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Life Cycle Assessment for the Production of Oil Palm Seeds

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Abstrak: Unit pengeluar biji benih sawit yang menghasilkan biji benih cambah sawit merupakan penghubung pertama dalam rantaian bekalan minyak sawit, diikuti dengan tapak semaian untuk menghasilkan anak benih sawit, ladang untuk menghasilkan buah tandan segar (FFB), kilang untuk menghasilkan minyak sawit mentah (CPO) dan isirung kelapa sawit, mesin penghancur isirung untuk menghasilkan minyak isirung kelapa sawit mentah (CPKO), kilang minyak tertapis untuk menghasilkan minyak sawit tertapis (RPO) dan diikuti dengan kilang biodiesel untuk menghasilkan biodiesel berasaskan sawit. Penilaian ini bertujuan untuk mengenalpasti kitaran hayat (LCA) bagi penghasilan biji benih cambah sawit serta untuk menentukan peringkat pemprosesan bagi penghasilan biji benih cambah sawit yang boleh menyumbang kepada pencemaran alam sekitar. Kaedah bagi penilaian impak kitaran hayat (LCIA) bagi kajian ini telah dimodelkan menggunakan SimaPro versi 7, (*System for Integrated environMental Assessment of PROducts*), iaitu satu alat yang telah diperkenalkan pada peringkat antarabangsa untuk digunakan oleh para pengguna LCA. Perisian ini mengandungi pangkalan data Eropah dan Amerika Syarikat mengenai beberapa bahan di samping pelbagai kaedah penilaian impak yang telah dibangunkan oleh Eropah dan Amerika Syarikat. LCA telah berjaya dijalankan bagi lima unit pengeluar biji benih cambah sawit dan telah didapati bahawa impak terhadap persekitaran bagi penghasilan biji benih cambah sawit adalah tidak signifikan. Keputusan pencirian (*characterised*) LCIA bagi penghasilan 1000 biji benih cambah sawit menunjukkan bahawa bahan api fosil merupakan penyumbang kategori impak yang terbesar, diikuti dengan inorganik respiratori dan perubahan iklim.

Kata kunci: LCA, LCI, LCIA, Biji Benih Cambah Sawit, Impak Kepada Persekitaran

Abstract: The oil palm seed production unit that generates germinated oil palm seeds is the first link in the palm oil supply chain, followed by the nursery to produce seedling, the plantation to produce fresh fruit bunches (FFB), the mill to produce crude palm oil (CPO) and palm kernel, the kernel crushers to produce crude palm kernel oil (CPKO), the refinery to produce refined palm oil (RPO) and finally the palm biodiesel plant to produce palm biodiesel. This assessment aims to investigate the life cycle assessment (LCA) of germinated oil palm seeds and the use of LCA to identify the stage/s in the production of germinated oil palm seeds that could contribute to the environmental load. The method for the life cycle impact assessment (LCIA) is modelled using SimaPro version 7, (System for Integrated environMental Assessment of PROducts), an internationally established tool used by LCA practitioners. This software contains European and US databases on a number of materials in addition to a variety of European- and US-developed impact assessment methodologies. LCA was successfully conducted for five seed production units and it was found that the environmental impact for the production of germinated oil palm was not significant. The characterised results of the LCIA for the production of 1000

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germinated oil palm seeds showed that fossil fuel was the major impact category followed by respiratory inorganics and climate change.

Keywords: LCA, LCI, LCIA, Germinated Oil Palm Seeds, Environmental Impact

INTRODUCTION

The palm oil industry plays an important role in the economic development of Malaysia and in enhancing the economic welfare of the people. The productivity of an oil palm plantation depends on many factors, including the critical starting point of the quality of the germinated oil palm seeds derived from cross pollination of selected parent palms used for planting. The production of high quality germinated oil palm seeds is also very dependent on good management practices at the seed production unit.

Fresh fruit bunches (FFB) from the plantation are first brought to the seed production unit where the bunch weight is recorded (Basiron *et al.* 2001). After weighing, the fruit bunch is chopped with an axe on a table to separate the stalk from the spikelets. The fruits are then retted in trays or sacks for approximately 3–5 days to allow them to detach. After retting, isolation and separation of normal/developed fruits from parthenocarpics are carried out.

The normal/developed fruits are depericarped to separate the mesocarp from the seeds, normally using an electrical motor-driven depericarper. Seeds that have been depericarped are soaked to ensure an optimum moisture content of approximately 18%–19%, and then washed with a suitable detergent to remove the mesocarp oil from their surface before they are treated with a fungicidal solution to avoid fungal infection. The seeds are air-dried and those with defects are discarded.

Heat treatment is essential for breaking the dormancy of oil palm seeds for germination. For germination to occur, an optimum moisture content, temperature and oxygen level are needed. The oil palms seeds are then packed in polyethylene bags and placed on the germination racks for 14–30 days at a temperature between 25°C and 35°C. During this time, the seeds are sprayed with distilled water to prevent them from drying. Following germination, only normal and undamaged seeds are counted and selected before they are finally packed and distributed to the customers.

Multiple Life Cycle Assessment (LCA) methods have been developed and published (Brentrup *et al.* 2001). These methods include Centre of Environmental Science (CML, University of Leiden, The Netherlands), Environmental Design of Industrial Products (EDIP) and Eco-indicator. A previous study reported that the Eco-indicator 95 is a suitable method for analysing the environmental impacts of agricultural systems. However, Eco-indicator 99, a successor for Eco-indicator 95, is currently being employed. Both methods use the damage-oriented approach (Goedkoop *et al.* 2008). For the LCA of sunflower oil production, Eco-Indicator 99 methodology was chosen and has been proven to be a powerful tool to compile the LCA results into a user-friendly form (Spinelli *et al.* 2012).

Recently, Malaysian Palm Oil Board (MPOB) studies completed the LCA of Malaysian palm oil, including palm biodiesel. (Halimah *et al.* 2010; Puah *et al.* 2010; Tan *et al.* 2010; Vijaya *et al.* 2010; Zulkifli *et al.* 2010). Researchers implemented a *cradle-to-grave* analysis starting from the production of oil palm seedlings to the production and use of biodiesel. The results from these studies showed that the main environmental impacts on the production of palm biodiesel were from upstream activities such as FFB production. and Determination of greenhouse gases (GHG) contributions by subsystems in the oil palm supply chain using the LCA approach and gate-to-gate case studies of an oil palm seedling were also published (Choo *et al.* 2011; Halimah *et al.* 2012). However, there was a gap in the data that needed to be filled in order to obtain a complete picture of the palm oil supply chain, i.e., regarding the LCA for the production of oil palm seeds. Therefore, with the completion of this study, data from this *cradle-to-gate* analysis can be linked to the previous LCA study, which started from LCA of oil palm seedlings to the production of palm biodiesel, for a complete supply chain.

The objective of this study is to identify and assess the environmental impact associated with the production of germinated oil palm seeds, and to evaluate and implement steps to improve the environmental performance in seed processing.

Goal and Scope

This LCA study will make available the life cycle inventory (LCI) for Malaysian oil palm seed production units, which includes *cradle-to-gate* analysis for the production of germinated oil palm seeds, starting from the transportation of the FFB from the mother palm to the seed production unit, the processing and management of the seeds at the seed production unit and the delivery of germinated seeds to the nursery. The LCI then can be calculated for the life cycle impact assessment (LCIA). Mitigation measures can be taken to reduce the environmental load based on the results of the LCIA.

METHODS

This LCA study was carried out according to established guidelines under ISO 14000, Environmental Management Standards in ISO 14040 and ISO 14044, using SimaPro software (LE Amersfoort, The Netherlands). The Eco-indicator 99 methodology (Goedkoop *et al.* 2008) was used to calculate the LCIA. This project inventoried the life cycle environmental impacts of germinated oil palm seeds by identifying the inputs and outputs into the system boundary outlined.

Functional unit – The average LCA study normally quantifies the impacts for either a unit of the product or mass of the product. In the production of germinated oil palm seeds, the unit used to express all inputs and outputs is related to the number of seeds germinated. Therefore, the functional unit selected was 1000 germinated oil palm seeds. In short, this study quantifies the inputs and outputs for the production of 1000 germinated seeds by the seed production unit.

System boundary – This study used a *cradle-to-gate* system boundary that included the transfer of the FFB from the mother palms to the seed production unit, the seed germination process, the management of germinated oil palm seeds and delivery to the nursery. Figure 1 shows the boundary of the LCA study. Inputs into the system boundary include materials and energy and outputs include emissions to air, water and soil.

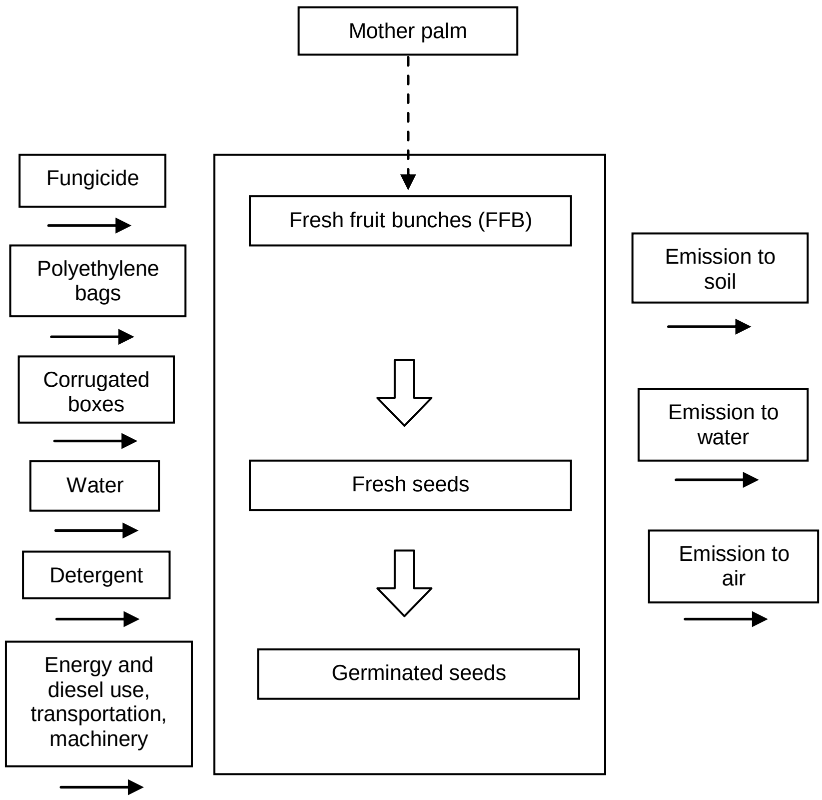

Figure 1: Boundary of the LCA study.

Assumption, limitations and exclusions – Capital equipment, building and machinery were excluded in this assessment.

Life cycle inventory analysis – The goal of this analysis was to examine all of the inputs and outputs in a product's life cycle, beginning with the raw materials used, the source of those materials and the inputs and outputs related to those component materials during their lifetime.

Data collection – Data were obtained from the SIRIM database, through stakeholders' input and also from on-site measurements. Additional sources of

LCA data were collected from other MPOB LCA projects. Data on palm oil related processes was not available and therefore general data from the SimaPro database was used. SimaPro is among the list of LCA software that is widely used in LCA analysis.

Impact categories and impact assessment method – The impacts of the emissions and raw material depletion were assessed and classified as carcinogens, respiratory inorganics, respiratory organics, climate change, radiation, ozone layer, ecotoxicity, acidification/eutrophication, land use, minerals and fossil fuels.

Life cycle impact assessment (LCIA) – Life cycle interpretation was carried out using Eco-indicator 99 methodology. The results for the LCIA were interpreted using weighted and characterisation results.

Allocation of co-products – For the production of germinated oil palm seeds no allocation was required because the present system only produces one product i.e., germinated oil palm seeds.

Data Collection Procedure

There were 20 seed production units registered under MPOB license (MPOB 2009). However, only five seed production units were considered for this study, partly due to a lack of response to the questionnaires. These five seed production units were chosen from several zones in Malaysia, i.e., two oil palm seed production units from Sabah, and one each from Pahang, Selangor and Johor, which satisfied the LCA and ISO criteria used.

Inventory data were collected directly for germinated oil palm seeds through questionnaires that were developed specifically for data collection and sent to seed production units. Compliance with geographical coverage for data collection was adhered to by collecting data from different regions in Malaysia. For each data set, the period and method of data collection were documented. The data validation procedure was carried out by on-site visits and discussions via e-mail and telephone interviews to obtain evidence and to verify the reliability of the collected data.

RESULTS AND DISCUSSION

It is to be noted that some inflows and outflows were not included in this system boundary because of difficulty in quantification; these have been shown in Table 1.

Life Cycle Inventory (LCI)

LCI for the production of 1000 germinated oil palm seeds is shown in Table 2.

Based on Table 2, the energy, sourced from both the national grid and diesel, needed to produce 1000 germinated oil palm seeds was 6.24E-01 kWh (2.25 MJ) and 1.73E-01 L, respectively. The weight of polyethylene bags to produce 1000 germinated oil palm seeds was 1.88E-02 kg. During the production of germinated oil palm seeds, fungicides are used for seed treatment, while

Table 1: System boundary definition criteria.

Processing category	Included	Excluded		
		Insignificant environmental impact	Difficult to obtain representative data	Not directly relevant to scope and goal of study
Production, maintenance and replacement of capital equipment		✓	✓	
Transportation of capital goods		✓	✓	
Production of fungicides inputs, e.g., benomyl and thiram	✓			
Production of small polyethylene bags	✓			
Disposal of small polyethylene bags		✓	✓	
Transportation of fungicides (benomyl and thiram)	✓			
Water supply	✓			
Production of chemicals, e.g., sodium hypochlorite, formalin, lissapol, dettol and spirit	✓			
Transportation of germinated seeds to nursery	✓			
Land occupation by seed production unit		✓	✓	
Electricity generation	✓			
Production of corrugated boxes	✓			

(*continued on next page*)

Table 1: (*continued*)

Processing category	Included	Excluded		
		Insignificant environmental impact	Difficult to obtain representative data	Not directly relevant to scope and goal of study
Disposal of corrugated boxes			✓	✓
Transportation of FFB from mother palm to seed production unit	✓			
Production of corrugated boxes	✓			
Production of diesel for machinery	✓			
Partitioning of fungicides in different compartment (water, soil and air)	✓			
Emissions from the application of fungicides (benomyl and thiram)	✓			

chemicals are applied as detergent and disinfectant. Two types of fungicides were used for the production of germinated oil palm seeds; benomyl and thiram, and the quantity used were 1.35E-02 kg and 1.12E-02 kg for the production of 1000 germinated oil palm seeds, respectively. For the application of chemicals, seed production units used 4.69E-03 kg sodium hypochlorite 15%, 1.08E-01 L ethanol, 1.67E-03 L phenol and 2.59E-03 L alcohol for the production of 1000 germinated oil palm seeds. From the LCI data, it was found that only one seed production unit used phenol as a detergent. One seed production unit used alcohol as a detergent during the processing of germinated oil palm seeds.

Table 2 also shows the transportation required for the production of germinated oil palm seeds. In the computation of the environmental burden for germinated oil palm seed production, all distances were considered as half of a round trip and the delivery van (<3.5 t) loads were considered full-load weights. Data on delivery van weights and distances were obtained through responses to the distributed questionnaires and also through dialogues with the stakeholders.

Table 2: LCI for the production of 1000 germinated oil palm seeds.

Input	Amount	Range
Electricity (kWh)	6.24E-01 (2.25 MJ)	3.81E-02–1.84
Diesel (L)	1.73E-01	2.04E-02–2.91E-01
Polyethylene (LDPE) (kg)	1.88E-02	6.99E-03–1.88E-01
Tap water (L)	7.44E-02	9.76E-02–1.64E-01
Fungicides		
Benomyl (kg)	1.35E-02	4.44E-05–2.49E-02
Thiram (kg)	1.12E-02	4.62E-04–3.22E-01
Chemicals		
Sodium hypochlorite 15% (kg)	4.69E-03	3.62E-04–2.16E-02
Ethanol (L)	1.08E-01	7.40E-05–3.23E-01
Phenol (L)	1.67E-03	1.67E-03
Alcohol (L)	2.59E-03	2.59E-03
Transportation (tkm)	3.07E-06	4.56E-07–1.44E-05
Corrugated boxes (kg)	1.70E-02	–

Electrical energy (electricity) from the national grid and fossil fuel (diesel) were used as power sources to run the machinery at the seed production units. According to the inventory data, the amount of electricity and diesel needed to produce 1000 germinated oil palm seeds varied from 3.81E-02 kWh to 1.84 kWh and 2.04E-02 L to 2.91E-01 L, respectively. Variations in diesel and electricity consumption depended on the amount of energy used for the machinery at the seed production unit. Some seed production units used electricity, while others used diesel, to operate the machinery during the processing of germinated oil palm seeds. Some used both diesel and electricity to operate the machinery. Therefore, it was found that there was great variation in the range of the electricity and diesel consumption for 1000 germinated oil palm seeds. The amount of water used at the seed production unit for soaking and treatment with fungicides and chemicals ranged from 9.76E-02 L to 1.64E-01 L. For corrugated boxes, the amount used to produce 1000 germinated oil palm seeds was 1.70E-02 kg.

According to the inventory data, the amount of polyethylene bags needed to produce 1000 germinated oil palm seeds varied from 6.99E-03 kg to 1.88E-01 kg. This great variation could be due to a difference in practice among the seed production units, where some units recycle the polyethylene bags for two uses and other units adopt single usage.

Fungicides were used for the treatment of fungus for germinated oil palm seeds. The commonly used fungicides in the seed production units are benomyl (classified under benzimidazole) and thiram (classified under dithiocarbamates). As shown in Table 2, the amount of benomyl and thiram ranged from 4.44E-05–2.49E-02 and 4.62E-04–3.22E-01 kg, respectively. These fungicides used varied from one seed production unit to another because of some variations in the amount of fungicide used to process germinated oil palm seeds when exporting the seeds to Sabah, Sarawak and Indonesia. Spraying of fungicide onto germinated oil palm seeds before the distribution to these regions is required. Another reason for the variation in the amount of fungicides used could be due to different practices; some seed production units only use thiram for seed treatment, while others use both benomyl and thiram in their practice. Occasionally, thiram and benomyl were used alternately to avoid fungal resistance due to prolonged use of the same fungicide.

The amount of sodium hypochlorite (ranged from 3.62E-04–2.16E-02 L) and ethanol (ranged from 7.40E-05–3.23E-01 L) used in the production of germinated oil palm seeds differs among seed production units. This range is largely due to detergent use. Some seed production units use more than one type of detergent, e.g., sodium hypochlorite together with phenol and alcohol, while other seed production units use only one type of detergent.

Materials such as fungicides, chemicals, polyethylene bags and corrugated boxes are transported to the seed production unit for the production of germinated oil palm seeds. Transportation includes the delivery of the FFB from the mother palm to the seed production unit, and the transport of fungicides, chemicals, polyethylene bags and corrugated boxes from the port in Malaysia to the seed production unit. The total transport distance was found to be 3.07E-06 tkm.

Life Cycle Impact Assessment (LCIA)

Figures 2–3 show the weighted and characterised results of LCIA for the production of 1000 germinated oil palm seeds.

Figure 2 shows the weighted results for the production of oil palm germinated seeds. The significant impact categories were, in decreasing significance, fossil fuels, respiratory inorganics and climate change. The fossil fuel impact was mainly due to phenol used as detergent or disinfectant during the processing of seeds and polyethylene bags used for packing the seeds. In addition, the fossil fuel impact also occurred as a result of diesel, followed by electricity, which were used to operate the machinery during the processing of germinated oil palm seeds at the seed production unit. Benzimidazole compound also contributed to the fossil fuel impact due to its application as a seed treatment during the processing of germinated oil palm seeds.

Figure 3 shows the characterisation results for the production of germinated oil palm seeds. The main impact came from the usage of polyethylene bags and phenol, followed by chemicals, diesel and electricity, respectively. Polyethylene bags contributed to carcinogens, respiratory inorganics, respiratory organics, climate change, acidification/eutrophication, land use, minerals and fossil fuel. For the category of chemicals organic, the main impacts were on radiation and land use. The contributions from diesel were mainly on the respiratory organics, ozone layer and fossil fuels impact categories. Electricity mainly contributed to the impact category of carcinogens, respiratory inorganics, climate change, acidification/eutrophication and fossil fuel.

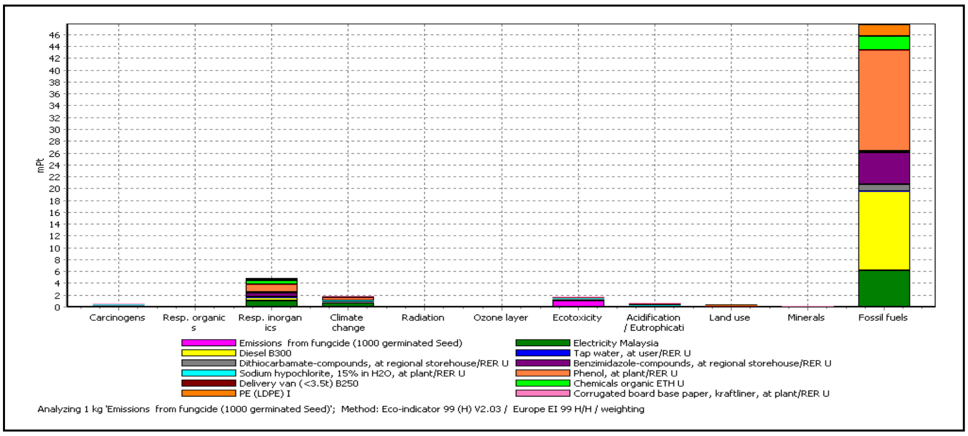

Figure 2: Weighted results for the production of germinated oil palm seeds.

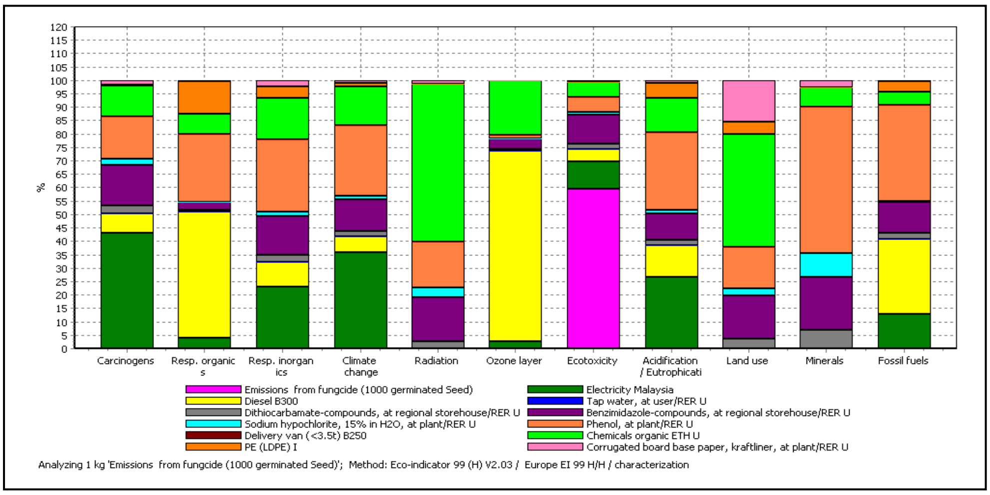

Figure 3: Characterisation results for the production of germinated oil palm seeds.

CONCLUSION AND RECOMMENDATION

Because the environmental performance of the production of germinated oil palm seeds at the seed production unit is influenced mainly by fossil fuels, improvements should be carried out to mitigate or reduce fossil fuel consumption. To date, most of the petrol stations in Malaysia use 5% of palm biodiesel. Hence, to reduce the environmental impact, the use of palm biodiesel in the processing of germinated oil palm seeds is recommended.

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