Journal of Sustainable Development; Vol. 8, No. 1; 2015
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Study of Local West Sumatera Stove Performances in Boiling Gambir (*Uncaria Gambir Roxb.*)

Firdaus[1], Muhammad Hatta Dahlan[2], Muhammad Faizal[3], Kaprawi[3] & Susila Arita[3]

[1] Student of Doctoral Program of Environmental Science, Sriwijaya University, Palembang, Indonesia

[2] Promotor

[3] Co-promotors

Correspondence: Firdaus, Student of Doctoral Program of Environmental Science, Sriwijaya University, Palembang, Indonesia. E-mail firdausmtmd@gmail.com

Received: October 24, 2014 Accepted: November 4, 2014 Online Published: January 29, 2015

doi:10.5539/jsd.v8n1p252 URL: http://dx.doi.org/10.5539/jsd.v8n1p252

Abstract

Gambir is one of traditional export commodity of West Sumatera Province mainly used as raw material of pharmaceutical industry, batik coloring, leather thinner and clarifier in beer refineries. This paper describes how the LWS Stove like in Siguntur village works to boil gambir leaves and branches. There are 400 "rumah kempa" home industries operates every day in Pesisir Selatan district to produce gambir using old model LWS Stove made of mixture of clay and cement. Gambir leaves and branches are harvested twice a year and one "rumah kempa" operates one month each harvesting period to produce around one tone of dried extract gambir and consumed 1.5 cubic meters of fire-wood as the main fuel. The dried solid waste of leaves and branches after being pressed, called "katapang", is used as additional fuel. Five aspects were considered in LWS Stoves performances evaluation, namely: heat efficiency, service life and simplicity in operation, health and safety, economics, and local environmental impact. The methods used in this study were identification and evaluation. Data was collected by surveying and interview, analyzing, and calculation. The results show that heat transfer efficiency of LWS Stove is lower than twelve percents; short service life but very simple operation; indoor pollution due to smoke and burnt risk are high because of no chimney and hot flue gas temperature is still higher than 200 ^{0}C; economically, the stove is very cheap; while environmentally, it caused seriously impact on local deforestation.

Keywords: stove, performance, smoke, pollution, fire-wood, deforestation

1. Introduction

Gambir (*Uncaria Gambir Roxb.*) is one of traditional export commodity of West Sumatera Province in Indonesia with Pesisir Selatan and 50 Kota districts as centre of production (Hasbullah 2001]. Since produced traditionally in "rumah kempa" home-industries, it is very difficult to search the articles about it.

In trading, what we called gambir is a dried extract taken from the leaves and branches of gambir plant. The extract contains *catechin* (gives sweat taste after being chewed), *catechu tanat* (tannin, gives bitter taste), and *quercetine* (yellow coloring). *Catechin* exists in two forms, *hydrate a*nd *un-hydrate. Hydrate catechin* (in the form of d, l, and dl) has melting point of 93 ^{0}C, and its un-hydrate form has a higher melting point, i.e. 174~175 ^{0}C. *Catechin* is solved in boiling water and cool alcohol. For pharmaceutical industry, Germany importer needs *catechin* contain 40~60%, while pharmaceutical Ciba Geigy company needs *catechin* contain at least 60.5%. For leather thinner, Cuirplastek R. Bisset and Cie Company needs tannin contain 40% (Hasbullah 2001).

Extraction process for gambir found in West Sumatera province like in Siguntur village Pesisir Selatan district started with boiling, continued by pressing step to take the gum out of the leaves and branches. In the next steps, the gum is settled and seeped, and then molded and dried to get dried gambir. Boiling using local West Sumatera stove (LWS Stove) plays the main role over the whole of process.

The flare of LWS Stove is traditionally kept throughout the boiling process by feeding certain quantity of fire-wood since it determines the yield without any attention to heat efficiency of the stove yet. Since strongly determined how much fuel consumption, it is clearly important to evaluate heat efficiency as well as others parameters influenced the performances of LWS Stove.

Efficiency of open fire stove is around 8% (Baldwin S. F. 2006). Traditional Plancha stove in Guatemala with relatively high initial cost of around US$ 100-150 was no more efficien than open fire stove because of heat losses to the stove body. However, additional chimney in this stove offers health and safety benefits (E. Boy et al. 2000). Meanwhile, efficiencies of wood-fired stoves in many others countries are showed in Table 1 (S. C. Battacharya et al. 2002). Old stove in China has an efficiency of around 10 to 12% (Qiu D. and Gu S. 1996). Efficiency of stove is influenced by stove geometry and fuel properties which give effects on the stove performance parameters such as effective maximum flame temperature, suction created inside the stove, propagation of ignition front inside the stove, and fuel burn rate (S.B. Kausley and A.B. Pandit 2010). Indoor pollutant of fire-wood chulha stove contain 156 ppm CO and 0.325 ppm NO_2 (C.V. Raiyani et al. 2010) while emission from softwood pellet stove contain 500 ppm CO and 3.1% CO_2 (M. Olsson and J. Kjallstrand, 2004). Socio-environmental perspectives to wood fuel use in traditional stove showed that pay attention have to be given in health and deforestation effects (Md. D. Miah, et. al., 2010). Ultimate analysis of biomass fuel by C. K. W. Ndiema et al. (1998) and Bhattacharya et al. (2002) is showed at Table 2.

Energy balances calculation to find heat efficiency in boiling the water in pan at the LWS Stove based on the first law of thermodynamics for closed system, i.e.:

$$\frac{dE}{dt} = \Delta H_c + \sum_k \dot{m}_{k,i} h_{k,i} - \sum_k \dot{m}_{k,e}\, h_{k,e} \tag{1}$$

where:

$\frac{dE}{dt}$ =heat accumulated in the stove, pan, and water in pan

ΔH_c= heat of combustion of biomass

$\sum_k \dot{m}_{k,i} h_{k,i}$ = enthalpy of mass flow rate entrance the stove

$\sum_k \dot{m}_{k,e} h_{k,e}$ = enthalpy of mass flow rate exit from the stove

Mass flow rate entrances the stove is air (O_2 and N_2) with sensible heat relative to reference temperature T_0 = 25 ^{0}C equals $q_i = \int_{T_0}^{T_i} m_k C_{p_k}\, dT$), where T_i is temperature of entrance air, Cp_k is heat capacity of k component in air, and m_k is mass of gas k component. Biomass fuel is taken as the source of heat of combustion. Heat energy ($q = h = \Delta H_v$) from combustion of biomass was absorbed by the pan to heat and vaporize the water. Biomass composition (C, H_2, O_2, H_2O, N_2, and ash) taken from ultimate analysis. Mass flow rate of flue gas exit from the stove contains CO_2, H_2O, N_2 and O_2 gases. Flue gas composition can be calculated by mass balances of combustion.

Heat accumulated in water is $h_a = q_a = \int_{T_0}^{T_a} m_{air} C_{p_{water}}\, dT$ where T_a is temperature of water in pan. Heat of vaporization of water is $h_v = m_{vap}\, \lambda$, where λ is heat of vaporization per grams of water vaporized at atmospheric pressure. Then heat absorbed by water in pan equal to h_a plus h_v. Heat absorbed by the water in pan for boiling was calculated using steam table of thermodynamics. Heat of combustion of biomass (ΔH_C) was taken from laboratory test. Then, heat efficiency of LWS Stove was simply calculated by equation:

$$\eta = \frac{\textit{heat absorbed by the water in pan}}{\textit{heat of combustion of biomass}} = \frac{h_a + h_v}{(\Delta H_C)} \tag{2}$$

The study was conducted to discuss the performances of LWS Stove in boiling gambir. Five aspects were considered, namely heat efficiency, service life and simplicity in operation, health and safety, economics, and local environmental impacts.

2. Method

Location of research was selected in accordance with purposive sampling to the operating stoves which can be visited eazily from Padang. The study of LWS Stoves performances was conducted using identification and evaluation methods, and Water Boiling Test (WBT) method was used in combustion test [Karen W.]. Data was collected by field trips for an observation and documentation, interview, sampling, measurement and calculation. Identification covering raw material processed capacity and residence time per batch as well as rate of production, model and material construction of LWS Stove and equipment, heat energy source and waste treatment management.

Measured parameters in this research were geometry of LWS Stove and its compartment (stove dimension, combustion chamber, stove wall thick, opening for entrances air and exit flue gas); kind, characteristics, and quantity of fuel need; mass of water; air flow rate entrances the stove; flow rate, composition, and temperature of flue gas exit; air temperature around the stove; the outside wall temperature of stove; accumulation of bottom ash per batch, and residence time of boiling.

Energy balances calculation was conducted by measuring biomass heating value, mass of fuel used, mass of water in the pan before and after boiling, flow rate and temperature of air entrances the stove, flow rate, temperature, and composition of flue gas exit the stove, air temperature around the stove, and the wall stove temperature. Measurement of rate of and flue gas composition exit the stove gave information about gas emission load. Measured parameters data collected and heat efficiency calculation then used to elavuate the performances of LWS Stove as cited in the aim of study. To measure stack temperature, the chimney was added on the beetle hole of the stove as height as 1.10 meters. Air emission temperature measurement was conducted on the height of one meter above beetle hole.

3. Results

Observation and interview gave data that one ”rumah kempa” home industry with four workers boiled about 80 kilograms of bundles of leaves and branches of gambir per batch with residence time was about 2 hours. Normally, there were five batches to produce 30 kilograms of dried extract gambir per day. Boiling and pressing were conducted 2 times. Water need for each boiling was about 40 liters. Boiling water rest in the pan was about 20 liters and hot water from settling of the gum after pressing was about 10 liters. Every harvesting period, one ”rumah kempa” produce 1 ton of dried extract gambir with the price 17,000 rupiahs per kilograms in 2013.

Production of dried extract gambir in Pesisir Selatan district reaches 80 tones per week. ”Rumah kempa” are spread out in Suranti, Taratak, Tapan, Barung-barung Belantai, Tarusan, and Siguntur sub-districts. If one ”rumah kempa” in averages produces 200 kilograms of dried extract gambir per week, so there are 400 ”rumah kempa” operate in Pesisir Selatan district every day.

There are two kinds of fuel usually used in local stove, namely fire-wood and ”katapang”. Fire-wood is nowadays sent from Taratak sub-district, while katapang, dried gambir leaves and branches waste of pressing, is available in the hut area. The quantity of fire-wood need is about 50 kilograms per day and katapang is about 1 kilogram. The stove is fed with seven rods of fire-wood with avarage effective diameter of 4 to 5 centimeters to keep the flare. Each ”rumah kempa” bought around 1.5 cubic of fire-wood for every production period.

LWS Stove for boiling gambir is made of mixture of clay and cement as construction material. Model and typical of LWS Stove made by local handyman is shown in Figure 1.a. The height of the stove is 80 centimeters with combustion chamber diameter 55 centimeters. The thick of the stove wall is varied smoothly from the bottom to the pot hole, namely around 28 centimeters at the bottom and 20 centimeters near the pot hole. The opening size for entrance of fire-wood fuel and natural convection combustion air is 45 centimeters height while its width is also varied, namely 60 centimeters at the bottom and 40 centimeters at the top as showed on Figure 1.b. Except to the opening side, the clay packed around the LWS stove as height as 60 centimeters.

The LWS Stove is operated twice a year. Operating time for one period around four to five weeks, depand on the quantity of leaves and branches harvested after five months each. For each five months period, the stove needs repaired before being operated. In each reparation, the pot hole was coated around by plastics waste to prevent leakage between the pot hole and the boiling pan.

In some local stoves there is a ”beetle hole” with effective diameter of around 12 centimeters for exit of hot flue gas flow. The beetle hole position is in line with the opening for entrance air and as height as the pot hole. The distance between ”beetle hole” and pot hole is around 25 centimeters as showed in Figure 1.c. The value of hot flue gas temperature exit is too high, i.e. 200-250 ^{0}C, depends on the flare.

The hot flue gas exit the ”beetle hole” was usually used to boil water or to cook rice. Besides that, the hot flue gas escapes in working area in the hut was used to dry the wet mold gambir placed on trays made of bamboo above the stove as showed on Figure 3.a. Flue gas analysis showed that air emission load was 2,4 m^3/minutes and flue gas composition was shown in Table 3.

4. Discussion

LWS Stove for boiling gambir is classified to old model. The height and material contruction of LWS Stove, together with the clay packed around it and the hot flue gas temperature contribute to low heat efficiency. With heat of combustion of fire-wood 19,1 MJ/kg, Water Boiling Test (WBT) and calculation referred to equation 2 showed that heat efficiency of LWS Stove was 11.6%. It is slightly higher than open fire stove's efficiency which is around 8% and in consistence with heat efficiency of traditional stoves in China which is around 10 to 12% and in some others countries tabulated in Table 1.

Service life of the LWS Stove is only for one period of production. Workers in this traditional stove indeed had tried to make longer life stove with river stone material but they failed so far. Indeed, the stove had just been broken-down in few days. They might not realize that river stone keep heat of combustion in the chamber while in clay material heat was absorbed and then loss through the wall. Consequently, there must be additional chimney or "beetle hole" on the stove made of river stone to reduce pressure and temperature in combustion chamber. Such stove made of stone equiped with "beetle hole" is used in sugar-cane production in Sungaipuar, Agam district, as showed on Figure 2.

The LWS stove is very simple in operation. The ignition of the stove is only done on the first day of each production period. As a trigger flame, the worker used to burn dried leaves, paper sheet, or waste plastics. Since the ember at the bottom of the stove is not suppressed during the night so the ignition for the next days is only done by feeding katapang. Extinguishing is only done in the last day of production period by watering the ember. Addition of fire-wood was done by the worker manually depend on the flare and the residual fire-wood in the stove. The bottom ash content accumulated was about 5 kilograms per day and the bed of ember as thick as 12 centimeters.

Direct contact between the dirty hot flue gas with the wet mold gambir caused the black color to the gambir product. Moreover, in health and safety view point, the dirty hot flue gas gave impact to workers as showed on figure 3.b. Not only the workers could suffer breathless but also burn by the spark of fire. The dirty in flue gas is especially caused by the present of particulates matter or fly ash. C.A. Arnez et. al. found out that the largest fraction of particulates matter in flue gas contributed by the size fraction of < 0.25 μm (C.A. Arnez et al. 2010). Actually, additional chimney on the local stove can overcome both the problem of too higher temperature and particulates matter content in flue gas exit (Mark B. et al.). Emission test showed that combustion in the LWS Stove used in Siguntur village Pesisir Selatan district does not complate yet. Emission air of LWS Stove contain 700 ppm CO and 152 ppm NO_2 compare to emission air of traditional fire-wood chulha stove in India which contain only 156 ppm CO and 0.325 ppm NO_2. However, Nitrogen diokside (NO_2) content in the emission air of LWS Stove is far below maximum quality standard refer to Minister of State Environmental Regulation No 07 in 2007, namely under 1000 mg/m^3 (1000 ppm) for boiler. It is probably because of air feed was much more than needed stoichiometrically as showed by high residual content of Oxygen in the flue gas, namely, 12,9%.

In economics aspect, local stove for boiling gambir is very cheap, less than 200.000,- rupiahs per period of production. According to the cultivators in many "rumah kempa", they only need to buy a sack of cement and payment for handyman to repair the stove in the beginning of every production period. While cost for fire-wood is nowadays 400,000.- rupiahs to produce 1 tone of mold extract gambir.

In environmental aspect, there are two cases need attention, namely fuel consumption and flue gas emission. Four hundreds of "rumah kempa" of gambir commodity operated in Pesisir Selatan district need 20 tones of fire-wood every day. Assumes moisture content fresh wood 60%, then about 40 tones of trees cut-off and collected every day for fire-wood. The impact of fire-wood need is clearly local deforestation. The flue gas emission is not harmful to the environment since the forest around the hut is still cared while the distance between one hut and anothers is not less than 1 kilometer.

5. Conclusion

1) Heat efficiency of the stove in boiling gambir under studied in Siguntur was 11.6 %.

2) Technically, the stove showed short service life, namely need repaired each period of production, but very simple in operation.

3) Health and safety aspect showed that indoor pollution due to smoke and burnt risk were high because of no chimney and hot flue gas temperature was still higher than 200 ^{0}C.

4) Economically, the local stove was very cheap less than 200.000,- rupiahs per period of production.

5) Environmentally, the local stove gave impact on local deforestation to fulfill fire-wood needs around 20 ton per day.

Table 1. Efficiencies of wood-fired stoves

Name of cookstoves	Efficiencies (%)
1. Cambodian traditional	11.0
2. Malaysian traditional	9.5
3. Lao traditional	14.3
4. Vietnamese traditional	15
5. Nepalese one-pot ceramic	10.5
6. Chinese traditional	12.2
7. Thai-bucket cookstove	14
8. Roi-et clay	11.2
9. Roi-et cement	11.4
10. Rungsit stove	12.0
11. Phil. charcoal/wood	12.0
12. Nepal one-pot metal	13.0
13. Nepal two-pot ceramic	13.0
14. Nepal two-pot metal	15.0
15. RTFD improved wood/char	15.0

Table 2. Ultimate and proximate analysis of fire-wood biomass

Ultimate Analysis			
No	Parameter	Composition, %	
		Ndiema et.al.	Bhattacharya et.al.
1	Carbon	47,56	51,2
2	Hydrogen	5,79	7,31
3	Nitrogen	0,73	
4	Oxygen	47,79	39,03
5	Ash	1,13	
Proximate Analysis			
1	Moisture	6,74	9,78
2	Volatile	73,14	72,49
3	Fixed Carbon	18,33	17,2
4	Ash	1,79	0,53
Heating Value (dry base) in accordance with Bhattacharya et. al., is 19,5 MJ/kg			

Table 3. Air Emission Analysis of Gambir Boiling Stove in Siguntur village Pesisir Selatan districs

No	Parameter	Units	Test result
1	Nitrogen Diokside (NO_2)	ppm	152
2	Carbon monokside (CO)	ppm	700
3	Carbon Diokside (CO_2)	%	7,6
4	Oxygen (O_2)	%	12,9
5	Stack temperature	^{0}C	130

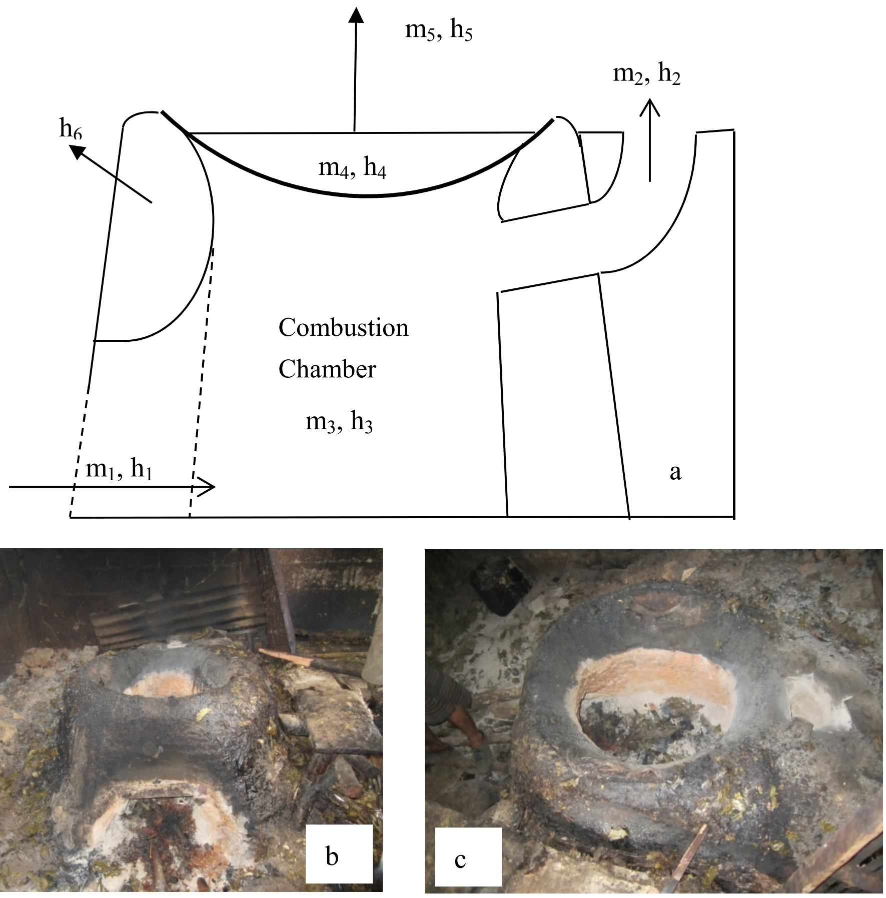

Figure 1. Model and typical of local stove for boiling Gambir in Siguntur. a). Model, b). Opening size for entrance of fire-wood fuel and combustion air, c). ”Beetle hole” on local stove

Figure 2. Sugar-cane stove made of stone equiped with ”Beetle Hole” in Sungaipuar, Agam, West Sumatera

Figure 3. a). Hot Flue Gas Escapes in Working Area in the Hut Used to Dry the Wet Mold Gambir Placed on Trays Made of Bamboo Above Local Stove, b). The Worker Could Suffer Breathless or Burn by Spark of Fire from Dirty Hot Flue Gas

Acknowledgments

The authors are grateful to Bung Hatta University Rector and vices-rector for the sustained encouragement by them throughout the course of this study. Special thanks are due to Prof. DR. Ir. Eddy Ibrahim, Chairman of Doctoral Program of Environmental Science of Sriwijaya University, for his guidance throughout the course of this study. Thanks are due to Mr. Zamroni Putra and Yurnalis for their help in conducting the survey and to Mr. Ahmad Susanto for his help in Analysis works.

References

Arnez, C. A. et al. (2010). Indoor Particle Size Distributions in Home in Open Fires and Improved Patsari Cook Stoves. *Atmospheric Environment, 44*, 2881-2886. http://dx.doi.org/10.1016/j.atmosenv.2010.04.049

Baldwin, S. F. (2006). *Biomass Stoves: Engineering Design, Development, and Dissemination.* New Jersey.

Battacharya, S. C. et al. (2002). Emission Factors of Wood and Charcoal-fired Cookstoves, Biomass and Bioenergy. http://dx.doi.org/10.1016/S0961-9534(02)00072-7

Boy, E. et al. (2000). Fuel Efficiency of an Improved Wood-burning Stove in Rural Guatemala: Implication for Health, Environment and Development. *Energy for Sustainable Development, IV*(2). http://dx.doi.org/10.1016/S0973-0826(08)60239-2

Hasbullah. (2001). Teknologi Tepat Guna Agroindustri Kecil Sumatera Barat, Dewan Ilmu Pengetahuan, Teknologi dan Industri Sumatera Barat.

Karen, W. (n.d.). *Standard Stoves Performance Testing.* Retrieved from http://darfurstoves.org/downloads/Cookstove_Testing_Brief.pdf

Kausley, S. B., & Pandit, A. B. (2010). Modelling of Solid Fuel Stove. *Fuel, 89*, 782-791. http://dx.doi.org/10.1016/j.fuel.2009.09.019

Mark, B. et al. (n.d.). *Design Principles for Wood Burning Cookstoves.* Retrieved from http://bioenergylists.org/stovesdoc/Pcia/Design Principles for Wood Burning Cookstoves.pdf

Miah, M. D. et al. (2010). Wood Fuel Use in Traditional Cooking Stove in the Rural Floodplain Areas of Bangladesh: A Socio-environmental Perspective. *Biomass and Bioenergy, 33*, 70-78. http://dx.doi.org/10.1016/j.biombioe.2008.04.015

Ndiema, C. K. W. et al. (1998). Emission of Pollutants from Biomass Stove, Energy Convers. *Mgmt, 39*(13), 1357-1367. http://dx.doi.org/10.1016/S0196-8904(98)00008-9

Olsson, M., & Kjallstrand, J. (2004). Emissions from Burning of Sooftwood Pellets. *Biomass and Bioenergy, 27*, 607-611. http://dx.doi.org/10.1016/j.biombioe.2003.08.018

Peraturan Menteri Lingkungan Hidup No 07 Tahun 2007 tentang Baku Mutu Emisi Tidak Bergerak Bagi Ketel Uap.

Qiu, D., & Gu, S. (1996). Diffusion of Improved Biomass Stoves in China.

Raiyani, C. V. et al. (1993). Characterization and Problems of Indoor Pollution Due to Cooking Stove Smoke. *Atmospheric Environment, 27A*(12), 1643-1655. http://dx.doi.org/10.1016/0960-1686(93)90227-P