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Energy Consumption and Greenhouse Gas Emission from Ceramic Tableware Production: A Case Study in Lampang, Thailand

Panatda Riyakad[a], Siriluk Chiarakorn[a*]

[a]*Division of Environmental Technology School of Energy, Environment and Materials King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand*

Abstract

This paper presents energy consumption and greenhouse gas (GHG) emission from ceramic tableware production in Lampang, Thailand. All data of energy consumption in ceramic production were collected from a small enterprise manufacturing plant and the unit of analysis was 1 kg of product. A scope of study was gate to gate. The amount of GHG emission in a unit kgCO_2e/kg of product was calculated by 2006 IPCC Guidelines for National Greenhouse Gas Inventories method and the emission factors were referred from Thailand Greenhouse Gas Management Organization (TGO) and IPCC databases. The results showed that the total energy consumption from ceramic tableware production was 24.28 MJ/kg of product and almost 98% of total energy consumption was from liquefied petroleum gas (LPG) consumption during firing. The amount of GHG emission was 0.237 kgCO_2e/kg of product. The glost firing was found to be a hotspot of energy consumption and GHG emission.

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Keywords: energy consumption, greenhouse gas emission, ceramic tableware,ceramic production, Lampang

* Corresponding author. Tel.: +66 2 470 8654; fax: +66 2 470 8660.
E-mail address: Siriluk.chi@kmutt.ac.th (S.Chiarakorn).

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1. Introduction

Ceramic industry is one of the important industries of Thailand. The revenues from ceramic industry has been increasing up to 20,000 million baht per year [1]. Main ceramic products consists of ceramic tiles, sanitary wares, gift and decorations, tablewares and insulators. Among all products, tablewares ranked the most exported ceramic product, contributed for 36.74% of total exported ceramic products in Thailand, followed by sanitary ware (27.06%) and ceramic tiles (24.03%) [2].

In Thailand, there are approximately 100 ceramic tableware producers but more than 50% are located in Lampang, Northern Thailand [3]. It is widely known that the most famous product, "Cham tra kai" a ceramic tableware with a hen design, is the signature of Lampang. But nowadays, Lampang ceramic industry has suffered from energy crisis because the cost of energy has been continuously increasing. As a result, many small plants have been shut down. Ceramic production are energy intensive because firing process requires the temperature ranged from 800 – 2000 °C [4].

Ceramic production is not only one of industry that consumes high energy but also emits large amount of greenhouse gases (GHG) which cause global warming [5]. However, the database of energy consumption as well as GHG emissions from ceramic tableware production have not been available. Therefore, this research aimed to evaluate the energy consumption and GHG emission of ceramic tableware production from a small enterprise manufacturing plant in Lampang, Thailand. The hotspots of energy consumption and GHG emission were identified. The output results could be useful information for energy conservation and GHG management in ceramic tableware production.

Fig. 1. A stoneware plate (7-inch diameter) selected in this study

2. Methodology

The activities data were collected from a small enterprise manufacturing plant in Lampang, Thailand. The 7-inch stoneware (Fig.1) was selected as an example in this study. The average weight of the plate was 0.41 kg/piece. The forming process was jiggering method. A jiggering machine was shown in Fig 2. A scope of this study was gate to gate. The energy consumption and GHG emission in each manufacturing process were analysed, based on the functional unit of 1 kg product. The amount of GHG emission was calculated by IPCC 2006 method. The emission factors were from TGO and IPCC databases as presented in Table 1. The GHG emission in a unit of $kgCO_2e/kg$ of product was calculated by Eq. (1) [6] and Eq. (2) [7]. The Eq. (1) was used to calculate amount of GHG emission from energy consumption (electricity and LPG). The Eq. (2) was used to calculate amount of carbon dioxide emission from decomposition of $CaCO_3$. In this study, the calcination fraction (f) was unknown and the method from IPCC(2006) recommended using f value as 1.00 for the calculation.

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

where

EF = emission factor, $kgCO_2e$/unit

$$CO_2 \text{ Emissions from decomposition of } CaCO_3 = M \times EF_{CaCO_3} \times F \quad (2)$$

where

EF_{CaCO3} = emissions factor for the particular carbonate, tonnes CO_2/tonne carbonate

M = weight or mass of the carbonate, tonnes

F = fraction calcination achieved for the carbonate, fraction

Fig. 2. A jiggering machine used in this study

Table 1. The emission factors used in this study

Activity data	Unit	Emission factor	References
Liquefied petroleum gas (LPG)	kg	0.4122 $kgCO_2e$/unit	[8]
Electricity	kWh	0.6093 $kgCO_2e$/unit	[8]
Calcium carbonate ($CaCO_3$)	tonne carbonate	0.43971 tonnes CO_2/ unit	[7]

* 1 tonne = 1000 kg

3. Ceramic tableware production

The production processes of stoneware plate was presented in Fig.3. The clay was purchased from clay manufacturer. Then, the products were formed by jiggering method and dried at room temperature. After drying, the products were loaded on shuttle kiln for a first firing at 800 °C for 5 h, called biscuit firing. The next step was glazing, the products were covered with thin glaze layer. After that, the glazed plates were loaded into shuttle kiln for glost firing at 1,220°C for 8 h. Both firing processes used LPG. Finally, the final products were conveyed to the quality checking and classified the quality level as either Grade A, Grade B or another Grades.

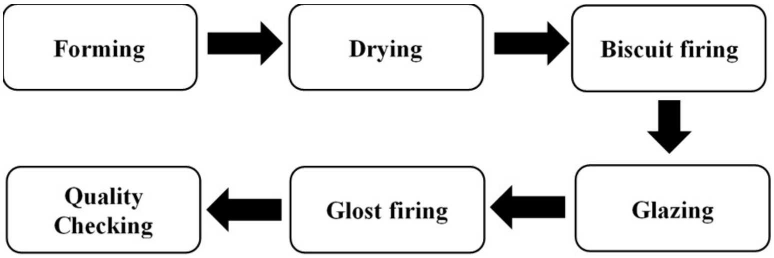

Fig. 3. Production process of a stoneware plate

4. Results and Discussion

The total energy consumption of ceramic tableware production was 24.28 MJ/kg of product, contributed by electricity only 1.11% and LPG 98.89%. The energy consumption and GHG emission from each process are shown in Table 2. Major energy sources consumed in ceramic tableware production were from electricity and LPG. The electricity consumption was only from forming process (0.27 MJ/kg of product) and LPG consumption was used for combustion in biscuit firing process (7.44 MJ/kg of product) and glost firing process (16.57 MJ/kg of product). Thus, glost firing process was determined as a hotspot of energy consumption, accounted for 68.25% of total energy consumption.

The GHG emissions from ceramic tableware production were from the consumption of energy (electricity and LPG) and the decomposition of calcium carbonate ($CaCO_3$) during glost firing, $CaCO_3$ was one of glaze materials composition. Total GHG emission was 0.237 $kgCO_2e$/kg of product. From Fig.4, the largest GHG emission was from LPG during biscuit and glost firing (80.97%), followed by electricity consumption (18.62%) and decomposition of calcium carbonate (0.41%). Similar to the energy hotspot, glost firing process was also found to be the hotspot of GHG emission with the largest share of 56.28% of total GHG emissions. Thus, the energy conservation and GHG mitigation options for ceramic tableware production should be focused in glost firing process.

Table 2. Energy consumption and GHG emission (per 1 kg of product)

Unit Process	Energy Consumption				GHG Emission	
	Electricity (MJ/ kg of product)	LPG (MJ/ kg of product)	Total (MJ/ kg of product)	%	$kgCO_2e$/kg of product	%
Forming	0.27	0	0.27	1.11	0.046	18.62
Drying	0	0	0	0	0	0
Biscuit firing	0	7.44	7.44	30.64	0.062	25.10
Glazing	0	0	0	0	0	0
Glost firing	0	16.57	16.57	68.25	0.138[a]+0.0009[b]	55.87[a]+0.41[b]
QC/packing	0	0	0	0	0	0
Total	**0.27**	**24.01**	**24.28**	**100**	**0.237**	**100**

[a]From LPG consumption
[b]From decomposition of calcium carbonate

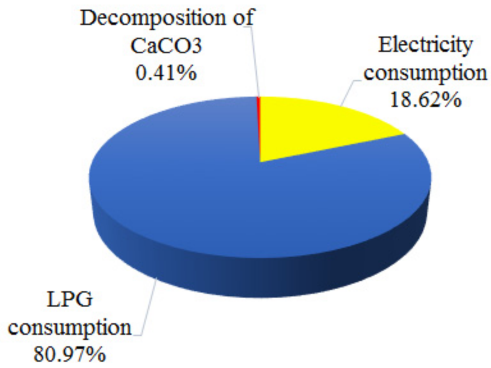

Fig. 4. Percentages of GHG emissions divided by sources from a stoneware plate production (gate to gate)

5. Conclusion

The total energy consumption from a 7-inch stoneware plate production was 24.28 MJ/kg of product and almost 98% of total energy consumption was from LPG consumption during firing. The amount of GHG emission was 0.237 kgCO_2e/kg of product. The shares of GHG emissions were from LPG (80.97%), electricity consumption (18.62%) and decomposition of calcium carbonate (0.41%). Glost firing was found to be a hotspot of energy consumption and GHG emission.

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