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Economic-Environmental Evaluation for Sugar Production in Thailand Using LCA Approach

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Abstract: The objective of this study is to evaluate, as a case study, the economic-environmental evaluation, more frequently referred to as eco-efficiency, of a sugar production company in Thailand. The comparison of the eco-efficiency between raw sugar production and refined sugar production was the key objective of this study. Firstly, the inventory data collection of sugar productions, both raw and refined sugar, were collected on-site at the selected factory. Secondly, an environmental Life Cycle Assessment (LCA) of both sugar productions was carried out. The study was based on the Eco-indicator 99. Finally, the eco-efficiencies were compared. Overall, the results of the study show that the refined sugar production generated more environmentally harmful impacts than the raw sugar production and the eco-efficiency of raw sugar production was preferable to refined sugar production.

Key words: Life cycle assessment, eco-efficiency, sugar production, raw sugar, refined sugar

INTRODUCTION

Three quarters of the world's sugar is produced from sugarcane in tropical zones located in the southern hemisphere. Global sugar consumption rises by about 2% per year and has increased 17% from 128 million tons in the year 2000 to 150 million tons in the year 2006 (Workman, 2007). Thailand is one of the largest sugar exporters in the world. As of the year 2006, Thailand was the second largest sugar exporter (Macleod, 2007) as shown in Fig. 1. The total export of raw sugar and refined sugar were about 1,920,000 and 2,575,000 tons in the year 2007, respectively (OCSB, 2006).

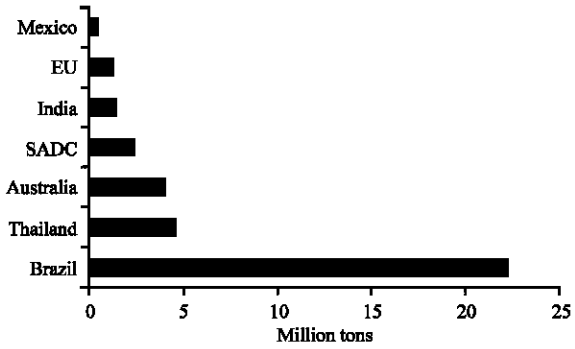

Fig. 1: Sugar exporters in year 2006 (Macleod, 2007)

Today, the world is facing challenges in the form of environmental problems such as air emission, waste-water or hazardous waste. The major causes of air emissions from sugar processing and refining result mainly from the combustion of bagasse, fuel oil or coal. The untreated wastewater effluents typically have BOD_5, 1,700-6,600 mg L^{-1} and COD, 2,300-8,000 mg L^{-1} (MIGA, 2006). Therefore, it is important to understand and evaluate the environmental impacts of sugar production if we are to develop a more sustainable production system. In order to evaluate the environmental burden associated with sugar production, it is necessary to consider all of the important environmental impacts by using Life Cycle Assessment (LCA) and the eco-efficiency approach. LCA is a technique for assessing the potential environmental impacts associated with a product or a service by compiling an inventory of relevant environmental exchanges of the product throughout, its life cycle and then evaluating the potential environmental impacts associated with a product, function or service (Ahmed, 2007).

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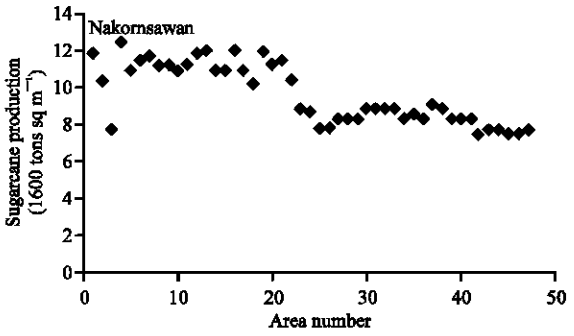

Fig. 2: Sugarcane production in Thailand (OCSB, 2006)

The goal of this research was to demonstrate the environmental impacts of sugar production to a sugar industry located in the central region of Thailand. Nakornsawan, which is one of the highest sugarcane production areas in the country, as shown in Fig. 2. The eco-efficiency evaluation approach was employed as a tool for economic-environmental analysis. This was followed by demonstrating the comparison of eco-efficiency between raw sugar production and refined sugar production.

MATERIALS AND METHODS

In order to determine the effects of sugar production, on the economic value and on the environmental impact value, the methodology of the life cycle assessment approach and the eco-efficiency concept were chosen.

Life cycle assessment: Life cycle assessment is a method to assess the impact on the environment of a product or process from cradle to grave, for example, from raw material acquisition to end of the product's or process's life (ISO1 4040, 2006). As for the environmental impact, LCA will provide endpoints as a unit of measure. To calculate a single score, one of the well known methods is to use the Eco-indicator 99. Eco-indicator 99 scores are based on an impact assessment methodology that transforms the data of the inventory table into 3 comprehensive damage scores; human health, ecosystem quality and resources (Gutierres *et al*., 2008).

Goal and scope: The main goal of the study was to evaluate the environmental and economic impacts with the life cycle approach of raw sugar production and refined sugar production. The environmental assessment was conducted using the Sima Pro 7.0 and the impact categories based on the Eco-indicator 99 were used to characterize the inventory data in this study. The

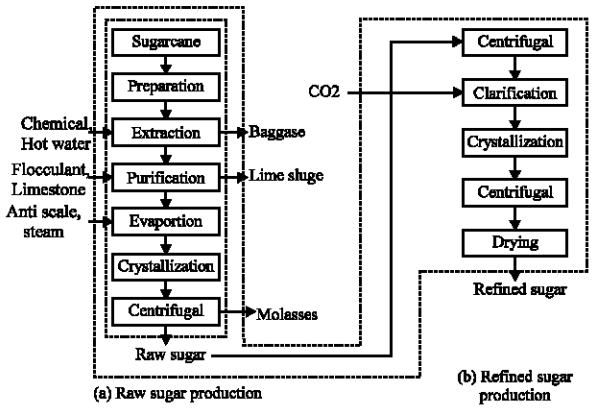

Fig. 3: System boundary for sugar production

functional unit was defined as the production of 1 ton of the product, both raw sugar and refined sugar. The purpose of the functional unit is to provide a reference unit to which the inventory data are normalized (Roy *et al*., 2007). The emphasis in this assessment was put mainly on the sugar production plant. The assessment was done on a gate-to-gate; from the receipt of sugarcane to sugar production. All necessary inventory data for sugar productions were obtained by on-site data collection. To collect the data and other information, questionnaire, interviews and environmental reports were used. During the production of the products examined in this study, there were co-products which required being allocated environmental impacts. This allocation was done according to economic value. However, there were some data gaps due to confidentiality. Figure 3a and b show the system boundary of raw sugar production and refined sugar production, respectively.

Eco-efficiency: To compare the environmental impact and economic value of the 2 types of sugar production, the eco-efficiency approach was used. Eco-efficiency is the adoption of a management philosophy that stimulates the search for environmental improvements that yield parallel economic benefits (Sinkin *et al*., 2008). In addition, eco-efficiency is increased by activities that create economic value, while continuously reducing ecological impacts and the use of natural resources. The objective of this evaluation was to identify the implementation of the marketing with economic and environmental concerns. Then, eco-efficiency can be shown as Eq. (1) (Phungrassami, 2008).

$$\text{Eco-efficiency} = \frac{\text{Economic benefit}}{\text{Environmental impact}} \quad (1)$$

RESULTS AND DISCUSSION

Sugar production: The processing of sugar from sugarcane mainly takes place in 2 stages, milling and refining. The sugarcane has to be transported to a mill which is located at Nakornsawan province, the selected factory area. A 23 ton truck is a common method of transporting the cane to the mill. In a sugar mill, sugarcane is washed, chopped and shredded by revolving knives. The shredded cane is mixed with water and crushed between rollers and then the juice is collected. The residual fiber called bagasse is used as fuel for the boilers.

The cane juice is next mixed with lime to adjust its pH to 7. The mixture then sits, allowing the lime and other suspended solids to settle out and the clarified juice is concentrated in an evaporator to make a syrup. This syrup is concentrated under vacuum until it becomes supersaturated and then it is seeded with crystalline sugar. A centrifuge is used to separate the sugar form the remaining liquid. The brown color of raw sugar is due to the presence of molasses (Bloch, 2007).

In sugar refining, raw sugar is further purified. It is first mixed with heavy syrup and then centrifuged until clean. The sugar solution is clarified by the addition of phosphoric acid and calcium hydroxide. The calcium phosphate particles entrap some impurities and adsorb others and then they float to the top of the tank, where they can be skimmed off. After any remaining solids are filtered out, the clarified syrup is decolorized. Subsequently, the purified syrup is concentrated to supersaturation and repeatedly crystallized under vacuum, to produce refined sugar.

Nearly, all stages of sugar production are water intensive, discharging wastewater, suspended solids, chemicals and emission from boilers. For the inventory data, effluents of wastewater and air emissions were collected on-site at the factory. Air emissions are primarily related to particulate matter, carbon dioxide, carbon monoxide and sulfur dioxide generated from bagasse fired steam boilers.

Environmental impacts: In the environmental assessment, the contributions to the following impact categories were assessed.

Human health: In this approach, damage to human health is expressed as Disability Adjusted Life Years (DALY). Models have been developed for respiratory and carcinogenic effects, the effect of climate change, ozone layer depletion and ionizing radiation.

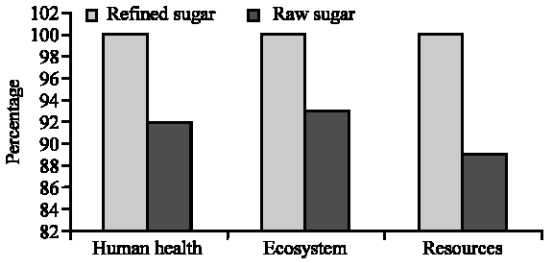

Fig. 4: Percentages of environmental impacts

Ecosystem quality: Damage to the ecosystem quality are expressed as the percentage of species that have disappeared in a certain area due to the environmental load. Acidification and eutrophication are treated as a single impact category.

Resources: The decrease in resources concentrations due to extraction is measured. Not only energy resources such as coal, oil, or raw materials are taken into consideration, but also environmental resources such as air, water and soil are covered by this category.

Based on the study carried out, refined sugar generated more negative environmental impacts for the 3 categories than raw sugar, as shown in Fig. 4 due to higher electricity consumption, CO_2 consumption and air emissions in the process of refining the sugar. For instance, raw sugar production generated an environmental impact in the human health category 8% less than that for refined sugar production.

Eco-efficiency: One of the most important uses of eco-efficiency is the identification of economic benefit associated with environmental impact. Eco-efficiency is about better products that have a lower ecological impact, are competitive and better meet consumer needs. Thus, the manufacturer needs to reduce the consumption of resources or increase the product value.

Eco-efficiency in this study carried out a product value and the environmental impact of the production stage. The results of raw sugar and refined sugar were used for the comparison, as shown in Fig. 5. These may provide the opportunity or assist the factory management in decision making for product improvement, not only with the product price but also with the environmental impacts. The eco-efficiency results are also useful for policy makers. This comparison showed that the most profitable scenario is raw sugar production. The result indicates that eco-efficiency of raw sugar is higher compared to that of refined sugar. The economic value of

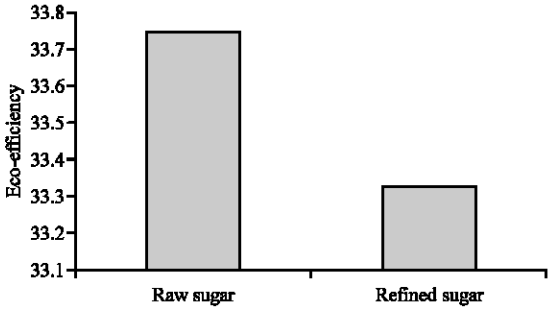

Fig. 5: Eco-efficiency of sugar production

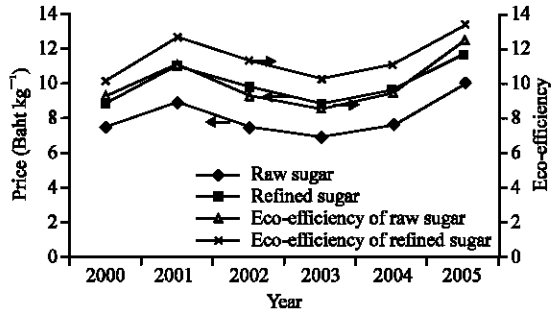

Fig. 6: Trends of sugar price and eco-efficiency

refined sugar is found to be higher than raw sugar; the retail price of raw sugar is 27 and 29 Thai baht per kg for refined sugar. Therefore, the selected company should place emphasis on raw sugar production because of the high eco-efficiency. However, the relationship between the average world sugar price and eco-efficiency is shown in Fig. 6. From the year 2000 to year 2005, the eco-efficiencies of refined sugar were higher than those of raw sugar, although refined sugar production generated more environmental impacts than those of raw sugar production. Therefore, the selected sugar company should increase the retail price of its refined sugar. By the same token, the company also should reduce environmental impacts during refining processes in order to increase the eco-efficiency of their refined sugar.

CONCLUSION

Today, environmental issues are considered as an essential part of the corporate image of food industries. LCA and eco-efficiency approaches are the effective tools to evaluate not only the environmental impacts, but also the economic benefits. To expand the system boundary of the study, the sugar manufacturer should use the LCA and eco-efficiency to identify the steps in the food chain that may have the largest impact on the environment in order to target improvement efforts. The results may be useful for policy makers to decide which product will be appropriate, considering both the economic scope and the environment. The results of this study for the selected company showed that the eco-efficiency of raw sugar production was preferable to refined sugar production.

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