Greenhouse Gas Emissions from Roasted and Ground Coffee Productions in Thailand

Tanomlap Ratchawat[1], Siriluk Chiarakorn[1,*], Amnat Chidthaisong[2,3]

[1]*Division of Environmental Technology, School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand*
[2]*Center for Energy Technology and Environment, Ministry of Education, Bangkok 10140, Thailand*
[3]*Division of Environmental Technology, The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand*
**Corresponding author. Tel.: +662– 470 – 8654 Email: siriluk.chi@kmutt.ac.th*

Abstract: This paper studied greenhouse gas (GHG) emissions of roasted and ground coffee production in Chumphon, Thailand. The scope of the study included robusta coffee cultivation and production of roasted and ground coffee. The data were collected by field surveys and questionnaires from the selected community enterprises in 2014. The functional unit of analysis was 1 kg of roasted coffee and 1 kg of ground coffee. The amount of GHG emissions in the unit of $kgCO_2e$/kg coffee was calculated by following the guidelines of carbon footprint of the product provided from Thailand Greenhouse gas management organization (TGO) and the emission factors were referred from national life cycle inventory and IPCC databases. The results showed that the production of roasted coffee and ground coffee emitted 1.67 and 1.69 $kgCO_2e$ per 1 kg coffee, respectively. The largest GHG emission was contributed from fertilizer applications in coffee cultivation, which was approximately 75% of total GHG emissions. The appropriate GHG emission reductions are optimal fertilizer application and using highly efficient stove which can reduce approximately 43% of GHG emissions from coffee production.

Keywords: Greenhouse gas emissions, robusta coffee, roasted coffee, ground coffee, Thailand.

1. Introduction

Coffee is one of the most favorite drinks around the world including Thailand. The coffee industry has grown continuously for decades. In Thailand, there are two popular species of coffee which are arabica and robusta coffee. The share of robusta coffee is approximately 80% of total coffee production. Robusta coffee is mostly grown in the south of Thailand, especially in Chumphon [1]. The roasted and ground coffee from robusta coffee beans are usually produced from community enterprises in local area. However, there is no GHG emission data from both robusta coffee cultivation and processing. This research aims to study the inventory of resources used and estimate GHG emissions from roasted and ground coffee from the community enterprise in Chumphon, Thailand.

2. Experimental

2.1 Scope of the study

The scope of the study included robusta coffee cultivation and production of roasted coffee and ground coffee from robusta coffee beans but excluded the packaging (see Fig. 1). The functional unit (FU) of analysis was 1 kg of roasted coffee and ground coffee.

2.2 Data collection

The 180 data sets of robusta coffee cultivation based on Taro Yamane's method [2] were obtained from questionnaires and field surveys. While, the production data of roasted and ground coffee were obtained by field surveys from the selected community enterprise in Chumphon in 2014. The lists of activity data were shown in Table 1. The GHG emission factors for fuel, material, and chemical substances are listed in Table 2.

2.3 Calculation of GHG emissions from coffee production

The activity data were then converted to GHG emissions by following the guidelines of the carbon footprint of product method provided from TGO as presented in Eq. (1) [3].

$$\text{GHG Emission (kg } CO_2e\text{)} = \sum [\text{Activity data (unit)} \times \text{EF (kg } CO_2e\text{/unit)}] \quad (1)$$

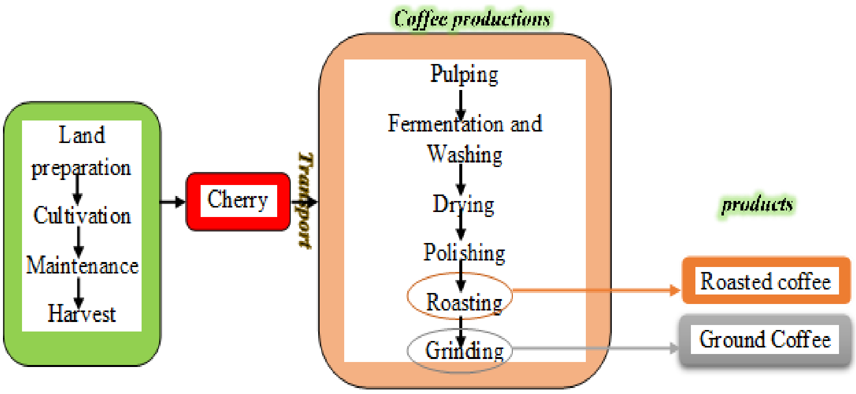

Figure 1. Scope of analysis robusta coffee beans processed in the community.

Table 1 Inventory of data collection in this study.

Process	Unit	Activity data	data collection method
Cultivation of robusta coffee	▪ kg ▪ kg ▪ L ▪ L ▪ L	▪ organic fertilizer ▪ chemical fertilizer ▪ gasoline ▪ diesel ▪ herbicide	questionnaire and field survey
Production of roasted and ground coffee	▪ m^3 ▪ kwh ▪ kg ▪ m^3	▪ water ▪ electric ▪ Liquid Petroleum Gas (LPG) ▪ wastewater	field survey

Table 2 Emission factors used in this study.

Materials and chemical substances	GHG emission factor (kg-CO_2eq.)	Unit	References
Organic fertilizer	0.3320	kg	[4]
Chemical fertilizers ▪ 15-15-15 ▪ 13-13-21 ▪ 46-0-0	 1.5083 1.3470 3.6738	 kg kg kg	 [4]
Gasoline	2.1896	L	[4]
Diesel	2.7446	L	[4]
Herbicide	10.2000	L	[5]
Water	0.7043	m^3	[4]
Electricity	0.6093	kWh	[4]
Liquid Petroleum Gas	3.1100	kg	[4]

3. Results

According to the surveys, the average ratio of coffee plant per rai is 145 and the average life time of coffee is 30-50 years. Robusta coffee is usually grown with fruit trees such as mangosteen, southern langsat, durian and rubber trees. The farmers regularly apply 0.6 kg of chemical fertilizers with various formulas (46-0-0, 15-15-15, 13-13-21) to coffee plant every four months. Rainwater is a main water supply because the planting area is located in high rainfall zone. After 3 years, the first crop of coffee cherries is ready for harvesting. The average yield of fresh coffee cherry is approximately 9 kg per a coffee plant. Next, the pulp and outer cover of fresh cherries are removed by soaking with water overnight. The green beans are then dried by sunlight for 1-3 days and ready for roasting. The beans are roasted at 240–275°C for 3.5 h. The LPG is consumed during roasting. For ground coffee, the roasted beans are further ground by electric grinding machine.

The GHG emissions of roasted and ground coffee are shown in Fig. 2. The total GHG emissions per 1 kg of roasted coffee and ground coffee are 1.67 and 1.69 kgCO_2e, respectively. The coffee cultivation emits 1.26 kgCO_2e while roasting and grinding process emit only 0.41 kgCO_2e and 0.43 kgCO_2e, respectively. The cultivation contributes 75% of total GHG emission.

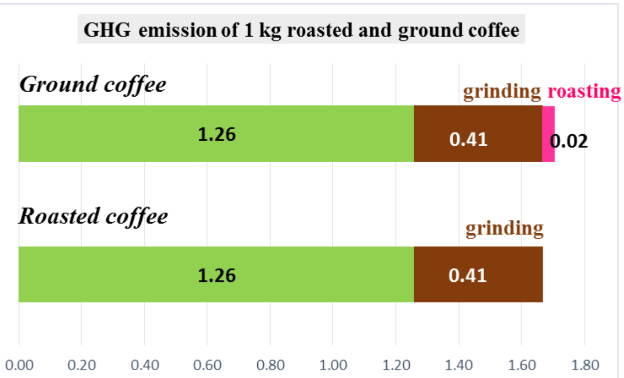

Fig. 2 GHG emissions from roasted and ground coffee (kg CO_2e per kg coffee).

4. Discussion

The hotspot of GHG emission from coffee production is nitrous oxide emission from excess fertilizer application in coffee farms. The optimal nitrogen content suggested by Chumphon Horticultural Research Centre can reduce 0.60 kgCO_2e per 1 kg of roasted coffee [6]. During the process of roasting and grinding, GHG emissions were mostly from electricity and LPG used. Replacement of conventional stove with highly efficient stove can also reduce 69% of LPG consumption [7], equivalent to 0.11 kgCO_2e of GHG emission during roasting.

5. Conclusion

The GHG emissions per 1 kg of roasted and ground coffee were 1.67 and 1.69 kgCO_2e, respectively. The hotspot of GHG emission is from coffee cultivation. The appropriate GHG emission reductions are optimal fertilizer application and using highly efficient stove which can reduce approximately 43% of total GHG emission from coffee production.

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References

[1] Office of Agricultural Economics (OAE), *Coffee Online* (2014) Available online: http://www.oae.go.th/ewt_news.php?nid=16698&filename=index. [Accessed on 1 June 2016].

[2] Yamane T, *Statistic: An Introductory Analysis* (1967) New York: Harper &row.

[3] Thailand Greenhouse Gas Management Organization (TGO), Guidelines for assessing the carbon footprint of products, The

program, promoting the carbon footprint of products (2015) No.5, pages 9-35.
[4] Thailand Greenhouse Gas Management Organization (TGO), *Emission Factor CFP* (2014) Available online: http://thaicarbonlabel.tgo.or.th/admin/uploadfiles/emission/ts_822ebb1ed5.pdf. [Accessed on 1 June 2016].
[5] Intergovernmental Panel on Climate Change (IPCC), *IPCC Fourth Assessment Report: Climate Change 2007* (2007) Available online: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html. [Accessed on 1 June 2016].
[6] Chumphon Horticultural Research Centre, Ministry of Agriculture and Cooperatives, *Fertilizer application in robusta coffee farm* (2011).
[7] High saver, *Energy-saving stoves* (2014) Available online: http://www.hi-saver.com/ [Accessed on 1 June 2016].