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Energy Saving Stove for Stew Coconut Sugar

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***Abstract*—**The purposes of this research is aim to build the energy saving stove for stew coconut sugar. The research started from explores ceramic raw materials in local area, create the appropriate mixture of ceramic raw materials for construction material of stove, and make it by ceramic process. It includes design and build the energy saving stove, experiment the efficiency of energy saving stove as to thermal efficiency, energy saving, performance of time, and energy cost efficiency, transfer the knowledge for community, stove manufacturers, and technicians. The findings must be useful to the coconut sugar enterprises producing, to reduce the cost of production, preserve natural resources, and environments.

***Keywords*—**Ceramic raw material, Energy saving stove, Stove design, Performance of stove, Stove for stew coconut sugar.

I. Introduction

THERE are many kinds of sugar, almost of them produce from plant: sugar cane, sugar palm, coconut, and beet roots. Coconut sugar is a traditional sweetener for more than a millennium of human being. In Thailand, producing the coconut sugar is a traditional occupation in many areas of the country. Making coconut sugar start from boil and stew coconut syrup in a large wok until dry. Stove for stew coconut sugar was a small and only one wok for use. In the present, coconut sugar produces in factory system from morning until the evening. Stove can be placed wok up to 5 leaves. Although occupational characteristics and the size of the stove will change, but one thing that remains unchanged is fuel for coconut sugar stew is still firewood. However, the wood is more expensive nowadays; the buyer can not choose the type of firewood, and the price. [1] Performance of stove, energy efficiency, and alternative fuel are important to consider. Therefore, the research on energy saving stove is one of the potential solutions to manufacturers of coconut sugar. This research aims to find the mixture of construction materials from ceramic raw materials in local, to design and build energy saving stove furnace, and to test the performance of energy saving stoves for stew coconut sugar.

The results of this research will be useful to the user community enterprises producing coconut sugar to fuel stove can be used with two alternatives and energy saving stove even using wood as a fuel as before. This will reduce the cost of production, preserve natural resources, and environments. It meets the needs of the producer of coconut sugar; achieve the strategic objectives of the provincial development strategy and sustainable development.

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II. Research Objective

1. To test the composition of ceramic raw materials in local that are suited with the production of the construction materials of stove for stew coconut sugar.
2. To design and build the energy saving stove for stew coconut sugar.
3. To test the performance of energy saving stoves for stew coconut sugar.

III. Research Methodology

This study aims to build energy saving stove from local ceramic materials. The scope of the research is as follows:

1. The composition of construction materials of stove are from ceramic raw materials in Bang Kon Tee sub distinct, Samut Songkharm province and near areas. Ceramic raw materials mean red clay or surface clay, rice husk, and sand, etc. They used for produce the main structure of stove as stove body, wall, chimney, and surface inside coating, not include materials to exterior decorating: cement, brick, and color etc.
2. Energy saving stove mean to stove for coconut sugar making with 2 woks for the boil and stew coconut sugar. Stove can use 2 types of fuels wood and gas; it is able to use one type of fuel, or two types.
3. Equipment used in this study were equipped to build the stove, such as cement, trowel, spades, and tool for measure the tilt, etc.

It is required to test the composition of ceramic raw materials in local that are suited with the production of the construction materials of stove for stew coconut sugar. The process works as follows:

1. Explore ceramic raw materials in Bang Kon Tee sub distinct, Samut Songkharm province, including in the vicinity that can be used in the construction of the main structure of the stove.
2. Create the appropriate mixture of ceramic raw materials for construction material of stove

Design and build the energy saving stove for stew coconut sugar as the following process:

1. Design the energy saving stove for stew coconut sugar.
2. Transfer the knowledge for community, stove manufacturers, and technicians about how the construction of energy saving stove for stew coconut sugar.
3. Build the energy saving stove for stew coconut sugar

The efficiency of energy saving stove as to thermal efficiency, energy saving, performance of time, and energy cost efficiency. The research process as follows: [2]

1. Prepare the biomass dry.
2. Weigh all biomass before use.

3. Weigh the empty wok leaf.
4. Measure the water into a wok 20 kilogram.
5. Insert the thermometer distance of the tip of the thermometer with the bottom of the wok 1 centimeter.
6. Water temperature record begins.
7. Start a fire and time record.
8. Record the time and water temperature till boiling water (95 degree Celsius).
9. Leave the water boil in the next 20 minutes after that record time, the weight of pan, and the weight of water.
10. The fuel out, douse, record the weight of biomass remaining, and calculate the thermal efficiency (η_{th}) as the following equation: [3], [4]

$$\eta_{th} = [M_H \times C_H \times (T_B - T_S) + M_S \times L_H] \times 100 / (M_B \times HV_B) \quad (1)$$

where:

M_H is weight of water (20 kg)
C_H is specific heat of water (kJ/kg.^{O}C)
T_B is boiling point of water (95^{O}C)
T_S is initial temperature of water (^{O}C)
M_S is weight of water evaporation (kg)
L_H is latent heat of vaporization (2,257 kJ/kg)
M_B is weight of fuel (biomass) (kg)
HV_B is heating value of fuel (18,631.2 kJ/kg)

11. Experimental the thermal efficiency by step 1.-10. for original stove and energy saving stoves then calculated the energy saving as the following equation: [5]

$$\% \text{ Energy Saving} = (\eta_{th},2 - \eta_{th},1) / \eta_{th},2 \times 100 \quad (2)$$

where:

$\eta_{th},1$ mean thermal efficiency of energy saving stove
$\eta_{th},2$ mean thermal efficiency of original stove

12. Experimental the performance of time by calculated the save time compared the original stove and energy saving stove, and calculate the save time per year.
13. For cost efficiency mean to the energy cost efficiency of stove including fuel savings per year and cost of fuel savings per year, compared between original stove and energy saving stove cost.

The experimental procedure of produce coconut sugar by energy saving stove as the follows:

1. Prepare the biomass dry.
2. Weigh all biomass before use.
3. Weigh coconut syrup 40 kilogram per each wok.
4. Start a fire and time record.
5. Stew coconut sugar and a douse fire.
6. Record the end time.
7. Weigh the remaining biomass.
8. Calculate the energy cost efficiency of stove including costs and revenues for each of the production of coconut sugar.

Assumptions of finding the cost effective for making coconut sugar are as follows:

1. Fuels used include coconut residues consisting of dried coconut and coconut leaf stalk.
2. Cost of fuel considering the supply cost and the cost of managing the waste of fuel is a 4 Baht per kilogram.
3. There is a coconut sugar make one time per day, 2 woks per time with 40 kilogram of coconut syrup per wok.
4. Coconut syrup 20 kilogram per 70 Baht.
5. Coconut sugar 45 Baht per kilogram.
6. Any other costs accounted for 25 percent of total costs.

IV. Research Result

A. Testing the Composition of Ceramic Raw Materials in Local That Are Suited with the Production of the Construction Materials of Stove for Stew Coconut Sugar

The study start form explores ceramic raw materials in Bang Kon Tee sub distinct, Samut Songkharm province including in the vicinity. The results found that red brick is the main raw materials used in construction coconut sugar stove. Red brick made from red clay or surface clay in the local. Red clay is depth of the surface soil of 30 centimeter or more. It is dark gray to black, if the clay at a depth of less than 30 centimeters the roots of coconut, leaves, and other debris will contamination.

When the red clay was tested for initial production of red brick properties by firing at varying temperatures: 800 degree Celsius which is the general temperature of the red brick in manufacturing, 1,200 degrees Celsius (cone no. 5), and 1,230 degree Celsius (cone no. 6) are the temperature for firing ceramics ware such as tableware, vases, souvenirs, and sanitary ware, etc. Experiment of the loss on ignition (LOI.), color, and refractory after firing. Test results are shown in Table I and Fig. 1.

TABLE I
Properties of Local Red Clay

Temperature (^{O}C)	Loss on Ignition (%)	Color	Refractory
800	2.59–2.93	Brown	✓
1,200	3.82–3.85	Hazel	✓
1,230	4.12–4.74	Dark Red	✓

800 ^{O}C 1,200 ^{O}C 1,230 ^{O}C

Fig. 1 Color of local red clay after firing

The local red clay used to make the red brick by using a mixture of ceramic raw material consisting of 60% sand, 30% red clay, and 10% rice husk, then forming by hand compression in wood mold. The red brick is approximately 10 centimeter long, 20 centimeter wide and 5 centimeter thick. After burn it at temperatures from 750 to 800 degree Celsius the red brick is 9 centimeter long, 19.5 centimeter wide, and 4.5 centimeter thick, used for the construction of the main structure such as fire wall, chimney base, and fire box.

B. Designing and Building the Energy Saving Stove for Stew Coconut Sugar

Energy saving stove is a stove for stew coconut sugar by 2 woks and can be used 2 types of fuels are wood and gas. Stove size approximately is 430 centimeter long, 100 centimeter width, and height of the area use equal to 60 centimeter. The main construction material is red brick, and the other materials are available locally and are commercially available such as steel bars, steel sheet, and cement. Energy saving stove has a unique and different are it can used two kinds of fuel, it had baffle wall inside, and coat inside surface by local red clay, shown as Fig. 2.

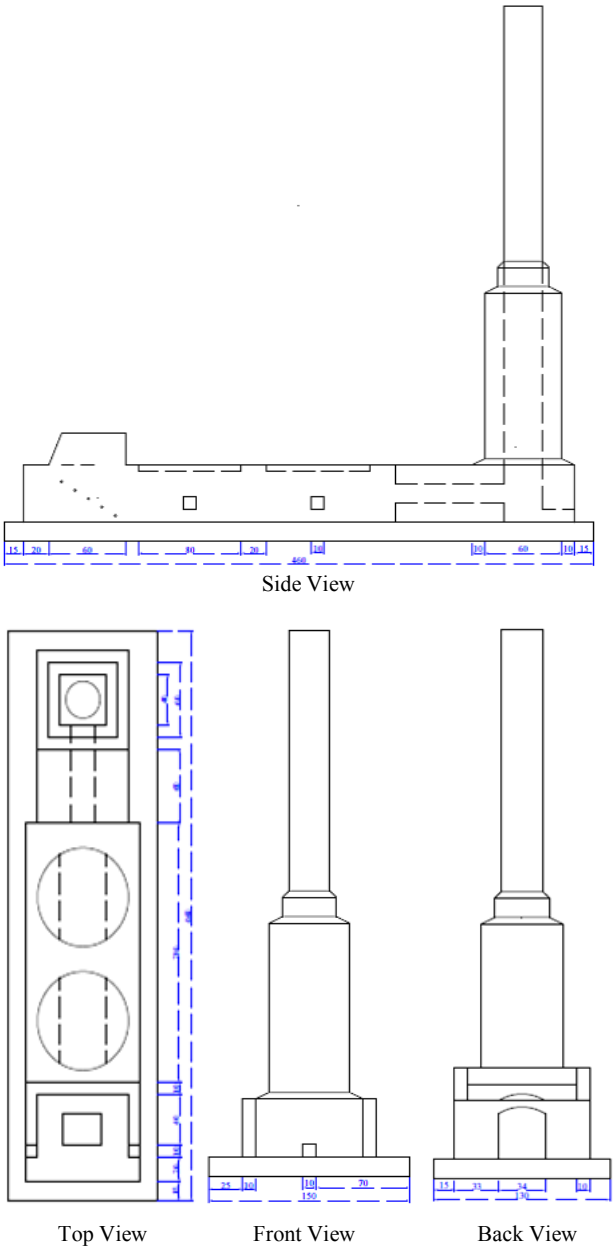

Fig. 2 Drawing of energy saving stove

C. The Performance of Energy Saving Stoves for Stew Coconut Sugar

Results for thermal efficiency test of the original stove and energy saving stove found that energy saving stove had average thermal efficiency by 9.99%, which was higher compared to original stove (thermal efficiency 5.24%). Tested by the two woks of both stove found that energy saving stove are higher thermal efficiency than original stove, the wok near the firebox higher efficiency than to 8.13% which are shown in Table II and Fig. 3.

TABLE II
THERMAL EFFICIENCY OF STOVE

	Original Stove	Energy Saving Stove
Weight of water (kg)	20	20
Weight of water after test (kg)		
Wok near the firebox	12.1	6.3
Wok near the chimney	13.1	14.0
Weight of water evaporation (kg)		
Wok near the firebox	7.9	13.7
Wok near the chimney	6.9	6.0
Specific heat of water (kJ/kg.^{O}C)	4.186	4.186
Latent heat of vaporization (kJ/kg)	2,257	2,257
Initial temperature of water (^{O}C)		
Wok near the firebox	27.0	34.5
Wok near the chimney	30.0	28.0
Boiling point of water (^{O}C)	95	95
Weight of fuel (Biomass) (kg)		
Wok near the firebox	22.25	14.0
Wok near the chimney	23.5	16.6
Heating value of fuel (kJ/kg)	18,631.2	18,631.2
Thermal efficiency (%)		
Wok near the firebox	5.67	13.80
Wok near the chimney	4.80	6.19
Average of thermal efficiency (%)	5.24	9.99

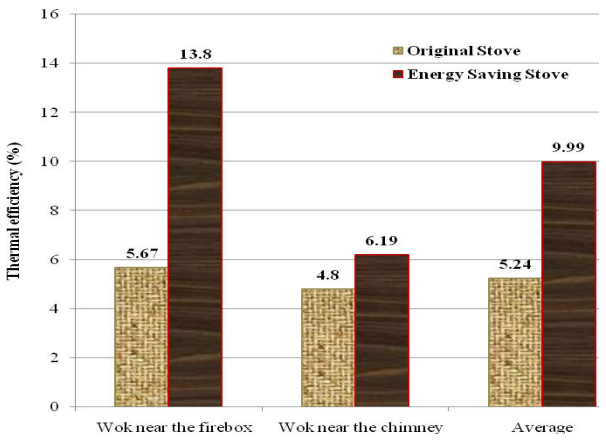

Fig. 3 Thermal efficiency of stove

Results for energy saving test found that energy saving stove was saving fuel than original stove on average equal to 90.84%. The wok near the firebox of energy saving stove save energy up to 143.13% and the wok near the chimney save 29.01% which are shown in Table III and Fig. 4.

TABLE III
ENERGY SAVING OF STOVE

	Original Stove	Energy Saving Stove
Thermal efficiency (%)		
Wok near the firebox	5.67	13.80
Wok near the chimney	4.80	6.19
Average	5.24	9.99
Energy saving (%)		
Wok near the firebox	143.13	
Wok near the chimney	29.01	
Average	90.84	

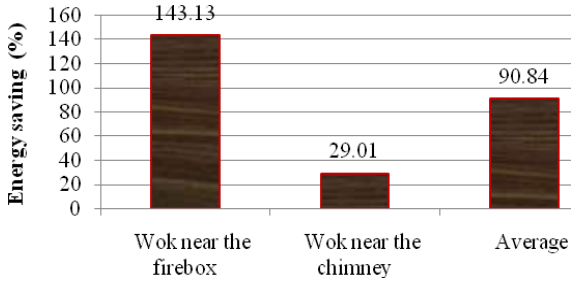

Fig. 4 Energy saving of stove

The results of the performance of time test was compared between the original stove and energy saving stove showed that the energy saving stove can save time by up to 9.19 minutes per once and was 3,354.35 minutes per year, or saving time 55.91 hours per year which show in Table IV.

TABLE IV
TIME PERFORMANCE OF STOVE

	Original Stove	Energy Saving Stove
Time of boiling water (95 ^{O}C) (min)		
Wok near the firebox	24.57	12.00
Wok near the chimney	26.31	17.12
All the time (min)		
Wok near the firebox	44.57	32.00
Wok near the chimney	46.31	37.12
Performance of time		
Time saving (min/Time)	9.19	
Time saving per year (hr)	55.91	

Test results of the energy cost efficiency for energy saving stove compared to an original stove found that energy saving stove energy saving than 6.9 kilogram per experiment once, or 2,518.50 kilogram of fuel saved per year that mean energy saving stove can help to saves fuel up to 10,074 Baht per year which is shown in Table V.

TABLE V
ENERGY COST EFFICIENCY OF STOVE

	Original Stove	Energy Saving Stove
Weight of biomass fuel use (kg)		
Wok near the firebox	22.25	14
Wok near the chimney	23.5	16.6
Energy cost efficiency		
Fuel saving per time (kg)	6.9	
Fuel saving per year (kg)	2,518.50	
Cost of fuel saving (Baht/year)	10,074	

Experimental results of coconut sugar producing by energy saving stoves showed that making coconut sugar in one time by two woks with the use of fuels 67 kilogram as fuel costs are 268 Baht and coconut sugar has 27 kilogram. The total cost of making coconut sugar 27 kilogram was 685 Baht; selling price is 1,215 Baht, and a profit of 530 Baht which show in Table VI.

TABLE VI
RESULT OF COCONUT SUGAR PRODUCE TEST

	wok near the firebox	wok near the chimney
Weight of coconut syrup (kg)	40	40
Time to stew the coconut sugar (min)	115	135
Weight of biomass fuel use (kg)	65	67
Weight of coconut sugar (kg)	27	
Energy cost (Baht/Time)	268	
Coconut syrup cost (Baht/Time)	280	
Others cost (Baht/Time)	137	
Coconut sugar production cost (Baht/Time)	685	
Revenues from the coconut (Baht/Time)	1,215	

V. RESEARCH DISCUSSION

1. Red clay or surface clay found in Bang Kon Tee sub distinct, Samut Songkharm province used in forming red brick are dark gray to black, coconut root contamination. Characteristics of the clay differ from the other in the landscape by the sea as the province should be seaside sludge. It is because the district in freshwater areas away from the coast of the parish over 6 Kilometer. Local red clay found as soil quality or soil morphology in Damnoen Saduak series (Dn). That is at a depth of 50-70 centimeter is dark gray or black plastic clay. Below a depth of 70-120 centimeter is gray mixed olive green color. If the depth is greater than 120 centimeter gray clay mixed greens, the shells are mixed. This is similar to the soil of Samut Songkhram series (Ss), but at a depth of 50-120 centimeter Samut Songkhram series soil is gray to green sludge clay [6].
2. Materials used in the production of red bricks used as construction materials including red clay, sand, and rice husk bring up the burning process of pottery production. Generally red clay as the main raw material is used in forming traditional ceramic. The chemical structure of red clay is the same as Kaolin and Ball clay in ceramic use, but red clay is a mixture of Ferric Oxide plenty. Calcinations red clay at various temperature is light brown to dark reddish brown is the influence of the Ferric

Oxide. Moreover, red clay is alkaline contaminant compounds itself made of refractory clay, each with a different source.

Sand is the raw material for Silicon Dioxide (SiO_2), heat resistant property, use for high temperature product especially ceramic ware and it is also used extensively in the construction industry. Rice husk is the raw material by rice milling process, it used as fuel for brick and folk pottery firing. Husk is composed of inorganic substances around 20–25%, Cellulose 30–40%, Lignin 19–47%, and sugar 17–26%. In inorganic substances are the main components is Silica 85–99%. Additionally there are Alumina (Al_2O_3), Sodium (Na_2O), Potassium (K_2O), Calcium (CaO), and others. Therefore there is a husk resistant to heat is the properties of Silica.

3. Fuel moisture affects the performance of the stove. In experiments, it has been prepared in a dry fuel by sun exposure and heat grill or oven to heat the stove of stew coconut sugar. But in actual use temperature and humidity in the air will result in natural fuel storage in the open division the humidity will increase. This is consistent with experiments of Bhattacharya, Albina, and Khaing [7] found that when moisture in the fuel increasing the efficiency of the stove decreased including the carbon monoxide (CO) while increasing carbon dioxide (CO_2) decreased slightly.
4. Experiments to determine the efficiency of energy saving stove by using fuel as biomass within the community including dried coconut and coconut leaf stalk, which is the remnants of leftover coconut. Although the characteristics of the biomass are different in shape and size; however, the size of the fuel will not affect the performance of the stove [7]. The size of the fuel will influence the amount of carbon monoxide, when the size of the fuel is bigger, it will have to be increased by carbon monoxide. They have found that the size of the container or wok does not affect the performance of the stove as well. But the kindling on top of the fuel causes carbon monoxide less light from the bottom of the fuel.
5. This study was found that the thermal efficiency is low both of the original stove and energy saving stove, which may be due to the method used to focus on productivity including boiling water and the amount of fuel consumed. Also without regard to temperature control, the flow of air for combustion control, the heat accumulated of the stove, the heat loss to the structure of the stove, and the atmosphere. However, experiments at various factors above to be controlled in a closed and controlled situation. Also this study presents the various factors and conditions in accordance with the actual production of the community, stove for stew coconut sugar are used to test in the actual work area. The heat may be lost to the factors already discussed.

VI. Recommendation

A. Suggestion for Research Use

1. To development of energy saving stove approach are following: Damper may be in the same level as main flue of exhaust from stove up to chimney. Front of chimney next to the last wok may penetrate the box above to take heat out the chimney for hot food along the ancient practice. Wall thickness and height of the chimney can be adjusted according to the requirements of the storage and flow of heat. Mixture of clay, sand, and rich husk, including the size of a red brick can modify the increase-decrease demand or use of red brick that are generally available. Red clay used in used in the research with high heat resistance, which is not qualified for all sources of red clay; anthill soil may be used instead.
2. The analysis result of cost, sales price, and profit from coconut sugar produce test showed that used 40 kilogram of coconut syrup per wok, if a real production can used up to 60 kilogram, which could save more than that.
3. How to put the fuel affects the thermal efficiency and energy savings. Put fuel on the top of fire box saves fuel than the fuel pressure deep beneath the wok. Although fuel on the top to get fire faster and stronger fire than, but the heat was getting into the stove to the chimney.

B. Further Suggestion for More Research

1. Test the quality of the local red clay to produce pottery, including the use of it for brick manufacturing industry.
2. Develop the sugar from coconut to add value, such as cube sugars, syrup, and sugar crystals, etc.
3. Develop the packaging for value-added of coconut sugar by preserving the local culture and wisdom.

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References

[1] Sushol Sukkasame. (2011). Background and problems of producing coconut sugar. (Interview).
[2] The Japan Institute of Energy. (2008). Asian Biomass Handbook: Guidelines for the Production and Use of Biomass. The Program Supports the Creation of Asian Alliance for Sustainable Agriculture and Environment. Ministry of Agriculture, Forestry and Fisheries.
[3] Volunteers in Technical Assistance, Inc. (VITA). (1985). Testing the Efficiency of Wood Burning Cook Stoves: International Standards, Volunteers in Technical Assistance, Inc., Arlington, Virginia.
[4] Indian Standard Institution. (1991). Indian Standards for Biomass Cook Stove Specification. IS 13152 (CIS 1315 Z) (Part 1).
[5] Panuwon Kryvongwon. (2003). Testing and Efficiency Improvement of Charcoal Stove. Bangkok: Energy Management Technology, School of Energy and materials.
[6] Office of Soil Survey and Land use Planning. (2005). Fantastic Soil. Bangkok: Land Development Department, Ministry of Agriculture and Cooperatives.
[7] Bhattacharya, S.C., Albina, D.O., and Khaing, A.M. (2002). Effects of selected parameters on performance and emission of biomass-fired cook stoves. Biomass & Bioenergy. p. 9

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