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Carbon Footprint of Straw Mushroom: A Case Study in Thailand

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Abstract

Carbon Footprint of product is a tool to calculate the quantity of GHG emissions from each production unit throughout the whole life cycle of a product start from the raw material acquisition, manufacturing, use, distribution and disposal. This tool is increasingly necessary for consumers to be informed the carbon footprint information for supporting their purchasing decision in Thailand. Therefore, the objective of this study was to analyze the carbon footprint of straw mushroom production to the environment. The method used is based on Thailand Carbon Footprint Guideline, which functional unit of the calculation is 1 kg of mushroom product. The inventory data were collected from the farm at Nakornsawan province, Thailand. The results were compared the carbon footprint of straw mushroom production with soybean hull as the conventional method, rapeseed hull and cassava hull formula. The result of this study indicated that the straw mushroom production with rapeseed hull had the highest carbon footprint. The comparative of carbon footprint of three formulas were 3.47 kgCO2eq for soybean hull formula, 12.8 kgCO2eq for rapeseed hull formula and 2.12 kgCO2eq for cassava hull formula. Mostly, the raw material acquisition stage had the greatest GHGs, 79% of carbon footprint from soybean hull formula, 49% of carbon footprint from rapeseed hull formula and 69% of carbon footprint from cassava hull formula. Furthermore, the Eco-Efficiency was to selected in order to evaluate the environment and economic of mushroom production. The result shown that the straw mushroom production with cassava hull had the greatest Eco-Efficiency that was 34.44 Baht/kg CO2eq, following by soybean hull formula at 18.95 Baht/kg CO2eq and rapeseed hull formula at 1.86 Baht/kg CO2eq. Therefore, the straw mushroom production with cassava hull formula was the best among those production methods.

Keywords: Carbon footprint, Straw mushroom, Greenhouse gas, Life cycle assessment

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Introduction

The new trends of environment, economy and society have been growing and are concerned about current non-sustainable development. These facts have led to an increased interest in the carbon footprint (CFP) and eco-efficiency. Food, one of the primary needs of human beings, creates carbon footprint of product (CFP) in each phase of its life cycle. In Thailand, food industrial sector concern about the significant amount of CFP. There were 726 products from 177 companies in Thailand that have been verified for CFP during year 2010-2012 (TGO, 2012). Furthermore, there are at least 80 companies of 177 companies that are in the food industrial sector.

Straw mushroom is scientifically known as Volvariella volvacea. It is a type of mushroom found widely distributed throughout Asia. Paddy straw is the most common substrate for this mushroom. It can also be cultivated on cotton waste, cotton ginning mill waste, sugarcane bagasse. Straw mushroom can be used as an ingredient in varieties of Thai recipes, such as stir-fried pork with oyster sauce, spicy soup with prawn and lemon grass or chicken tom yum. The production of straw mushroom is average 120,000 ton per year in Thailand and 30% of this production is exported.

There are varieties of CFP methodologies such as PAS2050 (Crown & Carbon Trust, 2008) for products and services, Korea CFP, Japan CFP including Thailand National Guideline for Carbon Footprint of Product. Thailand Greenhouse Gas Management Organization (TGO), as Thailand CFP certified body, has promoted the development of CFP since year 2010. To determine the CFP of a product or a process, its life cycle assessment (LCA) should be taken into account (Wiek & Tkacz, 2013). The unit of CFP is usually expressed as an equivalent of CO_2 and referred to a selected product or service. Carbon footprint of products takes into account the quantify of GHG emissions from each production unit throughout the whole life cycle of a product, start from the raw material acquisition, manufacturing, use, distribution and final disposal or waste management (TGO, 2012). However, there are two scopes of CFP in Thailand so called Business-to-Business (B2B) and Business-to-Customer (B2C). The scope of Business-to-Business is included the raw material acquisition and the manufacturing process. For the scope of Business-to-Customer is included the whole life cycle of product from raw material acquisition to end of life.

Methodology

Goal and Scope Definition

The objective of this study was to analyze the environmental impact in term of global warming category of straw mushroom production with three formulas; soybean hull, rapeseed hull and cassava hull. Moreover, the Eco-efficiency of three formulas was included in this study. The methodology used to determine the CFP was followed Thailand National Guideline of Carbon

Footprint of Product (TGO, 2012). This national guideline was adopted from life cycle assessment methodology.

Global Warming Potential (GWP) is used as a characterization impact for quantify of CFP. There are 6 GHGs that are considered in National Guideline; carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). Among all GHGs, carbon dioxide serves as a reference to compare the GWP of other gases. The global warming potential of GHGs can be referred from the Inter Governmental Panel on Climate Change report. Therefore, the carbon footprint can be calculated by the equation (1):

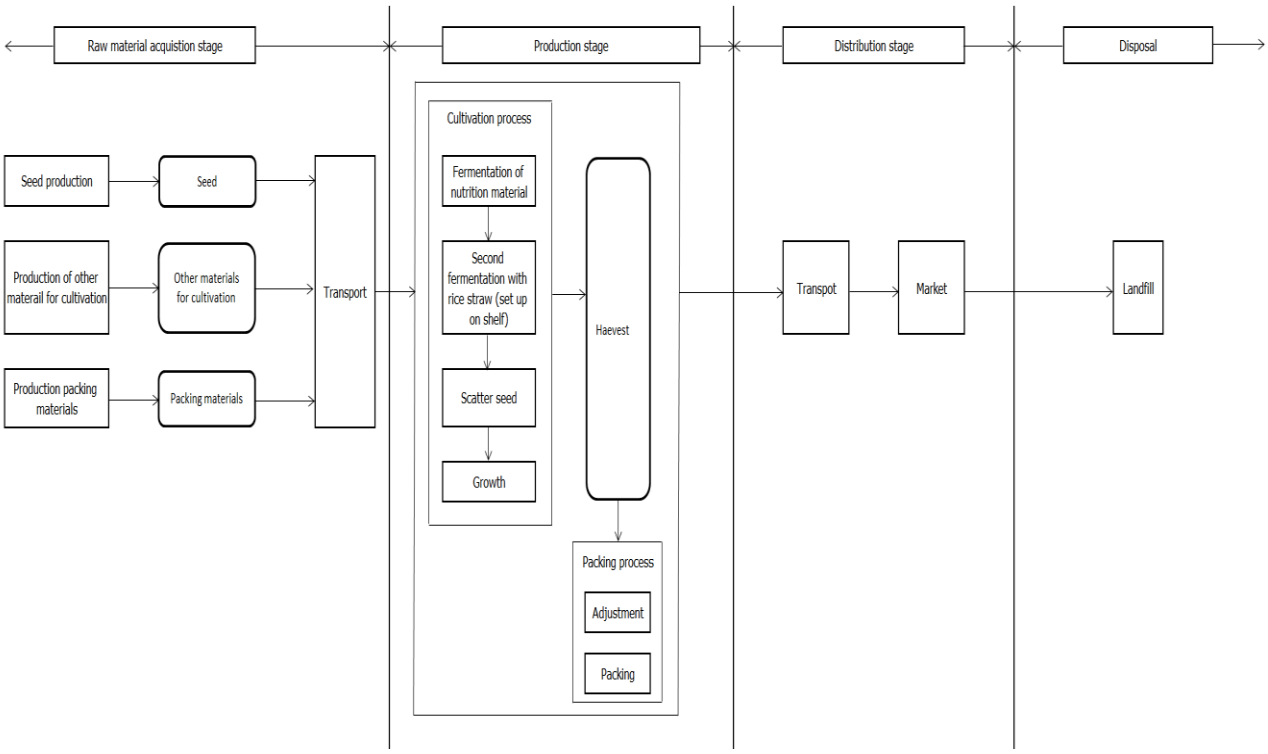
$$\text{Carbon Footprint} = \sum(\text{Environmental load} \times \text{Emission Factor})_i \quad (1)$$

Where: i = substance i

System Boundary

The selected factory is located at Nakornsawan province, the middle part of Thailand. The system boundary included the raw material of straw mushroom production such as soybean hull, cassava hull, rapeseed hull, urea, rice straw, production process including the CH_4 from the fermentation, distribution and end of life as so called Cradle-to-Grave or B2C, but not include use phase. The system boundary of this study is shown in Figure 1. However, the primary data used for this study was collected base on only one single farm as mentioned above.

Figure 1. *System boundary of the study*



Functional Unit

The functional unit is defined as a quantitative reference to which inputs and outputs are related to selected boundary. It is a one of the key in LCA, facilitating the comparison of alternative products and services (ISO14040, 2006). The function unit of this study is 1 kg of straw mushroom.

Eco-Efficiency

Eco-efficiency means producing economic output with minimal natural resources and environmental degradation (Kuosmanen, 2005). This tool reflects environmental and economy relationship (Spangenberg and et al, 2002). In general, the higher the output for a given input or the lower the input for a given output, the more efficient is an activity (Burritt & Saka, 2006). The Eco-efficiency equation can be expressed in equation (2).

$$Eco-efficiency = \frac{Product\ value}{Environmental\ impact} \tag{2}$$

Results and Discussion

Life Cycle Inventory

For the assembly of the inventory, the foreground system considered was based on the primary data from actual field operations during the production process. However, the data associated with the effects produced by the inputs in the background system such as fertilizer production, electricity, packaging production, chemicals production and transportation were derived from Thailand National Guideline of Carbon Footprint of Product, LCI database and literature sources.

A variety of waste materials have been used for general cultivation of the straw mushroom, which include; paddy straw, water hyacinth, oil palm bunch, banana leaves, saw dust, cotton or sugarcane bagasse. However, waste materials used in this study were soybean hull, cassava hull and rapeseed hull and the inventory with three formulas is shown in Table 1.The primary data were collected for 1 year, start from October 2011 to September 2012 at Nakornsawan province.

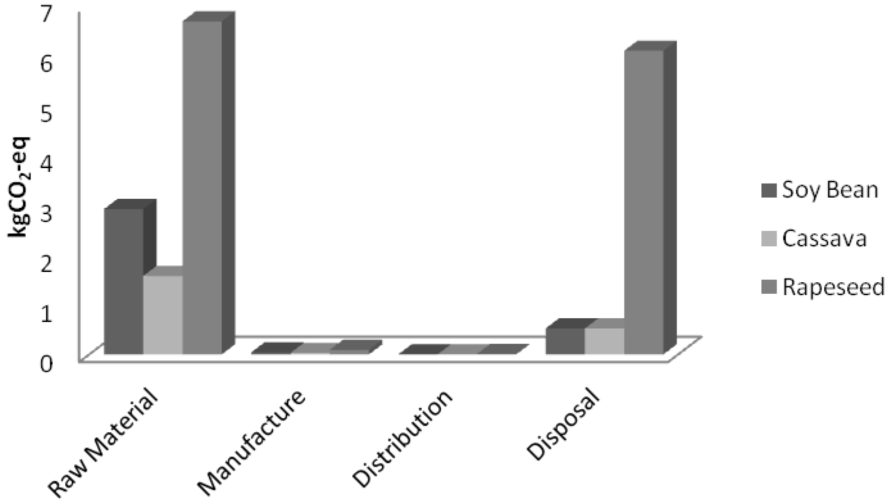
Table 1. *Inventory Data of Straw Mushroom with Soybean Hull, Cassava Hull and Rapeseed Hull Formulas*

	Soybean hull formula	Cassava hull formula	Rapeseed hull formula
Input			
Cotton (kg)	0.4990	0.3465	1.0850
Soybean hull (kg)	1.4969	-	3.2550
Cow dung (kg)	0.0832	0.0578	0.1808
Rice bran (kg)	0.2495	0.1733	0.5425
Lime (kg)	0.0125	0.0087	0.0271
Gypsum (kg)	0.0166	0.0116	0.0362
Urea (kg)	0.0042	0.0029	0.0090
Straw (kg)	1.0811	0.7508	-
Cassava hull (kg)	-	1.0396	-
Rapeseed hull (kg)	-	-	2.3508
Fungi sperm (kg)	0.3400	0.2300	0.7324
Underground water (L)	43.2432	30.0335	94.0325
Wood chip (kg)	0.9979	0.6931	2.1700
Plastic bag (kg)	0.0064	0.0064	0.0064
Transportation (km)	0.64	0.44	1.39
Electricity (kWh)	0.0124	0.0086	0.0270
Output			
CH_4 (kg)	2.7713E-05	2.1735E-05	3.1926E-05
Residue (Ton)	0.0002	0.0002	0.0024
Straw mushroom (kg)	1.00	1.00	1.00

Carbon Footprint Assessment

The carbon footprint assessment can be separated in 4 stages: raw material acquisition, production process, distribution and waste disposal by considering as a cradle-to-grave system boundary, but not include use phase in this study. The comparison of three straw mushroom formulas is shown in Figure 2. For soybean hull formula, CO_2 emissions are 2.91 kgCO_2eq at raw material acquisition, 0.04 kgCO_2eq at production stage, 0.002 kgCO_2eq at distribution stage and 0.52 kgCO_2eq at waste disposal stage. For cassava hull formula, CO_2 emissions are 1.57 kgCO_2eq at raw material acquisition, 0.03 kgCO_2eq at production stage, 0.001 kgCO_2eq at distribution stage and 0.52 kgCO_2eq at waste disposal stage. The last, for rapeseed hull formula, CO_2 emissions are 6.67 kgCO_2eq at raw material acquisition, 0.09 kgCO_2eq at production stage, 0.0075 kgCO_2eq at distribution stage and 6.08 kgCO_2eq at waste disposal stage. The main reason of the highest environmental impact from rapeseed hull is the yield of product. This experiment shown that the yield of straw mushroom production with rapeseed hull is one third of the yield of straw mushroom production with soybean hull and cassava hull. All in all, the result indicated that the main input that causes environmental impacts in mushroom cultivation is raw material acquisition stage for all formulas.

Figure 2. *Carbon Footprint of straw mushroom production*



CO_2 emission comparison to Shiitake Mushroom

The carbon footprint of Shiitake mushroom with three different packaging that referred to production category rule (PCR) no. PA-BW-01 of Japan was shown in Table 2 (Kubocom Ltd., 2013).

Table 2. *Carbon footprint of Shiitake*

Product Name	CO_2eq (kgCO_2eq/kg)
200g Shiitake mushroom with plastic bag packaging	4.39
100g Shiitake mushroom with tray	4.74
240g Shiitake mushroom with tray	4.63

The results shown that CFP of shiitake mushroom with plastic packaging was 4.39 kgCO_2eq per kg of product compared to CFP of straw mushroom with cassava hull formula with plastic packing was 2.12 kgCO_2eq per kg product. The fermentation that emitted methane gas during production process was unconfirmed in the scope of shiitake mushroom production. However, the CO_2 emissions of CFP of shiitake mushroom during use stage was included that was around 5% of CFP, but not include in the straw mushroom case study.

Eco-efficiency

The economic value (profit value) of straw mushroom was collected from October 2011 to September 2012 found that the average profit value of straw mushroom with soybean hull, cassava hull and rapeseed hull were 65.67 Baht/kilogram, 72.84 Baht/kilogram and 23.88 Baht/kilogram, respectively. Therefore, the eco-efficiency of straw mushroom with soybean hull, cassava hull and rapeseed hull were 18.95 Baht/kg CO_2eq, 34.44 Baht/kg CO_2eq and 1.86 Baht/kg CO_2eq, respectively.

Conclusion

The carbon footprint of 1 kg straw mushroom using soybean hull, rapeseed hull and cassava hull are 3.47 $kgCO_2eq$, 12.84 $kgCO_2eq$ and 2.12 $kgCO_2eq$, respectively. Therefore the cassava hull formula should be promoted to the farmer in stand of soybean hull formula as the conventional process. Moreover, the eco-efficiency of straw mushroom with cassava hull formula is the highest when compared to the others.

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