Life Cycle Assessment for Food Processing

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Abstract—Nowadays there are concerns with environmental issues and are increasing considerably in every agricultural sector. To preferably avoid, or at least reduce the environmental impacts, food production should involve assessing of the environmental impact of the complete food chain. One of the most important methodologies used for the evaluation of the environment is a life cycle assessment (LCA). Current trends in a number of indicators threaten and demolish the long-term economic, social, and environmental sustainability of the food system. Key trends currently include: rates of agricultural land conversion, income and profitability from farming, degree of food industry consolidation, fraction of edible food that is wasted, diet related health costs, legal status of farm workers, age distribution of farmers, genetic diversity, rate of soil loss and groundwater withdrawal, and rate of fossil fuel usage.

Keywords—Environmental issues, Life cycle Assessment, indicators food industry, sustainability.

I. INTRODUCTION

The present systems for food production require larger inputs of resources and cause several negative environmental effects. The systems must be optimized to satisfy economic demands and the nutritional needs of a rapidly growing world population[1]. Environmental issues, however, have not been central and there are many difficulties in conducting life cycle studies of food products. Ideally, a complete study should necessarily include agricultural production, industrial refining, storage and distribution, packaging, consumption and waste management, all of which together comprise a large and a complex system. The lack of public databases always hinders collection of suitable data. Another difficulty is that life cycle studies involve many scientific and research disciplines [3]. In the 1970s and early 1980s, the uses of energy in food production systems were widely studied. Most food life cycle studies carried out so far treat either the agricultural production or industrial refining. The aim is to carry out a screening life cycle assessment (LCA) to learn more about options and limitations of applying the method to various food production systems.

The efforts to assess sustainability in agriculture have centered on the supply side of agricultural production and have largely neglected the consumption pattern that comprises the balance of a food production system. In general, a sustainable system is one that can be maintained at a certain state or quality on a long-term time. This “quality” of the system can often be evaluated by the trends in certain indicators [4]. When addressing sustainability, it is critical to keep in mind that the ultimate societal need that is met by the system in question: in agriculture this is to provide necessary food and fiber. The long-term future of the agricultural production, therefore, cannot be assessed without consideration of the consumption patterns and processes the drive production. In other words, a sustainable food system must simultaneously address the production and consumption impacts and demands. A life cycle framework offers a systematic means of connecting production and consumption.

II. METHODOLOGY USING LIFE CYCLE ASSESSMENT

There are various techniques in quantifying the impact of agricultural activities on the ecosystem. One such method used in life cycle assessment is the process of evaluating the effects that a production system has on the environment over the entire period of its life cycle. The food industry uses the LCA to identify the steps in the food chain that have the largest impact on the environment in order to target improvement in efforts. In LCA, the various inputs include resources such as, energy or the chemicals that are used for the activities throughout the food system.

According to the International Organization of Standardization (ISO)[2], LCA is divided into four phases: goal and scope definition, inventory analysis, life cycle impact assessment and interpretation. The model system was divided into six subsystems. For the packaging and household subsystems, alternative scenarios were analyzed and it shows a summary of the subsystems, the processes they include and the scenarios investigated. For the packaging subsystem, the waste management scenarios investigated.
A. Goal and Scope Definition

The first step to perform LCA is to set the goal and scope definition is carried out. The goal of the study should include a statement of the reason for carrying out the study. The objectives of this study were to identify the environmental impacts that occur in the life cycle of milled rice and to suggest and implement energy conservation options in the rice mill. The scope of LCA mostly consists of the functional unit (FU), the system boundary, allocation procedures, data requirements and assumptions or limitations. Life cycle assessment (LCA) is an analytical method used to evaluate the resource consumption and environmental burdens associated with a product, process, or activity. LCA provides a systems-based accounting of material and energy inputs and outputs at all stages of the life cycle: acquisition of raw materials, production, processing, packaging, use, and retirement. While the standard LCA method has been applied mainly to manufactured products, methodological challenges and bottlenecks arising in agricultural product applications have been addressed by researchers and the numbers of LCAs evaluating agricultural and food production processes are increasing. Even though a comprehensive LCA of the food system is not currently possible, using a life cycle framework does provide a systematic basis for developing indicators [6,7,8].

B. Functional Unit

The functional unit is a measure of the function of the studied system and provides a reference unit to which the inventory data can be related. The reference unit translates the abstract functional unit into specific product flows for each of the compared systems, so that product alternatives are compared on an equivalent basis. The 5% loss assumed was validated as a reasonable estimate; other losses can easily be simulated with the scenario technique.

III. LIFE CYCLE IMPACT ASSESSMENT (LCIA)

A. Energy Use

The data on the energy used in the cultivation and processing were collected. The energy usage was divided into fossil fuel, electricity and biomass energy. When comparing the total energy required for different activities, the biomass energy was recalculated to its primary energy carrier [4]. The heating value for food wastes is about 14 MJ/kg. The contribution in this energy consumption is measured in MJ.

C. System Boundary

A system boundary is a collection of unit processes by flows intermediate products which perform one or more defined function (ISO14040, 2006). A system boundary is subdivided into a set of unit processes. Unit processes are linked to one another by flows of intermediate products. The system boundary in this study includes the stages of production from cultivation until the product reaches the consumer.

D. Inventory analysis

Life Cycle Inventory (LCI) of the LCA methodology is essentially the collection of data. This step includes data collection for inputs and outputs of the product system. The data from cultivation and harvesting were reviewed and collected. However, there were some data such as fertilizers and chemicals manufacturing were impossible to be collected, therefore they were cited from some international databases such as database from SimaPro software program. For the inventory analysis, a summary of the processes included, the data sources and the principles of allocation applied. The ambition is to use site-specific inventory data, whenever possible.

To collect this data and other information, we own questionnaire, interviews and environmental reports could be prepared.
From the assessment it can be seen that the drying process is the largest energy consuming process, which consumes 55% of energy in total, followed by the harvesting process (15%), cultivation process (10%), seeding process (10%) and transportation (6%).

Figure 2: Approximate energy demand for food production systems

IV. ENVIRONMENTAL IMPACT BASED ON LCA METHODOLOGY

LCA is a step towards using the information in order to develop sustainable farming practices and food processing operations. The emissions of the system boundary have been grouped into impact categories. The results of LCA are reported in terms of equivalent quantities of reference substances, for instance, CO$_2$ for climate change impacts, SO$_2$ for acidification, NO$_3$ - for eutrophication, etc. In this paper, three impact categories were considered: global warming, acidification and eutrophication [11].

A. Global Warming

In this study, 95% of the global warming inputs to the system are associated with the cultivation process, 2% with the harvesting process. Thus, the cultivation process contributed a significant share of the total impacts. The impact during cultivation is largely due to methane emission, 43% of the global warming potential. The emissions of methane are expected to continue as the second largest source of total greenhouse gases. To reduce methane emissions, the options include using enhanced production technology such as minimizing the use of green manure and substituting pre-fermented compost from farm residues, adding nitrate or sulfate containing nitrogen fertilizer to suppress methane gas production or; change cultivation practices. In addition, water management had a stronger dominating effect on methane emissions than the type of fertilizers had.

B. Eutrophication

Eutrophication is an impact on ecosystems from substances containing nitrogen or phosphorus. If these substances are added in the ecosystem, the growth of algae or plants will increase. This can cause the occurrence of situations without oxygen in the bottom strata due to increased algal growth and the results of eutrophication characterizations of the different processes in the system boundary.

V. CONCLUSION

Numerous trends in the food system threaten its economical, social, and environmental sustainability. The food is highly productive and has a tremendous capacity for providing high quality, inexpensive food. Yet, many of the social and environmental indicators considered here fall outside conventional discussions of productivity, and existing trends in these indicators may challenge the ability to sustain productivity growth. The current system tends toward reliance on limited genetic resources that are rapidly moving out of public control and are managed by corporate interests. Farmers are shrinking in number and growing in age, with large percentages of agricultural producers unable to survive economically on income from farming ventures. Heavy reliance on non-renewable energy poses additional environmental burdens and leaves the food system vulnerable to supply side price increases in fossil fuels. Prioritizing these indicators is challenging as it requires value judgement and public consensus. A number of the identified, however, are irreversible (e.g. fossil energy consumption, water withdrawal from confined aquifers, land conversion to built-up space) and may warrant preferential attention. The most important goal of any life cycle study is, of course, to improve and optimise the system.
Based on the study carried out, we have identified parts of the life cycle that are critical to the total environmental impact as well as some major gaps in the available data. The use of energy has often been employed as an indicator of environmental impact. For many of the impact categories, the packaging and food processing subsystems were found to be hot-spots. For primary energy use, the length of time for storage in a refrigerator (household phase) was found to be a critical parameter. With a storage time of one year, the use of primary energy in the household phase is as high as the energy use of the packaging and food processing subsystems together. An example of an impact category with a different result is eutrophication; for this effect, the agriculture subsystem is an obvious hot-spot. For the impact categories ozone depletion and photo-oxidant formation, it is not possible to draw any general conclusions.

REFERENCES