

## Energy Optimization in Cooking Devices

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**Abstract.** In the conventional cooking practice, where a pot or a pan is directly placed on a flame, the thermal energy efficiency is in the range of 10 to 25 per cent. In the developing world (85 % of world's population), open pan cooking is largely still practiced at the family level (4 to 10 persons) or at the community level (50 to 2000 persons or more). It is interesting to note that, cooking is physico-chemical process. Thus, basic Chemical Engineering principles have been combined to develop an energy efficient cooker. For different types of final application (family level and community level cooking), in the present work, cooking systems (batch and continuous) have been developed. Both the systems are highly energy efficient and give thermal efficiency of about 70 percent. The cooking device, or cooker developed and discussed here, is restricted to foods that can be cooked by boiling or steaming.

**Keywords:** Family, Community, Cooking, Thermal, Efficiency.

### 1. Introduction

Energy conservation and its optimum use has become an important need of our times. Population levels are rising. Conventional energy sources are steadily depleting. The developments in the renewable energy alternatives have been slow and are not yet economically viable. Because of these factors, it becomes important to look for the ways and means to reduce the consumption of energy from conventional sources.

About 40 % of the total energy consumed in the developing World (population more than 4 billion) is used for cooking. The large population size explains this astonishing figure. Out of the total energy consumed for cooking, 31 % comes from commercial fuels such as gas, kerosene or coal; the remaining 69 % is from non-commercial fuels such as firewood, dung cakes and agricultural waste [Legroset et al.<sup>1</sup>; Wikipedia<sup>2</sup>]. Due to its increased availability, economy and the convenience, the use of liquefied petroleum gas (LPG) is increasing at a faster rate in urban as well as rural area.

The problem of energy conservation has been seriously addressed in the industrial sector and various techniques and methods of operation that conserve energy have been developed and practiced. However, practically no information is available in the published literature on energy conservation in cooking. It may be noted that cooking is also a physico-chemical process, like any other operations in the Chemical Process Industry (CPI) and hence there is a possibility of applying conservation strategies in CPI to the cooking practices.

This paper considers the ways and means of minimizing the consumption of LPG in cooking. The cooking devices, batch and continuous cooker developed and discussed here, are restricted to foods that can be cooked by boiling or steaming. Basic Chemical Engineering principles have been combined to develop an energy efficient cooker for such foods.

### 2. Eco-cooker

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Table 1. Gas consumption and thermal efficiencies for different capacities of EcoCooker

S.N.	Capacity of cooker (lit)	Charge in vessels (lit)	Water in base (lit)	LPG flow rate (ml/s)	Time (s)	Gas Consumption (g)	$\eta_{\text{therm}}$ (%)
1	4.5	4.5	0.45	6.6	4350	66	65.9
2	6.0	6.0	0.55	7.3	5062	85	66.2
3	24.0	24.0	2.0	27.6	5360	340	67.2
4	72.0	36.0	12.0	84.3	2600	504	71.4

### 3. Continuous cooker

Batch cooker can cook food for a maximum of 500 people at a time, as further increase in the quantity increases the number of vessels to be handled. There are many places where more than 100000 meals are served at a time like Govt. of India mid-day meal scheme, Shirdi sansthan, Tirupati Balaji etc. At all these places cooking is done using conventional open pan cooking process which is energy inefficient and labour intensive. Thus a continuous cooker has been envisaged using the batch cooking knowledge and information generated in the EcoCooker experiments

The continuous cooker is shown schematically in Figure 2. It consists of a U-trough (1) with a single screw (2) (primary screw) for moving the material in the forward direction. The trough has a jacket (3) for providing the heat through condensing steam. Heat can also be supplied by open steam injected through nozzles (4). The speed of rotation of the screw can be adjusted through a variable frequency drive (5) attached to a motor (6). Rice or lentils or a mixture of both are fed through a hopper (7). The trough extends above the screw for accommodating extra water if necessary. A rectangular plate with two handles on top surface and hinges on one side are provided to cover the trough from above. The cover arrangement is handy during cleaning operation.

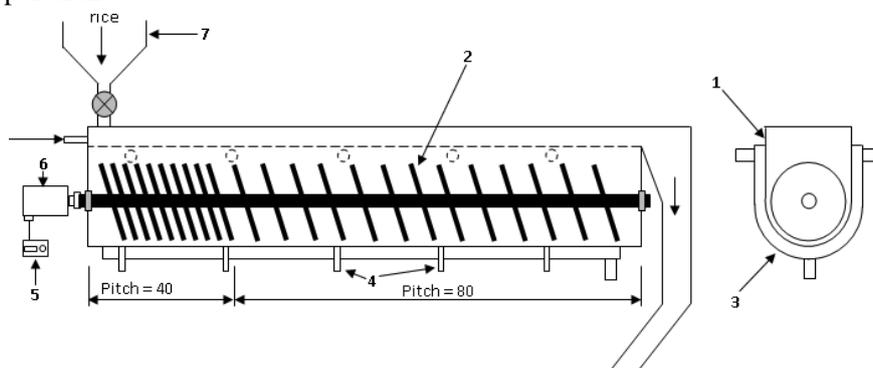


Fig. 2: Continuous Cooking Equipment

Since, the cooked rice was to be removed from the equipment in suspended form, initial trials were carried out to understand the effect of speed of rotation of the screw. A higher speed would result in the breakage of cooked rice while a very low speed can result in improper grain particle suspension. In the first trial, 30 kg of water was charged and brought to the boiling point and then rice was charged from the feed end with screws rotating at 0.5 r/s. It was observed that the rice grains moved gradually along the length of the trough. A sample of rice water slurry was removed from the other end. From the samples collected, it was found that cooked rice started coming out after an average particle residence time of about 25 min.

Though the rice was cooked completely, there was large breakage of grains indicating the need to lower the speed of rotation. In another trial, the rotation speed was decreased to 0.4 r/s with rice addition of 10 kg at the starting followed by 2 kg/hr on a continuous basis. Samples of rice coming out from the discharge end were continuously checked for cooking and the rice was found to be cooked satisfactorily. During the final trial, the speed of rotation was further reduced to 0.25 r/s. 10 kg rice was charged initially in heated water

and further addition was continued at the rate of 13 kg/hr. Considering that rice requires water in the proportion of approximately 1: 2.5 for cooking, and some water is required for suspension, water was charged at the rate of 71 kg/hr. The operation was carried out for 2 hrs. Rice coming out after the initial 20 min time was found to be cooked nicely. The ratio of cooked rice to free water was found to be 1:3. It was concluded from these trials that a residence time of 20 min was sufficient for cooking of rice when temperature was maintained above 90°C. Considering the enormous potential of continuous cooker, further work is in progress for the scale up and development of reliable procedure for large scale cooking.

Installation of scaled up model, which can cook 500 kg/hr (sufficient to feed ~2400 people/hr) is under progress. Energy balance and costing is done for the same model, and results are as follows

1. Amount of fuel required to cook food for ~2400 people/hr is 24 kg/hr, using conventional open pan cooking (20% efficiency), which can be reduce to 11 kg/hr using continuous cooker with 40% efficiency.
2. We can save ~5.4 lakh INR/yr and can reduce CO<sub>2</sub> emission by 0.06 MT per year.
3. Pay back period for continuous cooker is less than 10 months, if it is used 4 hr/day, to feed 10000 people/day.

#### **4. Conclusions**

1. For EcoCooker, the combined effect of all the optimization exercises has given the value of the thermal efficiency in the range of 65 to 72% and useful efficiency in the range of 50 to 60%. It may be noted that, conventional cooking methods give thermal efficiencies only in the range of 10 to 20 percent.
2. More than 50 cookers (72 to 160 liter) are in actual practice at various locations. The LPG consumption has found to reduce by about 60%.
3. At present, the cost of the 160 liter cooker is about 30000 INR which cater the food for about 500 persons. With 20% depreciation and 10 % interest on capital cost, the pay out period works out to be 8 months at the LPG price of 22 INR per kg.
4. Lab scale model for continuous cooker has been successfully tested, and scaled up model is installed which can cook 150 kg/hr of raw rice, at Iskon Food Relief Foundation, Palghar.
5. Both the models, batch and continuous cooker has enormous potential for fuel saving. Apart from direct fuel savings it also reduces carbon emission and offer hygiene, high nutritional food.

#### **5. Acknowledgement**

Author would like to acknowledge Land Research Institute for their support during the development of cooking devices.

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