Journal of Cleaner Production xxx (2014) 1–12

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Product carbon footprint and energy analysis of alternative coffee products in Japan

H.A. Hassard, M.H. Couch, T. Techa-erawan, B.C. McLellan*

Graduate School of Energy Science, Kyoto University, Yoshida Honmachi, Sakyo-ku, Kyoto 606-8501, Japan

ARTICLE INFO

Article history:
Received 20 March 2013
Received in revised form
25 January 2014
Accepted 4 February 2014
Available online xxx

Keywords:
Coffee
Product carbon footprint
Energy
Greenhouse gas
Lifecycle
Japan

ABSTRACT

Coffee is an important global beverage, and has received significant attention especially in terms of the social and environmental sustainability of its production. This paper calculates the product carbon footprint (PCF) and conducts an analysis of energy usage for six alternative coffee products. The analysis shows that espresso coffee had the lowest impact (0.13 kWh and 49 g CO_2 per serve), while canned coffee provided the highest impact (0.76 kWh and 223 g CO_2 per serve). The latte had the second highest embodied energy impact, with 0.54 kWh and the highest PCF of 224 g CO_2 per serve. On a per millilitre basis however, espresso coffee provided the highest impact (0.0048 kWh/mL and 0.8 g CO_2-eq/mL), followed by canned coffee and the latte. This indicates that care must be used in the selection of an appropriate functional unit, as the ranking of PCF can be overturned according to the basis of comparison. The highest contributing factors were the emissions from milk, packaging (for the can) and the production stages of the green coffee beans. Despite only holding around 17% of the market share of consumed coffee, the canned coffee product contributes around half of the national carbon footprint from coffee consumption. Current commercial incentives for consumers to use their own cups were compared to carbon taxation and found to value carbon approximately three orders of magnitude higher than carbon market rates.

1. Introduction

With close to 7 million tonnes of green beans consumed per year (ICO, 2012), coffee is one of the top 20 most traded agricultural commodities worldwide (FAO, 2012). On average, over 2.25 billion serves of coffee are consumed in the world every day (Ponte, 2002). However, the significance of global coffee production extends beyond the large consumption numbers – the socio-economic implications of its production in largely developing countries (Bacon, 2005; Danse and Wolters, 2003; Wilson, 2010), and the environmental burden due to fertiliser use, habitat destruction and effluent releases (Chanakya and De Alwis, 2004; Coltro et al., 2006) have been well-documented.

Consumers are becoming increasingly interested in information regarding the impacts resulting from their purchases, especially in terms of climate change. As a result, product carbon footprints (PCFs) have emerged as a method for assessing greenhouse gas emissions from goods and services over their life cycle, with moves to create global standard methodologies (BSI, 2011) in an attempt to improve the quality and comparability of reported PCFs. Despite the focus on the socio-environmental impacts of production, there have only been limited efforts to quantify and compare the energy and greenhouse gas emissions across the life cycle of coffee – notably Humbert et al. (2009) and Tchibo (2009). This paper examines the PCFs and energy use in a 'cradle-to-grave' analysis which ranges from cultivation to disposal of a selection of different coffee products available in the vicinity of Kyoto University's main campus in Kyoto, Japan.

With regard to end use, Japan ranks as the 4th highest consumer of coffee in total, but approximately the 26th highest per capita of the major importing and producing nations worldwide (ICO, 2012). In Japan, home to a culture that embraces convenience like no other, coffee is served in many forms and varieties. For the purpose of this study, we have examined the PCFs of the major available hot coffee products, namely: drip filter (multi-cup brewed coffee); espresso (and variations); single-cup filter bags (individually packaged); coffee press; instant; and canned. Based on surveyed consumption figures from the All Japan Coffee Association (AJCA, 2012), roasted coffee represented 54%, instant 16% and canned

* Corresponding author. Tel.: +81 75 753 9173; fax: +81 75 753 4775.
E-mail addresses: b-mclellan@energy.kyoto-u.ac.jp, b.mclellan@yahoo.com.au (B.C. McLellan).

http://dx.doi.org/10.1016/j.jclepro.2014.02.006
0959-6526/

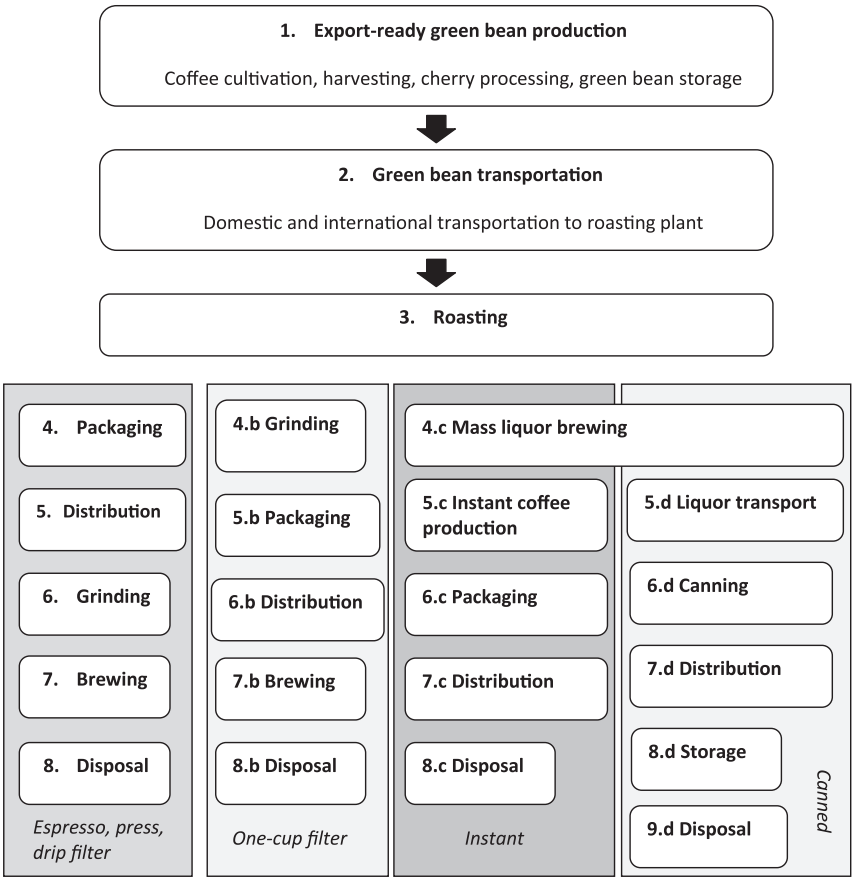

Fig. 1. General life cycle stages of the production of a serve of coffee (cradle to grave).

coffee 21% of the total consumption of coffee (when converted to a green bean equivalent, GBE, using factors from the International Coffee Organisation, ICO (ICO, 2012)) while on a "number of serves" basis roasted coffee represented 30%, instant 43% and canned 17%. A number of notable omissions to the current examination are siphon coffee, iced coffee and ready-to-drink liquid coffee, which were excluded either because they are typically served cold or because their application is not as widespread as the selected products.

The most relevant previous work in this area has been the presentation of a life cycle assessment of instant, drip filter and capsule espresso coffee (Humbert et al., 2009) which indicated that instant coffee had the lowest life cycle impacts. The current study differentiates from this by including a number of other alternatives. Another study by Tchibo GmbH examined the PCF of a serve of espresso from a single source country (Tanzania) (Tchibo, 2009) which again presented a limited product scope, but makes a useful comparison for the results of this study. There have also been a number of studies focussed on single elements in the life cycle – such as packaging (Büsser and Jungbluth, 2009; De Monte et al., 2005), heat recovery from roasting (De Monte et al., 2003), and the balance of greenhouse gas emissions over the cultivation of coffee using different environmentally-based agricultural practices (shade grown coffee and organic coffee) (Hergoualc'h et al., 2012; Noponen et al., 2012). Specifically within Japan, the recently completed project to demonstrate PCFs as a lead-up to a proposed carbon footprint labelling scheme has produced two PCFs for instant coffee products (available only in Japanese) (JEMAI, 2012).

Thus, there is an apparent gap in knowledge regarding the combined picture of the multiple routes and stages in the production and consumption of coffee. This study follows the current best available standard (PAS 2050: 2011) (BSI, 2011) and seeks to address most of the common routes to coffee that consumers (especially consumers in Japan) have available to them, which has not been accomplished in previous studies. The study further highlights a number of "hot spots" and presents some strategies for reducing the impact of these key stages through technology and input substitution as well as examining an existing carbon reduction incentive scheme to compare with carbon market prices.

2. Methodology

This study applies the publicly available specification (PAS 2050: 2011) (BSI, 2011) as the best available methodology for systematically assessing the PCF of alternative coffee products. Energy as well as greenhouse gas emissions have been assessed. Priority has been given to obtaining data from primary sources wherever possible, secondary sources with specificity to Japan as the second preference, followed by other secondary sources. Data has been obtained for the year 2010 as a basis wherever possible.

2.1. Functional unit

The functional unit used as a basis for comparison between product types is "one serve" of the respective hot coffee product. The serve of coffee product is thus variable in its volume and content of coffee liquor, dilution water, milk and other components. The justification behind the use of this non-standardised unit is that the actual purchasable product is in itself variable – for example, a regular sized latte is 230 mL, while a straight espresso is around 30 mL and a can of coffee is 190 mL – these volumes do not

Please cite this article in press as: Hassard, H.A., et al., Product carbon footprint and energy analysis of alternative coffee products in Japan, Journal of Cleaner Production (2014), http://dx.doi.org/10.1016/j.jclepro.2014.02.006