse structures using the LCA method. The normalized results show that the marine water eco-toxicity, freshwater eco-toxicity, and abiotic resource depletion had the highest values among all impacts, respectively. Gunady et al. [13] performed LCA with 1 kJ of strawberries, button mushrooms, and romaine/cos lettuces transported to retail outlets in Western Australia. The results show that the life cycle GHG emissions of strawberries and lettuces were higher than mushrooms.

This study uses LCA as a tool for evaluating heaven mushroom product from cradle to gate. The specific tasks conducted in this study include an assessment of the global warming potential, abiotic depletion potential, and human toxicity. The GHG emissions and environmental impacts focused on this scope and the payback period of the project included in this study.

2 Methodology

The LCA of heaven mushroom product was aimed to assess three aspects of the impact on the environment: the global warming potential, the abiotic depletion potential, and the human toxicity, and offer ways to use energy and resources that have the fewest impacts on the environment. In addition, the payback period was calculated.

2.1 Life Cycle Assessment

The LCA is increasingly used as a tool to organize environmental impact analysis across products throughout the entire life cycle, from "cradle to gate". A product LCA consists of four steps: goal and scope definition, inventory analysis, impact assessment, and interpretation.

2.1.1 Goal and scope definition

At this stage, first, the objectives of the study are defined and then, the functional unit and system boundary are determined. In this study, a functional unit of 2,000 pieces of mushroom cubes was considered. The goal of this study is to assess the cradle to gate impact environmental of heaven mushroom products as shown in Fig. 1.

2.1.2 Life cycle inventory

The life cycle inventory considers all relevant inputs and outputs for processes that occur during the life cycle of heaven mushroom product. The process data were collected directly from the database, and these process data were used to calculate the inputs for producing heaven mushroom product from 2,000 pieces of mushroom cubes.

2.1.3 Impact assessment

The assessment in this study details specific to evaluate the environmental effects. By defining and classifying the significance of each impact, the study seeks to convert the life cycle inventory obtained from the data collection as the input and then determine the outputs as the environmental impact indicators of the production of heaven mushroom product. The global warming potential value is calculated by the Intergovernmental Panel on Climate Change (IPCC), in which the global warming potential reflects the climate forcing of a kilogram of emissions relative to the same mass of CO_2. In order to calculate the amount of CO_2 emission of heaven mushroom product, the formula that is shown in equation can be used (1).

$$CO_{2\,\text{emission}} = \textit{Activity data} \times \textit{Emission Factor} \qquad (1)$$

Where the activity data refers to activity data that contributes to greenhouse gas emissions. The emission factor refers to representative value that attempts to relate the quantity of a pollutant released to the atmosphere with the activity associated with a release of that pollutant.

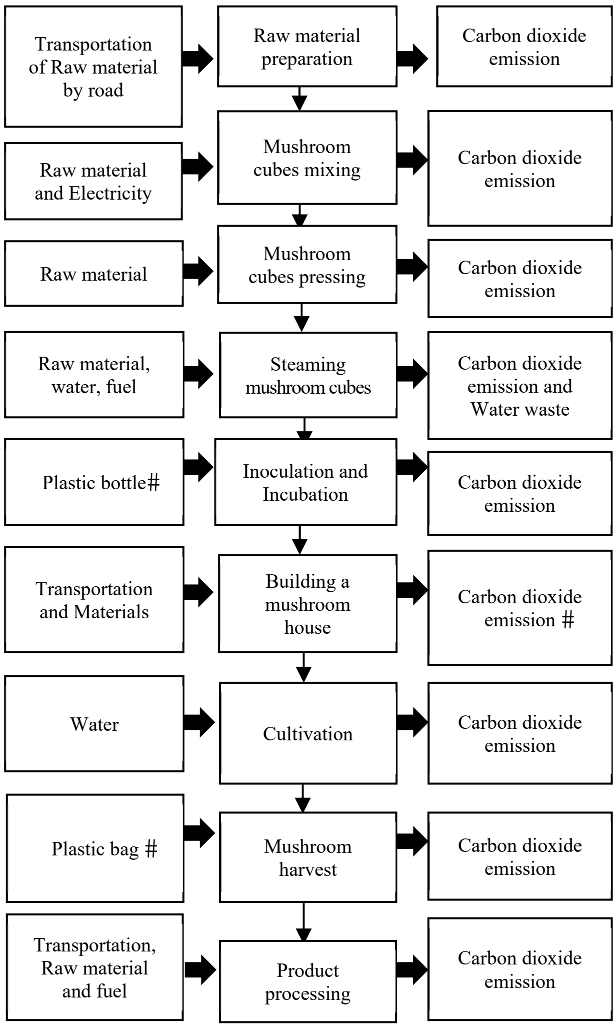

Fig. 1. The boundary of heaven mushroom product.

2.1.4 Interpretation

Data analysis was performed and proposals are made to reduce environmental impacts and improve resource efficiency.

2.2 Payback Period

Following recommendations on how to use energy and resources in ways which have the least environmental impact, further discussion concerns of how different approaches can be undertaken as both investment and non-investment. By following the investment approach, there must be a suitable and cost-effective payback period.

3 Results and discussion

3.1 Global warming potential

The study results indicate that the impact of heaven mushroom production in terms of raw material preparation of mycelium spawn 24.74% (887.626 $kgCO_{2eq}$) of total GHG emissions, mushroom cubes mixing accounted for 0.09% (3.349 $kgCO_{2eq}$), mushroom cube pressing accounted for 1.25% (44.926 $kgCO_{2eq}$), steaming mushroom cube process accounted for 0.06% (2.233 $kgCO_{2eq}$), inoculation and incubation accounted for 0.95% (34.038 $kgCO_{2eq}$), building a mushroom house process accounted for 41.71% (1,496.609 $kgCO_{2eq}$), cultivation process accounted for 0.02% (0.725 $kgCO_{2eq}$), mushroom harvesting accounted for 0.13% (4.798 $kgCO_{2eq}$), and product processing accounted for 31.05% (1,114.058 $kgCO_{2eq}$) of the total GHG emissions. The impact is similar to those assessed in published LCA studies investigating button mushroom production [13].# The highest GHG emissions were related to constructing mushroom houses because of transportation and materials such as shading nets and wood. The lowest GHG emission from heaven mushroom production was related to watering as shown in Table. 1.

3.2 Abiotic depletion potential

According to the results, the total energy input is estimated 5.595 kWh for stirring the ingredients of mycelium to produce 2,000 pieces of mushroom cubes. It is found that the highest amount of energy consumed in the production of heaven mushroom product (100%).

3.3 Human toxicity

The most important element for the growth of mushrooms is watering, while watering them, in addition to melting the raw materials of the mycelium spawn to the ground, the process also wastes water resources without benefit.

3.4 Payback Period#

The benefit of the heaven mushroom product is 969.76 USD. and the cost is 893.24 USD. The payback period is 0.92 years. It is found that acquisition of the product is costly, but it is a worthwhile long-term investment, because the process of mushroom cubes mixing and building a mushroom house are one-time investments.

Table 1. Global warming potential of production.

Input	Qty.	Emission factors ($kgCO_{2eq}$/unit)	Global warming potential	Ref.
4 wheel mini truck (km)	774	2.7446	2,124.320	[14]
Sawdust (kg)	2,000	0.0829	165.800	[14]
Rice bran (kg)	60	0.5661	33.966	[14]
Epsom salts (kg)	4	0.3385	0.582	[13]
Calcium carbonate (kg)	20	0.0366	0.732	[14]
Water (m^3)	3.75	0.2843	1.066	[14]
Plastic bag (kg)	14	2.3990	33.586	[15]#
Bottle neck (kg)	2	2.8854	5.771	[15]
Rubber and leathe (kg)	0.5	3.1300	1.565	[16]#
Cotton (kg)	9	0.978	8.802	[16]#
Electricity (kWh)	5.595	0.5986	3.349	[14]
Charcoal (kg)	9	1.0054	9.049	[14]
Plastic bottle (kg)	0.025	2.8854	0.072	[15]
Wood (kg)	153	0.0363	5.554	[14]
Leaf roof (kg)	21.6	0.0183	0.395	[14]
Shading net (kg)#	14	6.7071	93.899	[14]
Sand (kg)	500	0.0037	1.850#	[17]
PVC (kg)	2.88	2.1331	6.143	[14]
Palm oil (kg)	3.13	1.3990	4.379	[14]
Soy sauce (L)	4.5	0.1660	0.747	[18]#
Sugar (kg)	20#	1.0800	21.6000	[19]
Pepper (g)	900	1.1271	1,014.390	[14]
Salt (g)	165	0.0052	0.858	[14]
Coriander root (kg)	0.3	0.0868	0.026	[14]
Plastic box (kg)	27.13	1.8095	49.091	[14]
Logo Sticker (kg)	0.112	0.5100	0.057	[15]

4 Conclusion

The aim of this study was to evaluate the environmental effects of heaven mushroom product using the LCA method. The study found that the mushroom cubes mixing process has the highest energy consumption. The process of building a mushroom house has the highest greenhouse gas emissions, while the lowest GHG emission is the mushroom cultivation process. The water from the mushroom cultivation process did not affect the environment. The GHG is released amount 3,588.362 $kgCO_{2eq}$ throughout the process. In addition, the payback period of the heaven mushroom product is 0.92 years.

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