Energy efficiency analysis for various type of electric cooker

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Abstract. Efficiency is one of the important things to consider when choosing household appliances, especially cooking equipment. Currently the community is starting to switch from liquefied petroleum gas-based cookers to electric cookers. Therefore analysis is needed to determine the selection of electric cookers that are efficient in accordance with consumer needs. To accomplish this study, testing with boiling water was carried out on three types of electric cookers namely induction cooker, halogen and electric coil. This test is carried out to obtain input and output energy from each stove so that efficiency can be obtained. From the test results, it has been found that the induction cooker has the highest efficiency among the electric cookers.

1. Introduction
Cooking is an activity that has an important role in our daily lives. At the beginning, society used wood and gas as fuel for cooking activities. Along with the development of technology and economy, people begin to shift into electricity as the main energy for cooking [1]. A study states that from total energy consumption used in residential areas, 11 percent of energy is used for food preparation [2]. The main consideration in the selection of equipment for food preparation is the availability of energy sources, ease of use and effect of operating the equipment on the environment (cleanliness). Now days with rising fuel costs and energy shortages, efficient use of cooking equipment is an important factor for consideration.

There is an array of home cooking appliances in the current market. They may be classified into three categories according to energy sources. The appliances operated by electricity, natural gas, and liquid petroleum gas [3]. More specifically, cooker with electricity as energy are further divided into induction, electric coil, and halogen cooker.

Several studies about energy efficiency have focused primarily on the cooking pots and the type of material used [4]. They studied the heat transfer characteristic and thermal efficiency of various cooking pots which involves different height to diameter ratio of cooking pots with water boiling test. Differences in cooking efficiencies are due to differences in heating principles and cook top wattage, pan size and shape, composition, base thickness and mass [5]. In addition, several studies have conducted performance tests on electric, halogen and induction cookers for oven-baking and pan frying [1,6], also for several type of meal [7]. Unfortunately, these data were not representative of the thermal efficiency in cooker type that commonly used in Indonesia.

In view of this lack of data in the literature, the objective of the present study is to understand the efficiency and performance of induction cookers, electric coil and halogen as a whole so that consumers can determine the stove that suits their needs.
2. Methods
The study states that cooking activities are classified in several major parts, including: boiling water, cooking potatoes, boiling eggs. In addition, it was also mentioned that the cooking method makes the most sense in terms of energy consumption saved between 50% and 70% energy [8]. Furthermore, there are several aspects that can influence the amount of energy used when preparing a meal [9]. Appliance characteristics are shown to influence consumption, but human factors play an important role in the overall electricity usage [10]. Therefore, in this study food preparation was carried out by boiling water to control the parameter thoroughly.

In this paper energy use from various types of electric cooker including induction, halogen and electric coil was analysed to find the most efficient energy use among the three types of stoves. Generally, the efficiency of a process can be defined by the ratio of the useful energy output to energy input. Energy efficiency can be calculated as equation (1):

$$\eta(\%) = \frac{Q_{\text{out}}}{Q_{\text{in}}} \times 100 = \frac{m_1 \times C_1 + m_2 \times C_2}{V \times I \times PF} \times 100$$

Where: $\eta$ is energy efficiency (%); $Q_{\text{out}}$ is energy output (J); $Q_{\text{in}}$ is energy input; $m_1$ is water mass (kg); $C_1$ is specific heat capacity of water (J/kg.°C); $m_2$ is total mass of pot (kg); $C_2$ is specific heat capacity of pot (J/kg.°C); $\Delta T$ is temperature difference (°C); $V$ is voltage (V); $I$ is electrical current (A); $PF$ is power factor and $\Delta t$ is time difference (s).

The objective of this study to find energy efficiency from various electric cooker with various power used consisting of induction cooker (300W, 500W, 1000W, 1400W, 1800W), halogen (600W, 1000W, 1400W, 1800W, 2000W) and electric coil (300W and 600W). The experiment apparatus consisted of electric cooker including induction, halogen and electric coil, stopwatch, thermometer, pot, static, power quality meter, electronic balance, glass measuring 1 L.

For experiment using electric cooker and halogen are used pot with ferro-magnetic material, for electric coil using the aluminum pot. The experimental procedure consisted of preparation the apparatus, put the pot on the electronic balance, pour 1 L of tap water into the pot, put the pot on the electric cooker, connect the electric cooker with power quality meter and the mains supply, measure the initial temperature of the tap water (30°C), turn on the electric cooker and read the input electrical power from the power quality meter, start recording the time, voltage, electrical current, and power factor for each temperature increase of 10°C until the water temperature reaches 100°C. Then remove the water, cool the pot down to room temperature, and repeat the same step until five times.

3. Results and discussion
The obtained results allowed establishing: the relationship between energy efficiency of several types of electric cooker and energy efficiency with the amount of power used.

3.1. Experimental results for each type of electric cooker
From the experimental data five times for each electric cooker, the average time, voltage, current and power factor can be calculated for each 10°C temperature increase.

The average time is calculated using equation (2):

$$t(T) = \frac{t(T_1) + t(T_2) + \ldots + t(T_n)}{n}$$

Where: $t(T)$ is average time at certain temperature (s); $n$ is number of experiment.

For the average voltage, current and power factor also calculated as follows equation (2). Initial data obtained in this experiment:
\[ m_1 = 1L = 1000 \text{ gr} \]
\[ C_1 = 4.1868 \text{ J/gr.}^\circ C \]
\[ m_2 = \text{for ferro-magnetic material: 388.35 gr and for the aluminium pot: 211.00 gr} \]
\[ C_2 = \text{for ferro-magnetic material: 0.4605 J/gr. and for aluminium: 0.9211 J/gr.}^\circ C \]

The experimental results for average time, voltage, current, and power factor when using induction cooker, halogen and electrical coil shown in table 1-6. In this induction cooker type, it has several power mode. This power mode differentiate between several induction cooker type depend on the manufacture. Induction cooker deliver the heat directly into the cookware and do not add any additional heat to the surface of the cooktop [1]. Although induction cooker can adjusts the watt input automatically to provide maximum cooking performance, this study this study varies the input power of induction cookers and halogens so that they can be compared with electric coils.

| Table 1. Experimental results of 300W and 500 W induction cooker. |
|-------------------|-------------------|-------------------|-------------------|
| **300 W induction Cooker** | **500 W induction Cooker** |
| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor | Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
| 30 | 0.00 | 217.51 | 1.74 | 0.95 | 30 | 0.00 | 216.61 | 2.70 | 0.84 |
| 40 | 136.20 | 217.78 | 1.74 | 0.95 | 40 | 98.80 | 216.52 | 2.70 | 0.84 |
| 50 | 281.40 | 217.45 | 1.76 | 0.95 | 50 | 202.60 | 216.64 | 2.70 | 0.84 |
| 60 | 448.40 | 217.31 | 1.78 | 0.95 | 60 | 314.40 | 216.89 | 2.70 | 0.84 |
| 70 | 619.00 | 217.37 | 1.76 | 0.95 | 70 | 431.20 | 216.56 | 2.70 | 0.84 |
| 80 | 825.60 | 217.21 | 1.74 | 0.95 | 80 | 562.80 | 216.70 | 2.70 | 0.84 |
| 90 | 1,058.00 | 216.89 | 1.76 | 0.95 | 90 | 713.20 | 216.92 | 2.70 | 0.84 |
| 100 | 1,414.20 | 217.34 | 1.76 | 0.95 | 100 | 895.00 | 217.15 | 2.70 | 0.84 |

| Table 2. Experimental results of 1000 W and 1400 W induction cooker. |
|-------------------|-------------------|-------------------|-------------------|
| **1000 W induction Cooker** | **1400 W induction Cooker** |
| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor | Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
| 30 | 0.00 | 206.20 | 4.62 | 1.00 | 30 | 0.00 | 216.00 | 6.36 | 1.00 |
| 40 | 50.60 | 206.80 | 4.62 | 1.00 | 40 | 29.40 | 215.80 | 6.36 | 1.00 |
| 50 | 106.00 | 206.40 | 4.62 | 1.00 | 50 | 65.80 | 215.80 | 6.36 | 1.00 |
| 60 | 164.20 | 206.40 | 4.60 | 1.00 | 60 | 114.20 | 215.60 | 6.40 | 1.00 |
| 70 | 221.60 | 205.60 | 4.62 | 1.00 | 70 | 138.60 | 215.60 | 6.38 | 1.00 |
| 80 | 281.40 | 206.20 | 4.60 | 1.00 | 80 | 176.00 | 215.60 | 6.40 | 1.00 |
| 90 | 340.20 | 205.60 | 4.60 | 1.00 | 90 | 216.00 | 216.00 | 6.40 | 1.00 |
| 100 | 429.60 | 205.80 | 4.60 | 1.00 | 100 | 282.40 | 216.00 | 6.40 | 1.00 |

| Table 3. Experimental results of 1800W induction and 600 W halogen cooker. |
|-------------------|-------------------|-------------------|-------------------|
| **1800 W induction Cooker** | **600 W Halogen Cooker** |
| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor | Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
| 30 | 0.00 | 214.80 | 7.96 | 1.00 | 30 | 0.00 | 224.44 | 5.67 | 0.50 |
| 40 | 20.80 | 215.00 | 7.96 | 1.00 | 40 | 92.60 | 224.27 | 5.63 | 0.50 |
| 50 | 50.20 | 214.80 | 7.96 | 1.00 | 50 | 190.20 | 224.03 | 5.63 | 0.50 |
| 60 | 79.80 | 215.00 | 7.92 | 1.00 | 60 | 296.60 | 224.43 | 5.65 | 0.50 |
| 70 | 107.20 | 215.00 | 7.92 | 1.00 | 70 | 399.20 | 224.22 | 5.66 | 0.50 |
| 80 | 135.40 | 214.80 | 7.90 | 1.00 | 80 | 503.00 | 224.03 | 5.66 | 0.50 |
| 90 | 166.20 | 214.80 | 7.90 | 1.00 | 90 | 618.40 | 224.54 | 5.64 | 0.50 |
| 100 | 219.80 | 215.20 | 7.90 | 1.00 | 100 | 751.60 | 224.57 | 5.67 | 0.50 |
Table 4. Experimental results of 1000 W and 1400W halogen cooker.

| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
|----------|----------|-------------|-------------|--------------|
| 1000 W Halogen Cooker | | | | |
| 30 | 0.00 | 222.51 | 6.61 | 0.66 |
| 40 | 66.00 | 222.38 | 6.60 | 0.66 |
| 50 | 132.20 | 222.24 | 6.58 | 0.66 |
| 60 | 182.00 | 222.11 | 6.59 | 0.66 |
| 70 | 245.80 | 222.07 | 6.59 | 0.66 |
| 80 | 325.20 | 222.05 | 6.58 | 0.66 |
| 90 | 401.80 | 222.00 | 6.57 | 0.66 |
| 100 | 486.20 | 222.00 | 6.59 | 0.66 |

| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
|----------|----------|-------------|-------------|--------------|
| 1400 W Halogen Cooker | | | | |
| 30 | 0.00 | 218.97 | 7.70 | 0.83 |
| 40 | 46.80 | 219.20 | 7.70 | 0.83 |
| 50 | 94.20 | 219.17 | 7.70 | 0.83 |
| 60 | 137.40 | 219.13 | 7.70 | 0.83 |
| 70 | 180.20 | 219.32 | 7.70 | 0.83 |
| 80 | 226.20 | 219.23 | 7.70 | 0.83 |
| 90 | 271.80 | 219.20 | 7.70 | 0.83 |
| 100 | 328.20 | 219.23 | 7.70 | 0.83 |

Table 5. Experimental results of 1800W and 2000 W halogen cooker.

| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
|----------|----------|-------------|-------------|--------------|
| 1800 W Halogen Cooker | | | | |
| 30 | 0.00 | 220.10 | 8.48 | 0.96 |
| 40 | 37.40 | 220.18 | 8.48 | 0.96 |
| 50 | 72.40 | 220.11 | 8.44 | 0.96 |
| 60 | 106.60 | 219.74 | 8.40 | 0.96 |
| 70 | 141.40 | 219.54 | 8.40 | 0.96 |
| 80 | 176.80 | 219.57 | 8.40 | 0.96 |
| 90 | 208.00 | 219.80 | 8.42 | 0.96 |
| 100 | 257.20 | 220.03 | 8.40 | 0.96 |

| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
|----------|----------|-------------|-------------|--------------|
| 2000 W Halogen Cooker | | | | |
| 30 | 0.00 | 221.40 | 8.66 | 1.00 |
| 40 | 29.00 | 221.64 | 8.64 | 1.00 |
| 50 | 62.80 | 221.66 | 8.64 | 1.00 |
| 60 | 95.20 | 221.12 | 8.66 | 1.00 |
| 70 | 130.60 | 221.36 | 8.64 | 1.00 |
| 80 | 163.80 | 221.15 | 8.62 | 1.00 |
| 90 | 193.60 | 221.53 | 8.62 | 1.00 |
| 100 | 240.20 | 221.11 | 8.62 | 1.00 |

Table 6. Experimental results of 300W and 600 W electric coil.

| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
|----------|----------|-------------|-------------|--------------|
| 300 W Electric Coil | | | | |
| 30 | 0.00 | 221.11 | 1.30 | 0.97 |
| 40 | 326.80 | 221.55 | 1.30 | 0.97 |
| 50 | 659.00 | 221.86 | 1.30 | 0.97 |
| 60 | 1023.20 | 221.06 | 1.30 | 0.97 |
| 70 | 1399.00 | 221.24 | 1.30 | 0.97 |
| 80 | 1793.20 | 221.27 | 1.30 | 0.97 |
| 90 | 2444.00 | 221.79 | 1.30 | 0.97 |
| 100 | 3354.20 | 221.32 | 1.30 | 0.98 |

| Temp (°C) | Time (s) | Voltage (V) | Current (A) | Power Factor |
|----------|----------|-------------|-------------|--------------|
| 600 W Electric Coil | | | | |
| 30 | 0.00 | 218.07 | 2.58 | 1.00 |
| 40 | 197.00 | 218.02 | 2.56 | 1.00 |
| 50 | 364.60 | 217.90 | 2.58 | 1.00 |
| 60 | 524.80 | 217.85 | 2.58 | 1.00 |
| 70 | 692.00 | 218.03 | 2.56 | 1.00 |
| 80 | 861.40 | 218.24 | 2.58 | 1.00 |
| 90 | 1055.80 | 218.28 | 2.58 | 1.00 |
| 100 | 1302.60 | 218.86 | 2.56 | 1.00 |

From the tables above it can be seen that the time needed to heat up a pot of water for each type of cooker are very different. This is called heat up time. Broadly speaking, heat up time affects the efficiency of the cooktop. Some cooktops may have the same input power but different time to heat up. This certainly does not consider the response temperature of each type of cooktop because all cooktops are set at a constant power up to 100°C.

3.2. Calculation of energy output and energy input

Energy input and energy output is calculated by equation (1). The calculation results for energy output and energy input on various types of electric cooker see Table 7.
Table 7. Energy output and energy input.

| Type of electric cooker | Electric cooker power (W) | Type of electric cooker (J) | Electric cooker power (J) |
|-------------------------|---------------------------|----------------------------|---------------------------|
| Induction               | 300                       | 305,594.46                 | 513,909.65                |
| Induction               | 5000                      | 305,594.46                 | 440,784.10                |
| Induction               | 1000                      | 305,594.46                 | 406,693.73                |
| Induction               | 1400                      | 305,594.46                 | 390,389.76                |
| Induction               | 1800                      | 305,594.46                 | 373,677.58                |
| Halogen                 | 600                       | 305,594.46                 | 478,510.61                |
| Halogen                 | 1000                      | 305,594.46                 | 355,794.62                |
| Halogen                 | 1400                      | 305,594.46                 | 459,840.67                |
| Halogen                 | 1800                      | 305,594.46                 | 456,355.60                |
| Halogen                 | 2000                      | 305,594.46                 | 457,813.56                |
| Electric coil           | 300                       | 306,680.65                 | 10,596,325.94             |
| Electric coil           | 600                       | 306,680.65                 | 729,822.81                |

From Table 7 above, energy efficiency can be calculated for each type of electric cooker using equation (1) as in Fig. 1.

Figure 1. Energy efficiency of various electric cooker.

Energy output and energy input are used to calculate energy efficiency for each type of cooker. Energy efficiency is defined as the ratio of energy into the food/water versus the energy into the appliance. The higher the energy efficiency, the lower thermal losses into the environment.

From Fig.1 above, it is known that the energy efficiency is affected by type of electric cooker and the power of electric cooker used. In general, induction is more efficient compared to halogen and electric coil, the efficiency is highly dependent on the power used by the cooker. The range of energy efficiency of induction between 59.46% to 81.78%. The range of energy efficiency of halogen between 63.86% to 66.75% and the range of energy efficiency of electric coil between 32.43% to 42.02%. This graph means that electric coil cooktops have the highest thermal losses because the heat transfer from
the coil to the pan also heats up the air around the pot or pan, which turn heats up the kitchen. Also, the heating elements in resistance electric cooktops have high thermal mass resulting in higher thermal losses into the cooktop itself, which heats the air indirectly. Induction cooktops have the highest efficiency and the lowest thermal losses because they heat up the pot directly and not surrounding air.

4. Conclusion
This study investigates the thermal efficiency of electric cooker with water boiling test. It is found that from the result that induction stove 1800 Watt has highest efficiency of 81.78% for 3.6 minutes of heating time and electric coil stove 300 Watt has lowest efficiency of 32.43% for 55.9 minutes of heating time. The water boiling test result that halogen stove almost has the same efficiency in all power. The range of energy efficiency of halogen between 63.86% to 66.75%. It’s clearly show that induction electric cooker is the most efficient cooker and halogen and electric coil required more time to reach the water boiling temperature

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