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Review

A review of life cycle assessment (LCA) on some food products

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ABSTRACT

Life cycle assessment (LCA) is a tool that can be used to evaluate the environmental load of a product, process, or activity throughout its life cycle. Today's LCA users are a mixture of individuals with skills in different disciplines who want to evaluate their products, processes, or activities in a life cycle context. This study attempts to present some of the LCA studies on agricultural and industrial food products, recent advances in LCA and their application on food products. The reviewed literatures indicate that agricultural production is the hotspot in the life cycle of food products and LCA can assist to identify more sustainable options. Due to the recent development of LCA methodologies and dissemination programs by international and local bodies, use of LCA is rapidly increasing in agricultural and industrial food products. A network of information sharing and exchange of experience has expedited the LCA development process. The literatures also suggest that LCA coupled with other approaches provides much more reliable and comprehensive information to environmentally conscious policy makers, producers, and consumers in selecting sustainable products and production processes. Although LCA methodologies have been improved, further international standardization would broaden its practical applications, improve the food security and reduce human health risk.

Contents

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1. Introduction

The food industry is one of the world's largest industrial sectors and hence is a large user of energy. Greenhouse gas emission, which has increased remarkably due to tremendous energy use, has resulted in global warming, perhaps the most serious problem that humankind faces today. Food production, preservation and distribution consume a considerable amount of energy, which contributes to total CO_2 emission. Moreover, consumers in developed countries demand safe food of high quality that has been produced with minimal adverse impacts on the environment (Boer, 2002). There is increased awareness that the environmentally conscious consumer of the future will consider ecological and ethical criteria in selecting food products (Andersson et al., 1994). It is thus essential to evaluate the environmental impact and the utilization of resources in food production and distribution systems for sustainable consumption.

Life cycle assessment (LCA) is a tool for evaluating environmental effects of a product, process, or activity throughout its life cycle or lifetime, which is known as a 'from cradle to grave' analysis. Environmental awareness influences the way in which legislative bodies such as governments will guide the future development of agricultural and industrial food production systems. Although several researchers have compiled LCA studies to emphasize the need for LCA (Foster et al., 2006; Boer, 2002; Ekvall and Finnveden, 2001; Adisa, 1999; Andersson et al., 1994), some recent advances in agricultural LCAs have yet to be reported. Therefore, this study aims to present recent advances in LCA and provide a specific review of LCA in several food products.

2. LCA methodology

Although the concept of LCA evolved in the 1960s and there have been several efforts to develop LCA methodology since the 1970s, it has received much attention from individuals in environmental science fields since the 1990s. For this concept many names have been used, for instance eco-balancing (Germany, Switzerland, Austria and Japan), resource and environment profile analysis (USA), environmental profiling and cradle-to-grave assessment. The Society of Environmental Toxicology and Chemistry (SETAC) has been involved in increasing the awareness and understanding of the concept of LCA. In the 1990s, SETAC in North America, and the US Environmental Protection Agency (USEPA) sponsored workshops and several projects to develop and promote a consensus on a framework for conducting life cycle inventory analysis and impact assessment. Similar efforts were undertaken by SETACEurope, other international organizations (such as the International Organization for Standardization, ISO), and LCA practitioners worldwide. As a result of these efforts, consensus has been achieved on an overall LCA framework and a well-defined inventory methodology (ISO, 1997).

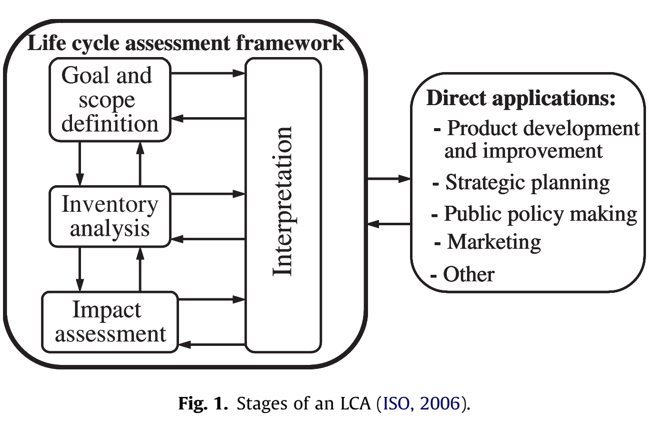

Fig. 1. Stages of an LCA (ISO, 2006).

The method is rapidly developing into an important tool for authorities, industries, and individuals in environmental sciences. Fig. 1 shows the stages of an LCA (ISO, 2006). The purpose of an LCA can be (1) comparison of alternative products, processes or services; (2) comparison of alternative life cycles for a certain product or service; (3) identification of parts of the life cycle where the greatest improvements can be made.

2.1. Goal definition and scoping

Goal definition and scoping is perhaps the most important component of an LCA because the study is carried out according to the statements made in this phase, which defines the purpose of the study, the expected product of the study, system boundaries, functional unit (FU) and assumptions. The system boundary of a system is often illustrated by a general input and output flow diagram. All operations that contribute to the life cycle of the product, process, or activity fall within the system boundaries. The purpose of FU is to provide a reference unit to which the inventory data are normalized. The definition of FU depends on the environmental impact category and aims of the investigation. The functional unit is often based on the mass of the product under study. However, nutritional and economic values of products (Cederberg and Mattsson, 2000) and land area are also being used.

2.2. Life cycle inventory (LCI) analysis

This phase is the most work intensive and time consuming compared to other phases in an LCA, mainly because of data collection. The data collection can be less time consuming if good databases are available and if customers and suppliers are willing to help. Many LCA databases exist and can normally be bought together with LCA software. Data on transport, extraction of raw materials, processing of materials, production of usually used products such as plastic and cardboard, and disposal can normally be found in an LCA database. Data from databases can be used for processes that are not product specific, such as general data on the production of electricity, coal or packaging. For product-specific data, site-specific data are required. The data should include all inputs and outputs from the processes. Inputs are energy (renewable and non-renewable), water, raw materials, etc. Outputs are the products and co-products, and emission (CO_2, CH_4, SO_2, NO_x and CO) to air, water and soil (total suspended solids: TSS, biological oxygen demand: BOD, chemical oxygen demand: COD and chlorinated organic compounds: AOXs) and solid waste generation (municipal solid waste: MSW and landfills).

2.3. Impact assessment

The life cycle impact assessment (LCIA) aims to understand and evaluate environmental impacts based on the inventory analysis, within the framework of the goal and scope of the study. In this phase, the inventory results are assigned to different impact categories, based on the expected types of impacts on the environment. Impact assessment in LCA generally consists of the following elements: classification, characterization, normalization and valuation. Classification is the process of assignment and initial aggregation of LCI data into common impact groups. Characterization is the assessment of the magnitude of potential impacts of each inventory flow into its corresponding environmental impact (e.g., modeling the potential impact of carbon dioxide and methane on global warming). Characterization provides a way to directly compare the LCI results within each category. Characterization factors are commonly referred to as equivalency factors. Normalization expresses potential impacts in ways that can be compared (e.g., comparing the global warming impact of carbon dioxide and meth-