Journal of Cleaner Production 17 (2009) 1351–1358

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Life cycle assessment of spray dried soluble coffee and comparison with alternatives (drip filter and capsule espresso)

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ARTICLE INFO

Article history:
Received 30 October 2008
Received in revised form
2 April 2009
Accepted 9 April 2009
Available online 3 May 2009

Keywords:
Life cycle assessment (LCA)
Coffee
Spray dried
Soluble
Roast and ground
Drip filter
Espresso
Water

ABSTRACT

This paper aims to evaluate the environmental burdens associated with spray dried soluble coffee over its entire life cycle and compare it with drip filter coffee and capsule espresso coffee. It particularly aims to identify critical environmental issues and responsibilities along the whole life cycle chain of spray dried coffee. This life cycle assessment (LCA) specifically uses foreground data obtained directly from coffee manufacturers and suppliers. Aside from energy consumption and greenhouse gases emissions, water footprint is also studied in detail, including regionalization of water impacts based on the ecological scarcity method 2006. Other impact categories are screened using the IMPACT 2002+ impact assessment method.

The overall LCA results for a 1 dl cup of spray dried soluble coffee amounts approximately to 1 MJ of primary non-renewable energy consumption, to emissions of 0.07 kg of $CO_{2\text{-eq}}$, and between 3 and 10 l of non-turbined water use, depending on whether or not the coffee cultivation is irrigated and wet treated. When considering turbined water, use can be up to 400 l of water per cup. Pouch – and to a lesser extent metal can packaging alternatives – show lower environmental burdens than glass or sticks.

On average, about one half of the environmental footprint occurs at a life cycle stage under the control of the coffee producer or its suppliers (i.e., during cultivation, treatment, processing, packaging up to distribution, along with advertising) and the other half at a stage controlled by the user (shopping, appliances manufacturing, use and waste disposal). Key environmental parameters of spray dried soluble coffee are the amount of extra water boiled and the efficiency of cup cleaning during use phase, whether the coffee is irrigated or not, as well as the type and amount of fertilizer used in the coffee field. The packaging contributes to 10% of the overall life cycle impacts.

Compared to other coffee alternatives, spray dried soluble coffee uses less energy and has a lower environmental footprint than capsule espresso coffee or drip filter coffee, the latter having the highest environmental impacts on a per cup basis. This study shows that a broad LCA approach is needed to help industry to minimize the environmental burdens directly related to their products. Including all processes of the entire system is necessary i) to get a comprehensive environmental footprint of the product system with respect to sustainable production and consumption, ii) to share stakeholders responsibility along the entire product life cycle, and iii) to avoid problem shifting between different life cycle stages.

1. Introduction and objectives

This paper aims to identify critical environmental issues and responsibilities along the whole life cycle chain of spray dried coffee and compare it with drip filter coffee and capsule espresso coffee.

Several life cycle assessment (LCA) studies have been published on coffee. However, few studies have performed a detailed analysis covering the full life cycle of a product system with the function of providing a cup of coffee, and even less have proposed a comparison between different alternatives of serving a coffee. Table 1 presents a summary and a short evaluation of the literature review on LCA of coffee production and consumption. There is also a need to go beyond energy consumption and greenhouse gases emissions and to study the water footprint of coffee in more details.

The general objective of this study is to assess the life cycle environmental impacts associated with spray dried soluble coffee (also called 'instant' coffee) applying the LCA methodology and compare it with drip filter coffee (also called 'traditional' coffee)

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doi:10.1016/j.jclepro.2009.04.011

Table 1
Summary of the literature review on LCA of coffee.

Stages	References and short evaluation
Growing and treatment	Coltro et al. [1] – Environmental profile of Brazilian green coffee. Strong paper. Covers energy, chemicals, land and water use for the growing and pulp and mucilage removal stages. Hergoualch [2] – Soil greenhouse gases emissions and carbon storage in coffee plantations.
Beans removal	Chanakya and De Alwis [3] – Environmental issues and management in primary coffee processing. Good description of processing including pulping, washing, and roasting. Includes a description of the social and economic conditions. Concentrates on water use and runoff and potential solutions to these problems.
Roasting	De Monte et al. [4] – Waste heat recovery at roasting plant. Concentrates on the roasting process and some of its costs. Menezes et al. [5] – Drying performance of vibrating tray. Very specific article. Gives an overview of the drying process. Comparison of energy costs for different methods.
Transport	De Monte et al. [6] – Alternative coffee packaging: an analysis from a life cycle point of view. Very specific thorough part of the whole seed-to-cup process with focus on packaging.
Consumption	Lopez Aizcorbe et al. [7] – LCA coffee maker. Specific and thorough. Student project: quality is not perfect but wide range of data is included.
Complete cycle	Büsser and Jungbluth [8]. Complete LCA, with focus on packaging issues and influence of consumer behavior. International Coffee Organization Study [9]. Study of the environmental issues relating to the coffee chain within a context of trade liberalization, through a life cycle approach. Outlines all the areas that need to be covered, including carbon balance, water pollution, biodiversity, and global warming. Salomone [10] – LCA coffee production. LCA applied to coffee production: investigating environmental impacts to aid decision making for improvements at company level. Traditional LCA. Covers energy use, waste management, raw material consumption from cradle to grave. Hanssen et al. [11,12]. Complete life cycle. Diers et al. [13]. Complete life cycle.
Social and economic effects	Cuadra [14] – Emergy evaluation on the production, processing and export of coffee in Nicaragua. Pelupessy [15] – Int. chain of coffee and the environment. Perfecto [16] – Biodiversity, yield, and shade coffee certification. Van der Vossen [17] – Agronomic and economic sustainability of organic coffee production

and capsule espresso coffee. This paper presents the main results of a study authored by Humbert and colleagues [18], with a focus on energy consumption, greenhouse gases emissions and water footprint, complemented by a screening of other impact categories. This study applied the international standards ISO 14040 [19] and ISO 14044 [20], but was not critically reviewed by an external review panel.

2. Methodology

2.1. Goal and scope

The goal of this LCA is primarily to identify the environmental hotspots of spray dried soluble coffee product system and its drip filter and capsule espresso coffee alternatives. It intends to be sufficiently robust and reliable to inform consumers about the comparative impacts of these three alternatives.

More specifically this study aims to: 1) assess the life cycle environmental impacts associated with spray dried soluble coffee (SDC); 2) compare the environmental impacts of spay dried coffee with those of drip filter coffee (DFC) using roasted and ground (R&G) coffee, and capsule espresso coffee (CEC); and 3) identify the key parameters and opportunities for optimization.

The functional unit used as a basis for comparison between the three systems is to 'provide a 1 dl cup of coffee ready to be drunk, at the consumer's home'. The product system covers the full life cycle needed to provide a cup of coffee. It considers the green beans production and delivery, the coffee and packaging manufacturing and distribution, the use phase (including washing the cup) and the end-of-life (Fig. 1).

2.2. Life cycle inventory

This study was performed in collaboration with the coffee producer, hence, easing the access to first hand foreground data. Primary data and information are obtained directly from the coffee producer, its production sites in Europe, its green coffee suppliers (Brazil, Colombia and Vietnam) as well as from our own measurements for the capsule packaging and the use phase. Secondary data are obtained from internal database, the scientific literature and the

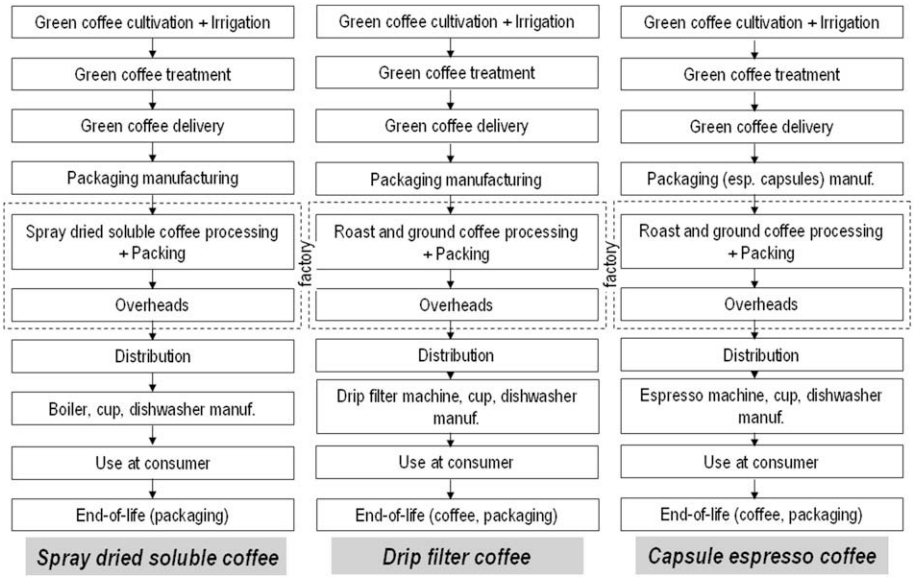

Fig. 1. Product system studied to provide a cup of coffee to the consumer.