Energy Effi cient Saving Utilized Stoves in Ratchaburi Region, Thailand

Grace TARTISIO KENYI SAMUEL[1], Phisit Suvarnaphaet[2], Mana Kanjanamaneesathian[2],
Chaowanee Laosutthipong[2], Pantipa Na Chiangmai[2]
[1]Student M.Sc. (Bioscience for Sustainable Agriculture),
Faculty of Animal Sciences and Agricultural Technology, Silpakorn University
[2]Lecturer, Faculty of Animal Sciences and Agricultural Technology,
Silpakorn University

Abstract

This study aims to evaluate the performance of Energy-saving braziers and Biomass Cook Stove, both from Rachaburi province, Thailand by conducting the Water Boil Test (WBT). The results showed that the Energy-saving braziers and Biomass Cook Stove is significantly more efficient with they shorter time required to heat the water until the water starts boiling and had the prolonged boiling time than the traditional three-stone stove. It can be concluded that the Energy-saving braziers and Biomass Cook Stove are sustainable solution for rural villages in Thailand to meet their energy needs.

Keywords: Energy-saving braziers / Biomass Cook Stove / Sustainable Energy

บทคัดย่อ

การศึกษานี้มีจุดมุ่งหมายเพื่อทำการประเมินประสิทธิภาพของเตาเผาแบบประหยัดพลังงานและเตาเผาชีวมวล ซึ่งทั้งเตาทั้งสองชนิดนี้มาจากจังหวัดราชบุรี ประเทศไทย โดยทำการทดสอบการต้มน้ำ (Water Boil Test; WBT) ผลการทดลองพบว่าเตาเผาแบบประหยัดพลังงานและเตาเผาชีวมวลมีประสิทธิภาพมากกว่าเตาหินสามก้อนแบบดั้งเดิมเนื่องจากใช้เวลาในการให้ความร้อนจนน้ำเริ่มเดือดสั้นกว่าและให้ช่วงความยาวนานของการเดือดยาวนานกว่า สามารถสรุปผลการศึกษาได้ว่า เตาเผาแบบประหยัดพลังงานและเตาเผาชีวมวลเป็นแนวทางที่ยั่งยืนสำหรับหมู่บ้านชนบทในประเทศไทยที่ต้องการใช้พลังงานดังกล่าวนี้

คำสำคัญ: เตาประหยัดพลังงาน / เตาพลังงานชีวมวล / พลังงานที่ยั่งยืน

Introduction

Countries in South East Asia, including Thailand and Vietnam are the major rice producers (Ministry of Agriculture and Rural Development, 2008). The rice straw, which is the main residue after harvest, is abundance and has been utilized as a biomass for source of energy in cooking. In conjunction with the rice straw, the improvised and low-cost stove has been developed for use in the household (Hulscher et al., 1999). For instance, the improved stoves are being successfully introduced to the people to replace simple-tripod stove by the Participatory Development and Training Center (PADETC) in both Laos and Vietnam (Hulscher et al., 1999). Using energy-saving stove is saving not only money but also health and environment (Wang and Smith, 1999) as a result of the reduction in both time and biomass required for burning (Kumar et al., 2013).

In Thailand, the forest as a source for wood has been continually reduced because this resource has been encroached and replaced by farming and other activities such as using the land for various industries and residential areas (Wattanakuljarsu and Coxhead, 2008; Leturque and Wiggins, 2011). In Thailand, bucket stoves which use wood as fuel have been extensively used and these stoves were reported to have the efficiency around 19.8%, while the less popular stove (the improved bucket stove and high price) has the efficiency around 28.7% (Hulscher et al., 1999). These stoves, which have been developed in Thailand for cooking, have been introduced to other countries such as Fiji (Kumar et al., 2013).

Nevertheless, research and development to increase the efficiency of the stoves are still needed because nearly 50% of the stoves used for cooking rely on wood and charcoal as a source of energy (Joseph et al., 1982; Wood Energy Section, The Royal Forest Department, 2017). Thus, the result from this study should provide the conceptual idea for developing or usage on efficiency stove is a target as saving energy to interesting others. This study aims to investigate the performance of energy saving stoves produced in Ratchaburi province, Thailand.

Objective

To compare the effectiveness of the Heat Properties by using the Water Boil Test (WBT) of Ratchaburi saving stoves (Energy-saving braziers and Biomass Cook Stove) with that of the three-stone cooking fire.

Materials and method

Instrumentation for testing

1) A thermometer with a measuring range of 0-100°C and graduated in 0.5°C.

2) A clock with error per day less than 2 minutes.

3) A platform scale with a measuring range of 0-10 kg and minimum sensing weight of 5 g.

4) psychrometer

Testing conditions

1) Ambient temperature: 25-30 ^{O}C

2) Relative humidity: less than 85 percent

3) Testing medium: water at normal atmospheric temperature

4) Fuels were charcoals from three species of woods including rain tree; *Samanea saman* (Jacq.) Merr., Black wattle; *Acacia auriculiformis* Cunn. and Bungor; *Lagerstroemia floribunda* Jack

A modified water boiling test (WBT) by Yuanbo and Jing (1984) as cited in Wang et al. (1993) was used for testing these stoves. This modified version of the well-known Water Boiling Test (WBT) is a rough simulation of the cooking process that is intended to help stove designers understand how well energy is transferred from the fuel to the cooking pot. It can be performed on most stoves throughout the world. In order to simulate the actual process of boiling in a cooking process, which comprises cooking and simmering, the water boiling test has been modified. The WBT consists of three phases that immediately follow each other: 1) The cold-start high-power phase: the stove is at ambient temperature. The quantity of fuel to boil a measured quantity of water in a standard pot is measured. Then, the boiled water is replaced with a fresh pot of ambient-temperature water to perform the second phase. 2) The hot-start high-power phase is conducted after the first phase while the stove is still hot. The protocol is the same except that the stove is hot. 3) The simmer phase provides the amount of fuel required to simmer a measured amount of water at just below the boiling point for 40 minutes. The combination of tests measures some aspects of the stove's performance at both high and low power outputs, which are associated with the stove's ability to conserve fuel. This test is used to yield several quantitative outputs such as time to boil and fuel consumption. Performance determination of these stoves was compared by measuring the following outputs:

1) Time required to heat the water until it starts boiling (adjusted for starting temperature)

2) The amount of fuel required to heat the water until the water boiled after which the heating was terminated (approximately 40 min after the experiment had started)

3) The boiling time

4) The amount of the remaining water after the experiment had been stopped (approximately 40 min after the experiment had started)

Experimental treatments and experiment design

The three experimental treatments including the three-stone stove was used as the control to evaluate the performance of the studied cook stove. The Biomass Cook Stove and Energy-saving braziers are the stoves which have been under development at Ratchaburi Province, Thailand.

The charcoal was used as a fuel to heat water in the pot which was placed 22 cm above the ground by three bricks (Umogbai and Orkuma, 2011) weighted about 400 g. ambient temperature and relative humidity were recorded simultaneously before the start of the experiment. Two liters of water were used for boiling in each treatment. The experiment was organized in a completely randomized design (CRD) with four replications. Analysis of variance (ANOVA) was used to analyze the data statistically and post-hoc least significant difference tests (LSD) was employed to compare the means.

Results and discussion Table 1 showed the data of the time required to heat the water until it starts boiling and the amount of fuel for boiling water until 40 min (Table 1). Moreover, the amount of remaining water after boiling the water for 40 min and the boiling time also were recorded (Table 1). The data suggested that the Energy-saving braziers and Biomass cook stove are more thermally efficient than the traditional 3-stone stove.

Table 1: WBT results for the Energy-saving braziers, Biomass cook stove and the 3-stone stove.

Stove Type	Time required until water starts boiling **(Min)**	**Fuel Use (g)**	**Water remained (L)**	**Boiled Time (min)**
Energy-saving braziers (1)	18.25 ± 2.63	322.70 ± 15.18	1.40 ± 0.05	12.25 ± 3.20
Biomass cook stove (2)	15.25 ± 2.63	318.06 ± 40.71	1.39 ± 0.08	14.00 ± 2.65
3-stone stove (3)	33.50 ± 3.70	188.96 ± 19.18	1.90 ± 0.01	2.50 ± 1.91
P-values	<0.001	<0.001	<0.001	0.001
LSD (1) - (2)	Ns	Ns	Ns	Ns
(1) - (3)	*	*	*	*
(2) – (3)	*	*	*	*

Ns, the mean difference is non-significant at the 0.05 level.

*, the mean difference is significant at the 0.05 level.

In terms of the time required to heat the water until it starts boiling, it was observed that significant differences of this parameter is dependent on the stove type (ANOVA: $F_{2,9}$= 41.79; p<0.001)(Table 1). The Energy-saving braziers and Biomass cook stove were significantly efficient more than the 3-stone stove, (ANOVA, LSD: p<0.05). However, there was no statistically significant difference between the Energy-saving braziers and the Biomass cook stove (LSD: p>0.05).

The Energy-saving braziers and the Biomass cook stove required 322.70 g and 318.06 g of charcoal to heat 2,000 mL of water while the 3-stone stove required comparatively less charcoal at 188.96 g, to heat the water, with statistically significant difference (ANOVA: $F_{2, 9}$= 30.64; p<0.001) (Table 1).

The result also showed that the boiling time and the amount of the remaining water after finishing the experiment were statistically significant difference according different type of stoves (ANOVA: $F_{2, 8}$= 20.51 and $F_{2,9}$ = 31.19, respectively; p<0.001) (Table 1). The Biomass cook stove and the Energy-saving braziers were not significant different regarding the duration of time for boiling the water and the amount of the remaining water. These stoves also were more efficient than the 3-stone stove with respect to the boiling time and the amount of the remaining water (ANOVA, LSD<0.05)(Table 1).

The time required to heat the water until the water started boiling and the boiling time after WBT of three different stoves were shown (Figure 1). The Energy-saving braziers and Biomass cook stove required less time span to heat the water until the water started boiling compared to the 3-stone stove. Moreover, these stoves had longer boiling time for water compared to the 3-stone stove did.

The 3-stone stove used less amount of fuel in the experiment compared to the other two stoves. The 3-stone stove also retained the higher amount of water after the water was boiled compared to the other two stoves (Figure 2), reflecting the low efficiency of the 3-stone stove for WBT. Nevertheless, the 3-stone stove was not efficient for use in boiling the water compared to the Energy-saving Braziers and Biomass Cook Stove when all parameters were taken into consideration (Table 1, Figure 1-2).The 3-stone stove may not be suitable for cooking because this stove required more time to heat the water until the water started boiling. This stove also may give comparatively lower thermal energy, making it to retain the water temperature to boil the water shorter than the other two stoves.

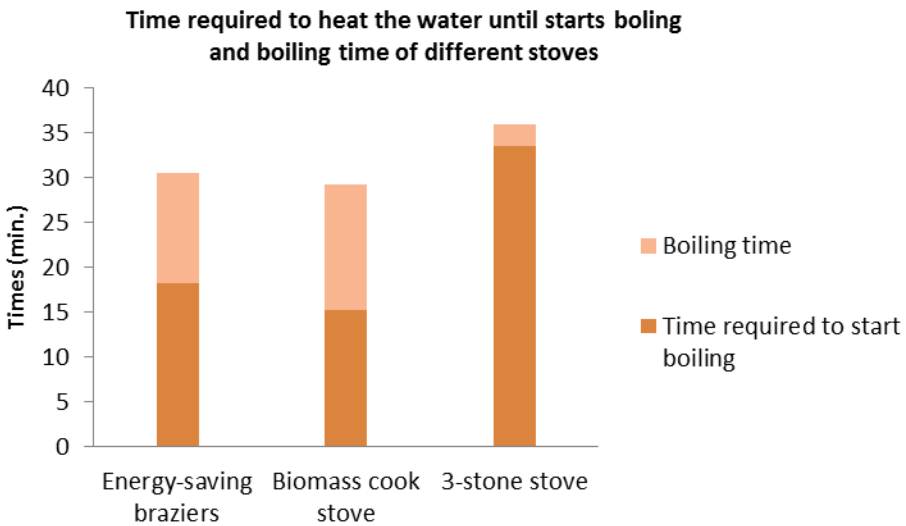

Figure 1: The time required to heat the water until the water started boiling and the boiling time of different stoves after about 40 min after the boiling had started.

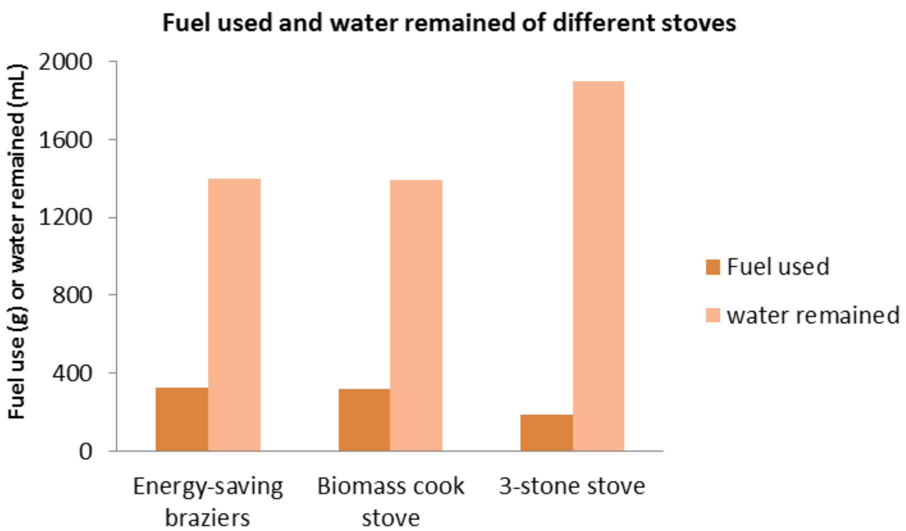

Figure 2: The fuel used and water remained of different stoves under the evaluate about 40 min after boiling starting.

There were studies which indicated that the traditional stove was just as efficient or even more efficient than several different types of improved cook stoves when using the WBT (Jetter and Kariher 2009; Vaccari *et al.* 2012). Furthermore, it is widely acknowledged that the Controlled Cook Test provides a better opportunity to assess the degree of a stove's efficiency and its ability to perform under realistic cooking conditions (Kazzi, 2016).

However, our studies were different from the other experiments with respect to the kind of traditional stove (3-stone stove) and condition for testing (outdoor testing). In the outdoor condition, the result of testing by WBT may different from the indoor cooking condition because many factors may affect the heating in boiling the water. These environment factors include wind speed, ambient temperature and humidity (Kazzi, 2016; Edward et al., 2017). The efficiency of the stoves for cooking is important because it may contribute to reducing both fuel consumption (FAO, 2010; Bwenge, 2011; Biratu, 2016) and air pollution (Hanna et al., 2016). The efficient stove should also contribute to reducing time for cooking, and hence reducing the hazardous effect of toxic smoke to people during cooking (Bwenge, 2011; Biratu, 2016; Hanna et al., 2016). The study about cooking in the outdoor setting is very relevant because it is estimated that there are 533 million people in 85 countries especially in tropical regions who have adopted this cooking in their household (Edward et al., 2017).

The Energy-saving braziers and the Biomass cook stove were more efficient than the 3-stone stove regarding the shortened time span required for starting the water to boil and prolonged the boiling time. These contributed to their overall efficiency in heating the water, resulting to an increased in water evaporation and hence less remaining water at the end of the experiment.

Conclusions

This study showed that the Energy-saving braziers and the Biomass cook stove require more fuel to boil the water. Nonetheless, both stoves required shorter time required to heat the water until the water starts boiling and had the prolonged boiling time. The Energy-saving braziers and the Biomass cook stove are more efficient than the 3-stone stove for cooking in the outdoor condition.

References

Biratu, A. A. (2016). The implication of wood-burning stove efficiency for environment, health and CO_2 emissions in the Jogogudedo watershed, Ethiopia. Academic Research Journal of Agricultural Science and Research, 4(4), 154-163.

Bwenge, N. S. (2011). The effects of adopting improved wood stoves on the welfare of rural woman: a case of Kibaha district in Tanzania [Master's Thesis]. Leeuwarden (Netherlands): Van Hall Larenstein University.

Edwards, M., Princevac, M., Weltman, R., Ghasemian, M., Arora, N. K., & Bond, T. (2017). Modeling emission rates and exposures from outdoor cooking. Atmospheric Environment, 164, 50-60.

Food and Agricultural Organization (FAO). (2010). Global Forest resource Assessment 2010, Country Report, Ethiopia.

Hanna, R., Duflo, E, & Greenstone, M. (2016). Up in smoke: the influence of household behavior on the long-run impact to improved cooking stoves. American Economic Journal: Economic Policy, 8(1), 80-114.

Hulscher, W., Zheng, L., and Koopmans, A. (1999). Stoves on the carbon market. The Meeting of Household Energy Development Organization Network (Hedon), Enschede, Netherland, 6 December 1999.

Jetter, J. J. & Kariher, P. 2009. Solid-fuel household cook stoves: Characterization of performance and emissions. *Biomass and Bioenergy* **33,** 294–305.

Josept, S., Shanahan, Y., Samootsakorn, P., Dunn, P., Yoyce, N., and Trussell, J. (1982). Boiling point. Intermediate Technology No.02, 12 p. Retrieved 21 August 2017.

Kazzi, M. 2016. A Case Study of the Performance, Adoption, and Dissemination ofImproved Clay Cook Stoves in Rural Senegal. Master of Forest Resources. University of Washington. 59 p.

Kumar, A., Prasad, M., & Mishra, K. P. (2013). Comparative study of effect of different parameters on performance and emission of biomass cook stoves. Impact Int J Res Eng Technol, 1(3), 121-126.

Leturque & Wiggins, S. (2011). Thailand's Progress in Agriculture: Transition and Sustained Productivity Growth.

Ministry of Agriculture and Rural Development. (2008). General report on agricultural product import and export and rural development. Ha Noi, Vietnam.

Umogbai, V. I., & Orkuma, J. G. (2011). Development and evaluation of a biomass stove. Journal of Emerging Trends in Engineering and Applied Sciences, 2(3), 514-520.

Vaccari, M., Vitali, F. & Mazzù, A. 2012. Improved cookstove as an appropriate technology forthe Logone Valley (Chad - Cameroon): Analysis of fuel and cost savings. *Renewable Energy* **47,** 45–54.

Wang, X., Smith, K. R., & World Health Organization. (1999). Near-term health benefits of greenhouse gas reductions: a proposed assessment method and application in two energy sectors of China.

Wang, M. et al. (eds) (1993) Chinese Fuel Saving Stoves, Bangkok, Food and Agriculture Organization of the United Nations (FAO).

Wattanakuljarus, A., & Coxhead, I. (2008). Is tourism-based development good for the poor?: A general equilibrium analysis for Thailand. Journal of Policy Modeling, 30(6), 929-955.

Wood Energy Section, The Royal Forest Department. Improvement and promotion of agri-residue stoves. Retrieved 21 August, 2017.