ENERGY CONSUMPTION BENCHMARK STUDIES ON PARBOILED RICE COOKING IN KERALA

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ABSTRACT

Rice is the staple food of vast majority of Kerallites and a major portion of it is consumed as cooked rice, mostly of parboiled variety. The quantity of thermal energy used for rice cooking is quite substantial taking note of the quantity of rice consumption in Kerala of about 40.68 lakh metric tones. It can be reasonably assumed that at least 70% of the rice consumption in Kerala is cooked rice mostly of parboiled varieties. Parboiled rice consumes more thermal energy for cooking than raw rice. Also the energy needed for cooking parboiled rice vary considerably depending on the rice variety and the parboiling process.*

This study mainly focuses on energy consumption benchmarking for cooking different verities of rice consumed in Kerala, to arrive at cost of cooking using different cook stoves. The annual consumption of different cooking fuel based on stove use pattern in Kerala also will be discussed. The energy needed for rice cooking also varies according to the cooking practices and use of cooking aids. Cooking aids such as pressure cookers and thermal rice cookers can reduce the fuel consumption substantially. Quantitative estimation of possible savings in fuel consumption by improved cooking practices, use of best cooking aids and selection of right variety of parboiled rice , energy efficient cook stoves will be helpful in shaping future policies and programmes to to promote energy efficiency in this sector , which will help to reduce the CO_2 emission and promote sustainable energy use. Future rice research programmes shall be founded not only on the yield, adaptability to climatic condition and other qualitative parameters but also on energy needed for cooking.

1. INTRODUCTION

fig 1 brown *basmati* rice

Rice is two species in the Poaceae ("true grass") family, *Oryza* sativa and *Oryza glaberrima.* These plants are native to tropical and subtropical southern and southeastern Asia and in Africa. Rice provides more than one fifth of the calories consumed by humans in their global diets. Rice is a monocarpic annual plant, growing to 1–1.8 m tall, occasionally more depending on the variety and soil fertility. The grass has long, slender leaves 50–100 cm long and 2–2.5 cm broad. The small wind-pollinated flowers are produced in a branched arching to pendulous inflorescence 30–50 cm long. The seed is a grain (caryopsis) 5–12 mm long and 2–3 mm thick.

Rice is a staple food for a large part of the world's human population, especially in East and Southeast Asia, making it the most consumed cereal grain. It is the world's largest crop (700 million metric tons in 2005), with maize ("corn") (692 million metric tons in 2005) and wheat (626 million metric tons in 2005) behind it. Rice cultivation is well-suited to countries and regions with low labour costs and high rainfall, as it is very labour-intensive to cultivate and requires plenty of water for irrigation, much like the licorice crops found in Eastern Europe. Rice can be grown practically anywhere, even on steep hillsides. Although its species are native to South Asia and certain parts of Africa, centuries of trade and exportation have made it commonplace in many cultures.

* 1 Lakh = 0.1 million

1.1. HISTORY OF RICE CULTIVATION

It is widely accepted that the term Rice comes from the Tamil word for rice *Arisi*. According to Microsoft Encarta Dictionary (2004) and to Chambers Dictionary of Etymology (1988), the word rice has an Indo-Iranian origin. It came to English from Greek *óryza*, via Latin *oriza*, Italian *riso* and finally Old French ris (the same as present day French *riz*).The same Tamil origin produced the Arabic *ar-ruzz*, from which the Portuguese and Spanish word *arroz* originated. *Orzo*, a pasta shaped like small grains of rice, presumably gets its name from the Latin *oriza*.

Rice is considered to have begun simultaneously in many countries over 6500 years ago. Two species of rice were domesticated, Asian rice (*O. sativa*) and African rice (*O. glaberrima*). The origins of rice cultivation is the object of research of specialized branch of archaeology called *palaeoethno botany.*

Fig 2 Japaneese short grain rice

O. sativa appears to have originated around the foothills of the Himalayas, with *O. sativa var. indica* on the Indian side and *O. sativa var. japonica* on the Chinese and Japanese side. One genetic study suggests that common wild rice, *Oryza rufipogon*, was the wild ancestor of Asian rice. However, some suggests that rice was cultivated at three separate locations, as shown by the three groups of cultivars: the short-grained *"japonica"* or *"sinica"* varieties, exemplified by Japanese rice; the long-grained *"indica"* varieties, exemplified by *Basmati* rice; and the broad-grained *"javonica"* varieties, which thrive under tropical conditions. However , the earliest find site for the *javonica* variety, dated to the fifth millennium BC, was in the earliest phases of the *Hemudu* culture on the south side of Hangzhou Bay in China, but was found along with japonica types.

Wild rice appeared in the Belan and Ganges valley regions of northern India as early as 4530BC and 5440 BC respectively. Agricultural activity during the second millennium BC included rice cultivation in the Kashmir and mature Harrappan regions. Mixed farming was the basis of Indus valley economy. Farmers planted their crops in integrated fields. Rice, grown on the west coast, was cultivated in the Indus valley. Rice, alongwith barley, meat, dairy products and fish constituted the dietary staple of the ancient Dravidian people. There is mention of *ApUpa*, *Puro-das* and *Odana* (rice-gruel) in the Rig Veda, terms that refer to rice dishes, The *Rigvedic* commentator *Sayana* refers to *"tandula"* when commenting on RV 1.16.2., which means rice. The Rigvedic term *dhana (dhanaa, dhanya)* means rice. Both *Charaka* and *Sushruta* mention rice in detail. The *Arthasastra* discusses aspects of rice cultivation. The *Kashyapiyakrishisukti* by *Kashyapa* is the most detailed ancient Sanskrit text on rice cultivation.

1.2. GROWTH

Rice is often grown in paddies. The shallow puddles take advantage of the rice plant's tolerance to water; the water in the paddies prevents weeds from outgrowing the crop. Once the rice has established dominance of the field, the water can be drained in preparation for harvest. Paddies increase productivity, although rice can also be grown on dry land (including on terraced hillsides) with the help of chemical weed controls.

In some instances, a deep-water strain of rice often called floating rice is grown. Floating rice can develop elongated stems capable of coping with water depths exceeding 2 meters (6.5 feet). Rice paddies are an important habitat for birds such as herons and warblers, and a wide range of amphibians and snakes. They perform a useful function in controlling insect pests by providing useful habitats for those who prey on them.

Fig 3 Terraced paddy fields in hill slope

The seeds of the rice plant are first milled using a rice huller to remove the chaff (the outer husks of the grain). At this point in the process the product is called brown rice. This process may be continued, removing the germ and the rest of the husk, called the bran at this point, creating white rice. The white rice may then be buffed with glucose or talc powder (often called polished rice, though this term may also refer to white rice in general), parboiled, or processed into flour. The white rice may also be enriched by adding nutrients, especially those lost during the milling process. While the cheapest method of enriching involves adding a powdered blend of nutrients that will easily wash off, more sophisticated methods apply nutrients directly to the grain, coating the grain with a water insoluble substance which is resistant to washing.

Fig 4 A paddy field

While washing is counter-productive for powder-enriched rice, it is absolutely necessary when talc-coated rice is used, not least because of concerns about the negative health effects of talc consumption and possibility of asbestos accompanying the talc. Despite the hypothetical health risks of talc (such as stomach cancer), talc-coated rice remains the norm in some countries due to its attractive shiny appearance, but it has been banned in some and is no longer widely used in others such as the United States. Even where talc is not used, glucose, starch, or other coatings may be used to improve the appearance of the grains; for this reason, many rice lovers still recommend washing all rice in order to create better-tasting rice with a better consistency, despite the recommendation of suppliers. Much of the rice produced today is in fact water polished.

Rice bran is a valuable commodity in Asia and is used for many daily needs. It is a moist, oily inner layer which is heated to produce an oil. It is also used in making a kind of pickled vegetable. The raw rice may be ground into flour for many uses, including making many kinds of beverages such as *amazake*, *horchata, rice milk*, and *sake*. Rice flour is generally safe for people on a gluten-free diet. Rice may also be made into various types of noodles. Raw wild or brown rice may also be consumed by raw foodist or fruitarians if soaked and sprouted (usually 1 week to 30 days).

Table -1 Rice, raw Nutritional value per 100 g (3.527 oz)	
Energy 360 kcal 1510 kJ	
Carbohydrates	79 g
Fat	0.6 g
Protein	7 g
Vitamin B6 0.15 mg	12%
Water	13 g

1.3. PARBOILING OF RICE

Much of today's rice is consumed as parboiled rice. Also known as easy-cook rice. Parboiling is a traditional and ancient unit operation given to paddy in India and other part of the world. It includes soaking, steaming and drying. Paddy is soaked in water for a time period of 12 hours and hot steam is applied to it. After draining it is sun dried or dried in commercial drier, and can then be milled as usual or consumed as brown rice. Milled parboil rice is nutritionally superior to standard milled rice.

Fig 5. Parboiled rice

During parboiling vitamins, minerals, proteins present in the bran diffuses to the germ so that the grain is more nutritious than the raw grain. The milling loss of parboiled rice is minimum .It has a good appearance. The cooking quality is improved and better head rice yield.

The parboil process causes a gelatinization of the starch in the grains. The grains become less brittle, and the colour of the milled grain changes from white to yellow. Parboiled rice has an additional benefit in that it does not stick to the pan during cooking as happens when cooking regular white rice.

1.4. MILLING OF RICE

The major steps involved in milling are;

- **Cleaning and shelling:** The rough rice is first cleaned and passed through a machine which removes the hull
- **Whitening and polishing:** Whitening is the removal of silver skin and bran layer followed by polishing.
- **Glazing:** It is a coating with talcum powder and glucose after polishing to give a transparent look to rice.

Fig 6. A modern rice mill

The by-products of rice milling are used for a variety of purposes. Rice bran is the most valuable by-product of rice milling industry. It is obtained from the outer layers of the brown rice. Generally, rice bran consists of *pericarp*, *aleurone layer*, *germ* and a part of *endosperm*. Bran removal amounts to 4 to 9 per cent of the weight of paddy milled and is abundant in oil. Raw rice bran contains about 18 to 20 per cent oil whereas parboiled rice bran contains about 22 to 25 percent oil. The de-oiled bran, which is a rich source of protein (about 17%) and vitamins (Vitamins A and E), is used as cattle feed and poultry feed. It is a good source of foreign exchange earnings. Rice hulls can be used in manufacture of insulation materials, cement and cardboard. It is also used as litter in poultry keeping. Rice straw is used as cattle feed and it is also used as litter during winter season.

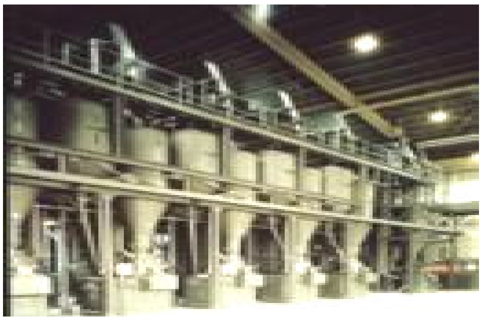


Fig 7. Modern rice polishing machines

Quality preference of rice varies from country to country and region to region and are depended on a number of factors. The rice industry which include breeders, farmers, processors and marketers, respond to consumer preferences across the world by developing and producing a vast array of varieties and hybrids of rice. Attempt at controlling the cooking characteristics of a rice variety or hybrid deal with determining various physico-chemical parameters, breeds of rice and cross breeding to arrive at a proper *amylose* content, gelatinization temperature, gel consistency, grain dimensions and other such parameters.

1.5. CHARACTERISTICS OF RICE COOKING

Cooking requires the transformation of the potential energy in fuel into heat energy. There are many factors influencing the efficiency of cooking like the phenomenon of heat production, heat utilization, heat transmission and heat rejection during combustion. The waste heat recovery has a great aspect for improving the performance of any thermal system.

Fig 8 Uncooked pre-steamed long rice

Rice is cooked by boiling or steaming. It can be cooked in just enough water to cook it through (the absorption method), or it can be cooked in a large quantity of water which is drained before serving (the rapid-boil method). Electric rice cookers, which are popular in Asia and Latin America, simplify the process of cooking rice.

Rice may also be made into rice porridge by adding more water than usual, so that the cooked rice is saturated with water to the point that it becomes very soft, expanded, and fluffy. Rice porridge is very easy to digest, so it is especially suitable for the sick. Rice may be soaked prior to cooking. Soaked rice cooks faster. For some varieties, soaking improves the texture of the cooked rice by increasing expansion of the grains.

In some culinary traditions, especially those of Latin America, Italy and Turkey, dry rice grains are fried in oil ,before cooking in water.

The present invention relates to a process for changing the cooking behaviour and cooked rice texture of a given rice by varying only the milling degree of the rice. A grater degree of milling produces cooked rice which is substantially softer and sticker and a lesser degree produces cooked rice which is substantially fluffier and drier.

Quality of rice depends on:

- Physical characteristics
- Cooking characteristics
- Nutritional composition
- Effect of parboiling

Cooking characteristics play a vital role in determining the quality of rice. Some high yielding varieties are less acceptable due to poor cooking quality. There is a good relation existing between cooking and eating qualities of rice with respect to starch content. The starch present in the rice are *amylose* and *amylopectin*. Varieties in which low dispersion of *amylose* into cooking water found to be superior cooking quality. Cooking time was positively correlated with protein content. Parboiled low *amylose* samples cooked 1.5 minutes faster than raw kernel.

1.5.1. Gelatinization Temperature

Gelatinization temperature of starch is the range of temperature within which the starch starts swell irreversibly in hot water with simultaneous loss of crystalline. Gelatinization temperature of raw rice variety is 73-85°c and those of parboiled variety are 78-88°c. The time required for cooking is depending on gelatinization temperature of starch. High gelatinization temperature requires more water and a longer cooking time. Thermal degradation was slower in brown rice than white rice. Mostly longer variety absorb more water than medium or short grain.

1.5.2. Volume Expansion

Cooking definite amount of milled rice in uniform sized test tubes and the ratio of increase in volume was calculated .Higher volume expansion after cooking is a desirable trait preferred by consumers. Parboiled rice show high volume expansion compared to raw rice. The mean cooking time of parboiled variety is 46.9 minute.

Cooking characteristics of rice varieties are evaluated by:

- Optimum cooking time
- Volume expansion
- Water uptake
- Gruel loss
- Gelatinization temperature
- Viscosity
- *Amylose* content
- *Amylose amylopectin* ratio

1.6. RICE EATING HABITS OF KERALITES

Rice is the unique food grain sustaining two-thirds of the world's population. It is the major staple food in Kerala. It is nutritious and one of the cheapest source of food energy and protein. Whether it is Break fast, lunch or dinner there will be some rice preparations along with some vegetarian or non-vegetarian dishes. '*Choru*' or '*Kanji*' (a rice porridge) along with some curries is the main course for Kerala families for lunch and supper. A large majority of People in Kerala prefer parboiled rice. Raw rice is mainly used for making *Puttu*, *Idly*, *Dosai*, *Idiyappam*, *Pathiri* etc. *Basmati* rice is one of the rice variety which has a special fragrance after cooking. It is used for making *Biriyani*, Fried rice ,*Pulavu* etc. In the northern region of Kerala people prefer white rice whereas in southern region it is red rice. It is reasonable to estimate that at least 70% of the rice consumed in Kerala is used for making "Choru" the Kerala traditional meal prepared mostly from parboiled rice which is eaten along with Curries.

Fig 9 Traditional Kerala meal in plantain

The population of Kerala is 31841377 according to the latest census data, in which 14288995 are men and 14809523 are women. The average daily rice consumption of a person is 350gm. The annual requirement of rice in Kerala is about 40.68 lakh tonnes, but the production is only 3.65 lakh tonnes. So the 80% of the requirement is satisfied by importing rice from other states.

1.7. MAJOR VARIETIES OF RICE CULTIVATED IN KERALA

- ***Jyothi*** *:* High yielding variety cultivated in Kole and kuttanad region.Red variety with long bold grain.
- ***Mattathriveni*** : Red variety with medium bold grain, cultivated in Palakkad region.
- ***Uma*** : Red variety with medium bold grain ,cultivated in Kuttanad region.
- ***Annapurna*** : Red ,short and bold
- ***Jaya*** : White, long bold, very high yield potential.

About 5.7 lakh tonnes of paddy is produced in Kerala. Out of this 22400 tonnes is used for cultivation, from the rest, 3.65 lakh tonnes of rice is obtained. The area under rice cultivation has been declining in Kerala, at a rate of 52 ha/day in recent years. Failures of the monsoon in recent years, more pressure on land for other purposes, non-availability and high cost of labor and higher input costs are factors responsible for this decline.

Most of the rice cultivators in Kerala are small scale farmers, cultivate paddy in their small landholding. After harvesting paddy is subjected to post harvest treatments to meet the consumer requirements and for improving the shelf life. The post harvest treatments include parboiling, de-husking, polishing, whitening and glazing. Different traders collect the grain from the farmers in a large scale and after processing they introduce it in the market under different brand names. The different brands of rice are *Nirapara, Sabari, Palakkadan matta, Pavizham, Ponni, Double Horse, Sadhya* etc.

1.8. COOKING FUEL USE PATTERN IN KERALA

The fuel use pattern for cooking in Kerala is given in table 2. Majority of the households depends on firewood and other biomass like crop residue , cow dung cake etc, for cooking. Total use of biomass as fuel in Kerala is about 79.3 %. Only 17.7 % of the household has access to LPG. 0.8 % of the households uses biogas for cooking, as per the 2001 census data.

Table -2 Cooking Fuel usage pattern in Kerala
(Source: Census of India 2001)

Types of fuel used for cooking	No of Households	percentage
Fire wood	5107552	77.4
Crop residue	116947	1.8
Cow dung cake	3814	0.1
Coal, lignite, charcoal	3204	0.0
Kerosene	113890	1.7
LPG	1168536	17.7
Electricity	6285	0.1
Biogas	50078	0.8
Any other	5926	0.1
No Cooking	18974	0.3
Total	6595206	100.00

Taste Prejudices of Kerallite's

Kerallites doesn't adopt energy efficient method for rice cooking because of Taste prejudices/myths associated with cooking of rice. Some people prefers to cook rice in earthen vessels only for better 'taste', by using ordinary wood stoves having very low thermal efficiency. The high thermal resistance of the earthen vessel further contributes to poor thermal efficiency. Due to the same reason majority of the household avoid the use of pressure cookers and even thermal cookers. The taste prejudices also plays an important role in the selection of the rice. There is a certain notion that only rice having longer cooking time is having a better taste. This belief ends up in wasting a lot of fuel.

1.9. COOK STOVES USED IN KERALA

In Kerala, people prefer different cook stoves. Most of the households uses (about 70%) three-stone-stove which is having a thermal efficiency of 10% only. Though the introduction of improved wood stove, having a thermal efficiency of about 25% - is a means to reduce the consumption of wood fuel - only about 9 % of the households uses such devices in Kerala. The rest of the people uses LPG stoves (17.7%) and Kerosene stoves(1.7%). There are other methods to conserve cooking fuel, especially for cooking rice , like the use of a thermal cooker. This device utilse the stored heat of the boiled food at around 100 ^{o}C , to continue with the cooking, even after stopping the flame. Though this device substantially reduces fuel consumption, there will be a slight increase in the total time required for cooking. Statistical data are not available, on number of house holds using this method, but the numbers could be few. The other option available for reducing the fuel requirement and total cooking time is by using a pressure cooker. Pressure cookers allow cooking at a higher temperature, which can be called as a high-temperature cooker, cutting both fuel and cooking time.

Other types of cook stoves though used rarely are Induction type cookers and electric rice cookers. In Kerala, the induction type cookers are aggressively being marketed these days, claiming high thermal efficiency of above 96 % and more economical compared to LPG. These claims are not validated by anybody and people are often being misled to buy such devices. These devices are used in more numbers in developing countries, mainly for aesthetic, health and safety reasons, as these doesn't produce a high temperature flame and harmful flues. There is need to be verify these claims. Among stoves which use electricity for cooking, electric rice cookers are supposed to have higher efficiency. But electric rice cookers are also not much in use in Kerala.

1.9.1. Cooking Regime

It is the description of the sequence of different power levels and time periods the stove must be able to deliver to cook the food according to the recipe. The three very important qualities a stove should have are:

- A high power output level
- A high efficiency at this high power output level
- A low power level

The high power or the maximum power P_{max} of a stove determines with the efficiency ,the time needed to bring the contents of a pan to the boil. The higher the power, the quicker the boiling point be reached. In practice P_{max} should be 2-5 kW.

The efficiency at maximum power E_{max} determines with P_{max} , the speed of reaching boiling point . At low power P_{min} the only task for the stove is to compensate for the heat losses of the pan. For preparation that involves long simmering time it is P_{min} that determines to a large extent the total fuel consumption and thus the costs of cooking.

2. OBJECTIVES THE STUDY

The major objectives of this study are;

i. To find out the fuel requirement of cooking different rice varieties used in Kerala using an LPG stove.

ii. Bench mark the energy requirement of different rice varieties consumed in Kerala in relation to taste, cooking time and other quality parameters , to arrive at the optimum Varity of parboiled rice which saves cooking fuel , considering the qualitative and nutritional aspects.

iii. To estimate the fuel requirement and its cost implications of cooking different varieties of rice , using different cook stoves such as ordinary 3 stone wood stove, improved wood stove, kerosene wick stove(*Nutan*) electric hot plate , Induction type cooker and electric rice cooker.

Apart from the above, it is also the objective of this study to determine:

- Fuel losses in open vessel cooking and cooking with full stove power throughout
- To study the comparative advantage if any, for Induction type heater against an LPG stove, as claimed by manufacturers/dealers of these devices.
- To quantitatively determine the advantages of using pressure cookers and thermal cookers in cooking rice

2.1. STUDY METHODOLOGY

The methodology adopted in this study was first to determine the thermal efficiencies different cook stoves normally used in Kerala, from water boiling test. Different varieties of rice (both parboiled and raw rice) were then cooked using an LPG stove to find out the fuel requirement and cooking time . From the thermal efficiency figures these results were then adapted to other types of cook stoves to estimate the fuel requirement in each case. The thermal efficiency figures in the case of wood stoves were not determined as a part of this study, and the efficiency figures available from other studies were used for estimation purpose.

Cooking of rice was also performed using Induction cooker, electric rice cooker, thermal cooker and pressure cooker to arrive at fuel consumption and cooking time etc; to evaluate the comparative performance of these devices.

2.2. THERMAL EFFICIENCY DETERMINATION OF DIFFERENT COOK STOVES

Thermal efficiency indicates the performance of cooking stoves. It is the ratio of energy absorbed by the food to the total energy supplied by the fuel. Different methods available for thermal efficiency determination as proposed by Bhatt (1983) are discussed below:

2.2.1. Water boiling test

This method will be discussed in detail in the later section.

2.2.2. Constant heat output method

It consist in bringing a definite quantity of water to high temperature such as 96°c and repeating it with successive batches of water in similar vessel, presumably till all wood in the stove is used up. The heat absorbed by the water is simple to calculate, if the initial temperature and mass of water is known. The amount of wood used can be measured and if one knows the moisture content and calorific value of wood used, the heat input for accomplishing the job can be calculated leading to an efficiency value.

2.2.3. Constant temperature rise method

This is a modified version of the Indian Standard for electric stoves and is suitable for constant power output stoves. A fixed quantity of water is heated through a temperature rise of, say 20 or 30 °c and the time to accomplish this is noted. The test is repeated several times and an average time to accomplish the task is computed. Since the power and time is known one can compute the energy input. The heat absorbed by the water is easy to evaluate and calculate the efficiency.

2.2.4. Constant time method

In this method heat a fixed quantity of water over a fixed interval of time and the temperature rise is noted. The experiment is repeated several times and an average temperature rise is computed.

2.2.5. Cooking simulation test

Fuel consumption and cooking efficiency tests in the field require the surveyor or researcher to interfere with cooking to some extent. While the level of inconvenience should be minor, it may be difficult to conduct field tests in some locations, Furthermore, fuel consumption and efficiency tests during cooking are highly task and site specific. This makes it difficult to compare fuel economy between different regions.

Because of these problems, the performance of fuel wood cook stoves is often measured using laboratory-based simulation tests. Simulation tests usually involve only the heating and boiling of water. Therefore, they are much simpler than cooking tests. Critical parameters such as fuel and pot types are kept constant during a series of simulation tests unless the effect that one of these parameters has on efficiency is being studied. It may be useful to include simulation tests in a fuel wood survey if cooking tests are not possible or if detailed information regarding cooking fuel economy under controlled conditions is desired.

2.2.6. Process simulation test for large stoves

Process simulation test for large stoves used in small scale industries. There are a variety of products made in such stoves.

2.2.7. Indirect method

In large scale cooking establishments, it is not feasible to estimate the efficiencies easily. Bhatt proposes the indirect test. The energy input is estimated by performing the task on either scaled version or full-scale on the electric stove .From the users of such stoves, fuel consumption is obtained. Comparison of energy consumption in the electric stove test with the latter gives an estimate of efficiency of the large stove.

2.2.8. Approximate method

This is generally called “quick and dirty method” proposed by *Bhatt*. This is applicable to large installation where the stove is in continuous use. A known quantity of water is heated for a 15 minutes and temperature rise of the water is noted.

2.3. STOVES USED IN THIS EXPERIMENT

2.3.1. Electric coiled stove

Specification	
Make	**Johnson Delite**
Rated Voltage	240V
Rated Power	1250W

Fig 10 Electric coiled stove

Actual Wattage of this electric heater in different knob position is shown below;

Stove Power Calibration	
Input voltage =220V	
Knob position	**Wattage(kW)**
Position1	0.23
Position2	0.39
Position3	0.95

2.3.2. Induction cooker

Specifications

Model - AMC20
Product - Maginer
Rated Power - 600-2000W
Rated voltage - 220V,50Hz
Net weight - 2.5 kg

Fig 11 Induction cooker

Power measurement values for Auger Maginer induction heater

The value indicated by the watt meter of Auger Maginer was found to be different from the actual value. The actual power was measured by using FLUKE 41 B Power Analyser.

The table below shows the actual and set values of power;

Stove Power Calibration	
Input voltage = 220V	
Actual value (watt)	**Set value (watt)**
680	600
810	1000
920	1200
1120	1400
1260	1600
1420	1800
1480	2000

2.3.3. Kerosene wick stove (Nutan)

Fig 12 Kerosene wick stove

The weight of empty stove is about 2.6kg. The stove consists of fuel tank, burner assembly and load bearing assembly. The fuel tank capacity of stove is 2 liters. The fuel tank is fitted with filter cap assembly, a kerosene level indicator to indicate the level of kerosene in the tank and a wick control lever designed for raising or lowering the wicks to control the intensity of flame. The burner assembly consist of ten wicks and inner and outer sleeves.

The space between two sleeves is designed to supply more preheated air to ensure better combustion. An insulated outer walled outer burner casing is provided to minimize the heat loss. At the top of burner assembly a load bearing assembly is placed to provide a platform for vessel. An optional triangular pan support is provided to place small utensils. This stove is used in all parts of India especially in urban areas.

2.3.4. L P G stove

The stove is made up of stainless steel body for use with liquefied petroleum gases sold in refillable tanks at 2.5 - 3.4 kPa pressure. A tap is provided in the stove to control the pressure. If the tap is turned "full on" the intensity of the flame is high. A detachable metal frame is provided to support the pan. The stove connected to the gas cylinder with rubber tubing. A detachable regulator is provided at the end of the tube to connect to the cylinder .There is a key in the regulator to control the supply of gas from the cylinder to the stove.

Fig 13 LPG Stove

Flow rate of L.P.G was measured using the large and small burner and the results were:

For large burner;

- at Max. position =144gm/hr
- at Sim position =45gm/hr

For small burner;

- at Max. position =133gm/hr
- at Sim position =34gm/hr

(The actual flow rate of LPG measured with the small burner was found to be high compared to an expected value of about 65gm/hr, at maximum position)

Following values were used in this study:

Calorific value of L.P.G(LHV)	45837kJ/kg	Price of Fuel Wood	Rs 2.5 /kg
Calorific value of kerosene(LHV)	43116kJ/kg	Price of LPG	Rs 320/14.2 kg cylinder
Calorific value of wood (LHV)	5000 kJ/kg	Price of Electricity	Rs 3.0/kwh
Calorific value of biogas (LHV)	20000 kJ/m3	Price of Kerosene	Rs 25/lr
Specific heat of stainless steel	0.12 kcal/kg°C	Thermal efficiency of Ordinary wood stove	10 %
Specific heat of Aluminium	0.214kcal/kg°C	Thermal efficiency of improved wood stove	25 %

3. WATER BOILING TEST

In this study the water boiling test method was used for thermal efficiency determination.

3.1. Equipment used

i. A stainless steel pot with lid having a capacity of 5 lit.
ii. Electronic weighing balance 0-6kg, with 0.5gm accuracy.
iii. Fuels like L.P.G, Kerosene
iv. Water
v. Thermometer 0-110^{o}C

3.2. procedure

- Weigh the initial quantity of fuel more than what is needed for the test.
- Weigh the pot.
- Fill the pot up to two third of capacity with room temperature water.
- Weigh pot and water at the start.
- Record the temperature of water.
- Start the fire at high power to bring the water in the main pot to boil.
- Note the time and temperature; and note the weight of pot with water
- Again weigh the quantity of fuel at the end

3.3. Equations used

The equivalent mass of fuel burned on energy basis was calculated in the following manner

a) For solid, liquid and gaseous fuels, when the heat absorbed by the vessel is not considered;

Efficiency, $\eta = \dfrac{\left(4.186 \times W_i \times cp_w \left(T_f - T_i\right)\right) + \left(2260 \times W_v\right)}{F_d \times LHV}$

where;
W_i = initial weight of water in kg
T_f = final temperature of water ,°C
T_i= initial temperature of water , °C
W_v = water vaporized in kg
F_d= fuel consumed in kg
LHV = lower heating value of fuel kJ/kg
cp_w= specific heat of water in kJ/kg °C

b) For solid, liquid and gaseous fuels ,when the heat absorbed by the vessel is considered,

Efficiency ,$\eta = \dfrac{\left(4.186 \times W_i \times cp_w \left(T_f - T_i\right)\right) + \left(4.186 \times W_p \times cp_v \left(T_f - T_i\right)\right) + \left(2260 \times W_v\right)}{F_d \times LHV}$

where;
W_p = weight of vessel in kg
cp_v= specific heat of vessel in kJ/kg °C

c) For electrically operated stoves, when the heat absorbed by the vessel is not considered;

$$\text{Efficiency},\eta = \frac{(4.186 \times W_i \times cp_w (T_f - T_i)) + (2260 \times W_v)}{P \times 3600}$$

where;

P= electrical energy consumed in kWh

d) For electrically operated stoves, when the heat absorbed by the vessel is considered;

$$\text{Efficiency},\eta = \frac{(4.186 \times W_i \times cp_w (T_f - T_i)) + (4.186 \times W_p \times cp_v (T_f - T_i)) + (2260 \times W_v)}{P \times 3600}$$

3.4. Stove power

3.4.1. For electric stoves;

Stove power P = (power consumed x 60)/Time taken

3.4.2. For solid, liquid or gas stoves ;

Stove power P = (Fuel consumed (kg) x LHV)/(60 x time taken)

The water boiling test was conducted using a weighed quantity of 4 kg of water at an average temperature of 32°C. The time taken , stove power , fuel consumed and the efficiencies of each stoves were then calculated. The test was conducted both for with vessel open and closed as well as the efficiency figures were calculated with and with out considering the sensible heat absorbed by the vessel. These results are tabulated in Table 3 and 4

4. COOKING OF RICE

The test was conducted for about 13 types of commonly used rice varieties in Kerala. In each test 500g of rice was weighed accurately and its dry volume was noted. The rice was cooked in a 5 liter stainless steel vessel used in thermal efficiency determination. First about 3.5 kg of water was taken in the vessel and heated to about 80oC using the large burner of the LPG stove in full mode. Washed rice, drained of water was then added and allowed the content to boil. After the start of boiling, flame was reduced to low power (Sim) position and the cooking continued. After full cooking the flame was cut off and the time for cooking and the quantity of LPG consumed were noted from the initial and final weight of the gas cylinder. The final weight and volume of cooked rice was also noted, after draining out the water completely. The taste of each variety of rice was then ascertained by serving the cooked rice to a group of people.

The comparative performance of cooking of rice using pressure cooker, National Panasonic rice cooker and Thermal cooker (Urja-2) were also done.

4.1. Pressure Cooker

Hawkins Pressure Cooker having a capacity of 5 liters was used to do the experiment.
500g of Co rice was cooked for 17.23 minutes in 2 liters of water The L P G used and time taken were noted.

Fig 14 Pressure cooker

4.2. National Panasonic rice cooker

It is an automatic electric rice cooker of capacity 4ltrs. It can cook up to 1kg of rice.

Specifications

Model	SR-W18
Voltage	230V, 50Hz
Power	560W
Cooking pan	Aluminium
Cooking plate	Aluminium

500g of Co rice was cooked in 3ltrs of water using this device. The electrical energy used and time taken were noted.

Fig 15 Electric rice cooker

4.3. Thermal Rice Cooker (Urja-2)

Urja-2 is a thermal cooker designed and manufactured by Energy Management Centre, Kerala. There is no specific size of vessel for cooking The material of the thermal cooker is Polystyrene and that of the bottom plate is Polypropylene.

The main advantages of this cooker are;
It saves

- Fuel
- Time
- money

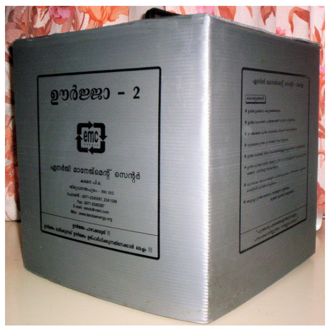


Fig 16 Thermal rice cocker Urja-2

500g of Co rice was cooked in 3.5 liters of water in a stainless steel vessel using LPG stove. After the start of boiling the vessel was removed from the stove and placed in the thermal cooker. After about 74.2 minutes the thermal cooker was removed and the cooked rice was weighed and its volume measured.

5. RESULTS AND DISCUSSIONS

5.1. Thermal Efficiency of Different Cook Stoves

From the water boiling test the thermal efficiencies of stoves were in the order of National Panasonic rice cooker (86.94 %), Augur Maginer induction cooker (83.77%), Johnson Delite electric coiled stove (65.65%) , for L.P.G stove (59.84%) and the Nutan kerosene wick stove (54.49%). The above efficiency figures are for vessel in closed position and with out considering the sensible heat absorbed by the vessel. The above calculation, based on accepted practices for computing the thermal efficiency were used in this study.

These were an apparent increase of about 3-6% in the calculated value of thermal efficiency with the vessel in open. This could be due to high rate of vaporisation of water from the vessel in open, and the heat content of vapour is considered as useful heat in thermal efficiency calculation. In the case of a closed vessel there will be condensation of water vapour below the lid surface, duel to external cooling effect and the quantity vapour evolved will be less.

At higher output level the Induction heater was having about 2% higher efficiency where as in the case of LPG stove the efficiency was marginally less with higher output power (large burner). The energy consumption for boiling is found to be more by 20-50% in the case of open boiling due to additional time requirement and higher evaporation rate. The fuel consumption is found to be varying inversely with the stove power.

Many induction cooker manufacturers /dealers claim that these devices have efficiencies of above 96%. This was proved wrong in this study. Its average efficiency is about 84%, which compares well with thermal efficiency value reported for these devices. The calculated thermal efficiency values for different cook stoves with vessel open and closed are shown table 3 and 4 and vapour loss in each cases are given in Table 5

Table – 3 Results of water boiling test with the vessel closed

Type of stove	Time taken (min)	Electricity or fuel used (kWh or gm)	Stove power (watt)	Efficiency % (with vessel)	#Efficiency% (without vessel)
Electric Rice Cooker	40	0.31	0.47	89.27	**86.94**
Induction Cooker(600-2000W)					
1400W	18.18	0.385	1.18	84.51	**82.86**
2000W	13.62	0.38	1.67	86.98	**84.67**
Electric Coiled Stove (1250W)	35.42	0.505	0.86	67.4	**65.65**
L P G Stove					
Small burner	19.15	42.5	1.7	62	**60.3**
Large burner	17.8	43	1.85	61.13	**59.38**
Kerosene Wick Stove	33.25	52.75	1.14	55.9	**54.49**

these values were used for estimation in this study

Table – 4 Results of water boiling test with vessel open

Sl No:	Type of stove	Time taken (min)	Electricity or fuel used (kwh or g)	Stove power(watt)	Efficiency % (With vessel)	Efficiency % (without vessel)
1	Induction Cooker (600-2000 w)					
1.1	1400w	24.28	0.55	1.36	88.93	87.66
1.2	2000w	16.67	0.46	1.66	89.72	88.3
2	Electric Coiled Stove 1250 w	53.93	0.79	0.88	70.35	69.52
3	L P G Stove					
3.1	Small burner	23.7	51.5	1.66	67.4	66.46
3.2	Large burner	21.42	52.5	1.87	63.26	62.01
4	Kerosene Wick Stove	42.6	67.75	1.14	65.15	64.25

Table – 5 The vapour loss during each test with vessel close and open position

SL No	Type of stove	Vessel closed(g)	Vessel opened(g)
1	Electric coiled stove	28	336.65
2	kerosene wick stove	48.25	328.75
3	Induction cooker		
3.1	1400 watt	15.5	207
3.2	2000 watt	18	137.5
4	L P G Stove		
4.1	Small burner	19.5	196
4.2	Large burner	19.75	168
5	Electric rice cooker	51.5	_-

5.2. Fuel and Energy Requirement for Cooking Rice

The fuel, cooking time requirement and other parameters for different varieties of rice cooked using an LPG stove is given in Table-6. The energy and time requirement was more for the parboiled rice varieties as compared to the raw rice and *basmati* rice. On an average par boiled rice requires 100 % more energy and 150 % more cooking time than for raw rice. Among the parboiled rice varieties *Jaya* rice consumed more energy and the *doppi* rice consumed the lowest. From the cooking fuel end use pattern of Kerala as provided by Census 2001 data, the annual quantities of different types of fuel consumed for cooking rice is shown in Table-7. These figures were computed based on the assumption that 79% of the households still depend on fire wood for cooking, as per the Census data of 2001. Out of the above value 9% of the house hold uses improved wood stove and the rest uses ordinary 3 stone stoves. The next major fuels used for cooking are LPG (17.7%) and kerosene (1.7%). About 0.8 % of the households use biogas for cooking and 0.3 % doesn't cook food at home. The use of electricity as cooking fuel is very insignificant (0.1% only).

Table 6. Parameters of Cooking Rice with LPG Stove

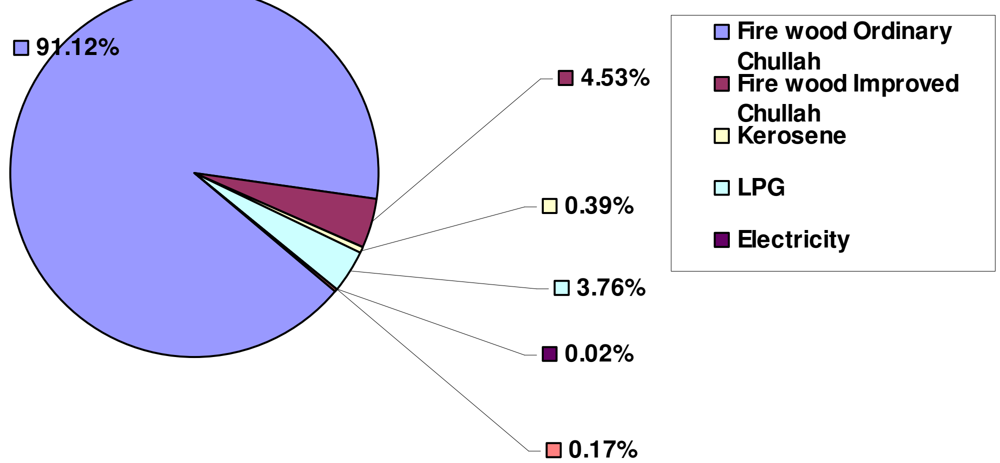
S I No:	Type of rice	Price/kg of rice Rs	Initial weight gms	Initial volume Litre	LPG consumed gms	Time (min)			Final weight kg	Final volume Litre
						Boiling started	For cooking	Total		
1	*Raw rice*	16	500	0.534	43	12.17	16.5	28.67	2.153	2.46
2	*Basmati*	35	500	0.601	56	15.42	18.65	34.07	2.314	2.684
3	*Doppi*	13.5	500	0.524	57.5	16	17.55	33.55	1.966	1.834
4	*Nadan chambavu*	13	500	0.595	67.5	17.02	34.3	51.32	1.717	2.338
5	*Nirapara vadi*	18.5	500	0.5285	70	18.1	55.85	73.95	1.937	2.573
6	*Ration rice*	10	5000	0.872	73	15.85	23.3	44.15	1.8725	2.44
7	*Pavizham unda*	14.5	500	0.5325	83	17.05	52.07	69.12	1.924	2.566
8	*CO rice*	12	500	0.572	86.5	16.22	51.67	67.89	2.628	2.7025
9	*Nirapara unda*	18.5	500	0.509	88.5	17	50.5	67.5	1.885	2.568
10	*Surekha*	15	500	0.546	90.5	16.2	61.77	77.97	2.117	2.9285
11	*Pavizham vadi*	17.5	500	0.62	99	16.27	53	69.27	1.96	2.6375
12	*Ruchi rose*	14	500	0.55	117.5	16.42	90.85	107.3	2.1075	2.791
13	*Jaya*	15	500	0.526	121.6	15.5	101.5	115	2.176	2.6145

Table 7 Fuel and Energy Use Pattern for Rice cooking in Kerala						
Type of Fuel	Qty of rice Cooked MT /yr	Quantity of Fuel Per yr	Fuel Cost/Yr Rs Crores*	Thermal Energy Tj/yr	Mtoe	Thermal Energy %
Fire wood Ordinary Stove	2298062	7424570 MT	1856.2	111369	2651631	91.12
Fire wood Improved Stove	292877	368907 MT	92.2	5534	131762	4.53
Firewood Total	2590939	7793477 MT	1948.4	116903	2783393	95.65
Kerosene	55543	13553 KL	33.9	482	11479	0.39
LPG	578305	100371 MT	226.2	4601	109540	3.76
Electricity	3267	6534525 kwh	2.0	24	560	0.02
Biogas	26138	10455240 m3	--	209	4979	0.17
Total	3254194	--	2210.4	122218	2909950	100.00

* 1 Crore = 10 million

The total consumption of rice in Kerala is 40.68 lakh metric tonnes per year. Assuming that 70% of the rice is consumed as cooked rice , the total thermal energy requirement for parboiled rice cooking in Kerala will be around 1.2×10^5 Tj/Year, which will be equivalent to about 7.9×10^6 metric tonne fuel wood per year or 2.9×10^6 metric tonne of oil equivalent , and 96 % of this energy comes from wood. Though the wood fuel dependency, including other biomass residues for cooking is only 79 % in Kerala , higher percentage of thermal energy use from wood is because of its inefficient utilization. By adopting improved wood stoves, anticipated saving in firewood in the case rice cooking alone will be 4.45×10^6 metric tonne per year . which will reduce the CO_2 emission by 6.11×10^6 metric tonne of CO_2 per year. The thermal energy end use percentage for rice cooking is shown in fig.17

Fig-17 Thermal energy Use pattern For Rice cooking in Kerala (Total 1.2×10^6 Tj/yr)



There could be some differences in the estimated figures of energy use in rice cooking, largely due the selected batch size (500 gms) for cooking and the energy requirement per kg is calculated by from this figure. This may lead to some error as the fuel consumption may not be linear with the quantity of rice cooked and depends on the batch size as well. How ever considering the fact that most of the house holds in Kerala cook rice twice a day ,and the batch size of an average household per day will be about 500g, the estimated energy figures will be realistic to some extend.

5.3. Cost Aspects of Rice Cooking

The comparative energy cost of cooking a kg of rice with different cook stoves are given in Table -8. The cost is the lowest in the case of improved wood stove and the highest in the case of ordinary wood stove, assuming a purchase cost of Rs 2.5/kg for the fuel wood. The cost of cooking in the increasing order was found to be

Improved wood stove → Electric Rice Cooker → LPG Stove → Induction Cooker → Electric Hot Plate → Kerosene wick stove (Nutan) → Ordinary wood stove .

The cost of fuel and electricity considered in the calculation were LPG Rs 22.54 Rs/kg , Kerosene Rs25/lr(open Market), Electricity Rs 3.00/kwh and fuel wood @ Rs 2.5/kg. This confirms that poor sections of the households using ordinary wood stoves for cooking pays more cost for cooking fuel.

Table-9 Comparative Cost of Cooking with different cook stoves and electric cookers and other cooking aids

Sl No	Type Cook Stove	Cost in Rs./kg of rice cooked
1	Improved wood stove	3.15
2	Electric rice cooker	3.37
3	LPG stove	3.91
4	Induction Heater	4.75
5	Electric Hot plate	5.99
6	Kerosene Wick Stove(Nutan)	6.10
7	Ordinary wood stove	7.87
8	Pressure cooker with LPG	1.85
9	Thermal cooker with LPG	1.83

The cost of cooking raw rice is found to be just half the cost of parboiled rice. As per this a family of 4 will be consuming about 358 Kg of parboiled rice per year using an LPG stove will save about Rs 700 per year, if switch over to raw rice. The saving will be more for those uses ordinary wood stove and entirely depending on purchased wood. Fig 18-23 shows the percentage energy cost out of the total cost (Price of rice/kg + Fuel cost/kg) when different cook stoves are used. The percentage energy cost is the highest for the *Ruchi Rose* and *Jaya* and lowest for *Basmati* and Raw rice. Comparative Cost of Cooking with different cook stoves and electric cookers and other cooking aids are given in table-9 and fig 24.

Table-8 Fuel Consumption and Cost of Cooking Rice with Different cook Stoves

Sl. No.	Type of rice	L P G Stove[1]		Kerosene wick Stove[2]			Electric Rice cooker[2]		Electric Coiled Stove[2]		Induction Cooker[2]		Three stone stove[3]		Improved chula[3]	
		L P G g/kg rice	Cost Rs/kg rice	Kerosene g/kg rice	Kerosene ml/kg rice	Cost Rs/kg rice	Electricity kwh/kg rice	Cost Rs/kg rice	Electricity kwh/kg rice	Cost Rs/kg rice	Electricity kwh/kg rice	Cost Rs/kg rice	Wood g/kg rice	Cost Rs/kg rice	Wood g/kg rice	Cost Rs/kg rice
1	*Raw rice*	86	1.92	99.63	120.76	3	0.56	1.67	0.99	2.97	0.78	2.34	1560	3.90	624	1.56
2	*Basmathi*	112	2.52	129.75	157.3	4	0.73	2.18	1.29	3.87	1.02	3.06	2032	5.08	812	2.03
3	*Doppi*	115	2.6	133.23	161.5	4	0.74	2.23	1.32	3.96	1.05	3.15	2086	5.22	834	2.09
4	*Nadan chambavu*	135	3.04	156.4	189.6	4.74	0.87	2.62	1.55	4.65	1.23	3.7	2449	6.12	979	2.45
5	*Nirapara vadi*	140	3.15	162.2	196.6	5	0.91	2.72	1.61	4.83	1.28	3.84	2540	6.35	1016	2.54
6	*Ration rice*	146	3.3	169.14	205	5.12	0.95	2.84	1.68	5.04	1.33	4	2649	6.62	1059	2.65
7	*Pavizham unda*	166	3.74	192.31	233.1	5.8	1.07	3.22	1.91	5.73	1.51	4.53	3012	7.53	1204	3.01
8	*Co rice*	173	3.9	200.42	243	6.1	1.12	3.36	1.99	5.97	1.58	4.74	3139	7.85	1255	3.14
9	*Nirapara unda*	177	4	205.06	248.55	6.2	1.15	3.44	2.03	6.1	1.61	4.83	3211	8.03	1284	3.21
10	*Surekha*	181	4.08	209.69	254.17	6.35	1.17	3.52	2.08	6.24	1.65	4.95	3284	8.21	1313	3.28
11	*Pavizham vadi*	198	4.46	229.38	278	7	1.28	3.85	2.28	6.84	1.8	5.4	3592	8.98	1437	3.59
12	*Ruchi rose*	235	5.3	272.25	333	8.25	1.52	4.56	2.7	8.1	2.14	6.45	4264	10.66	1705	4.26
13	*Jaya*	243.2	5.48	281.75	341.5	8.53	1.57	4.72	2.8	8.4	2.22	6.66	4413	11.03	1765	4.41
	Average [#]	173.56	3.91	201.08	244.00	6.10	1.12	3.37	2.00	5.99	1.58	4.75	3149.00	7.87	1259.18	3.15

[1]—Experimental values

[2]—Calculated values considering the thermal efficiency of respective cook stoves obtained in water boiling test with lid closed and not considering the heat absorbed by the vessel

[3]—Calculated values assuming thermal efficiency of three stone stove and improved stove as 10% and 25% respectively.

Thermal efficiency of induction cooker = 82.86% Thermal efficiency of electric coiled stove = 65.65% Thermal efficiency of L P G stove = 59.38% Thermal efficiency of Kerosene stove = 54.49%

Cost of electricity per unit is taken as Rs.3/- Cost of one cylinder of L P G(14.2kg)is Rs.320/- Cost of one litre of Kerosene is Rs.25/-(open market) Cost of one kilogram of fire wood is Rs 2.50/-

[#] the average value for parboiled rice varieties only, excluding raw rice and basmati rice

Fig- 18 LPG Stove - Energy Cost(%)

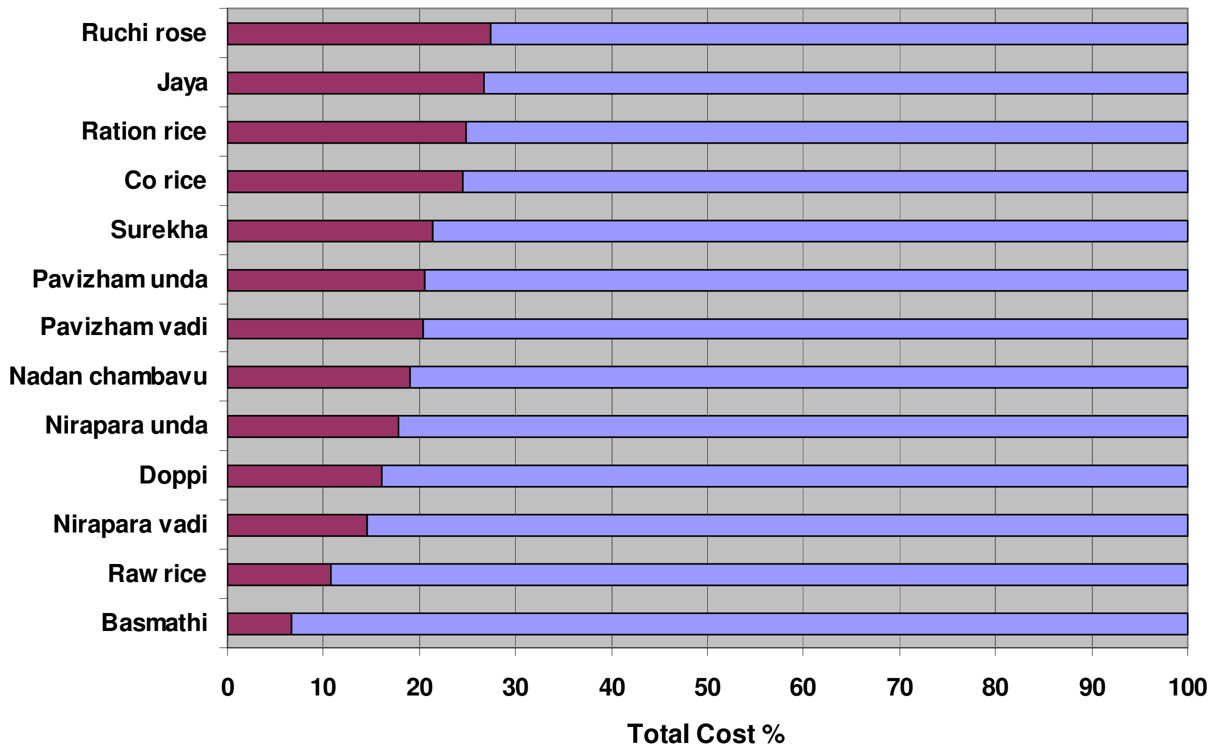


Fig 19 Kerosene Wick Stove - Energy Cost(%)

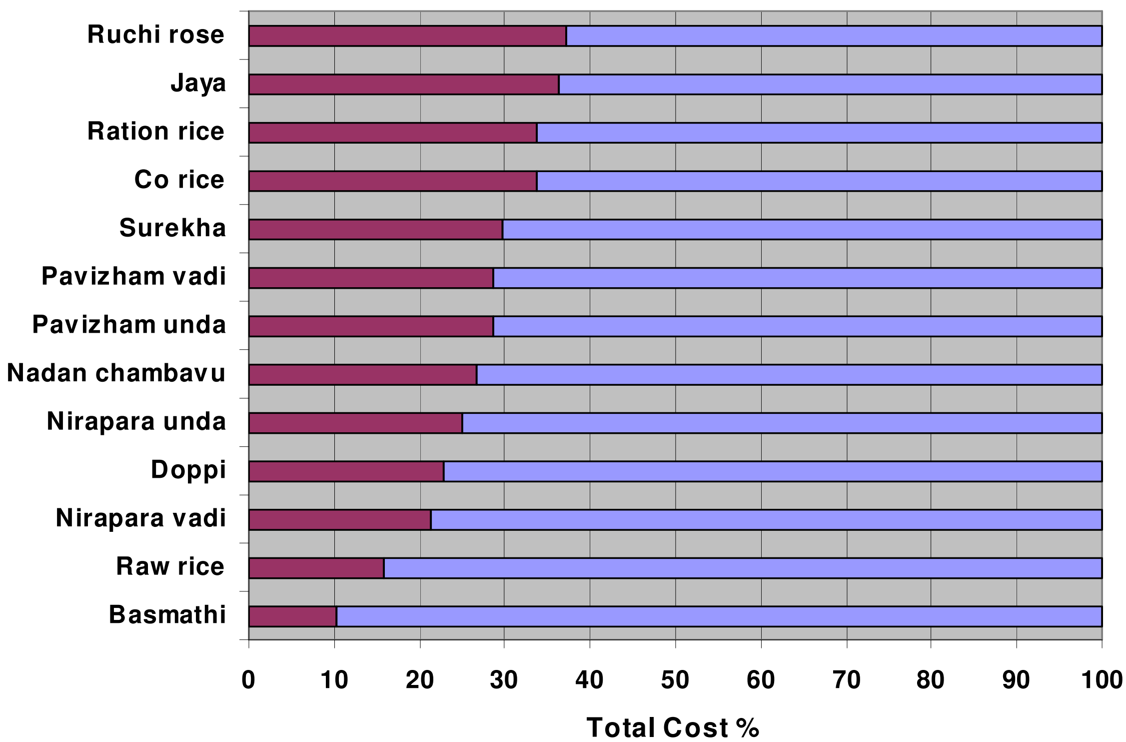


Fig 20 Electric Coiled Stove- Energy Cost(%)

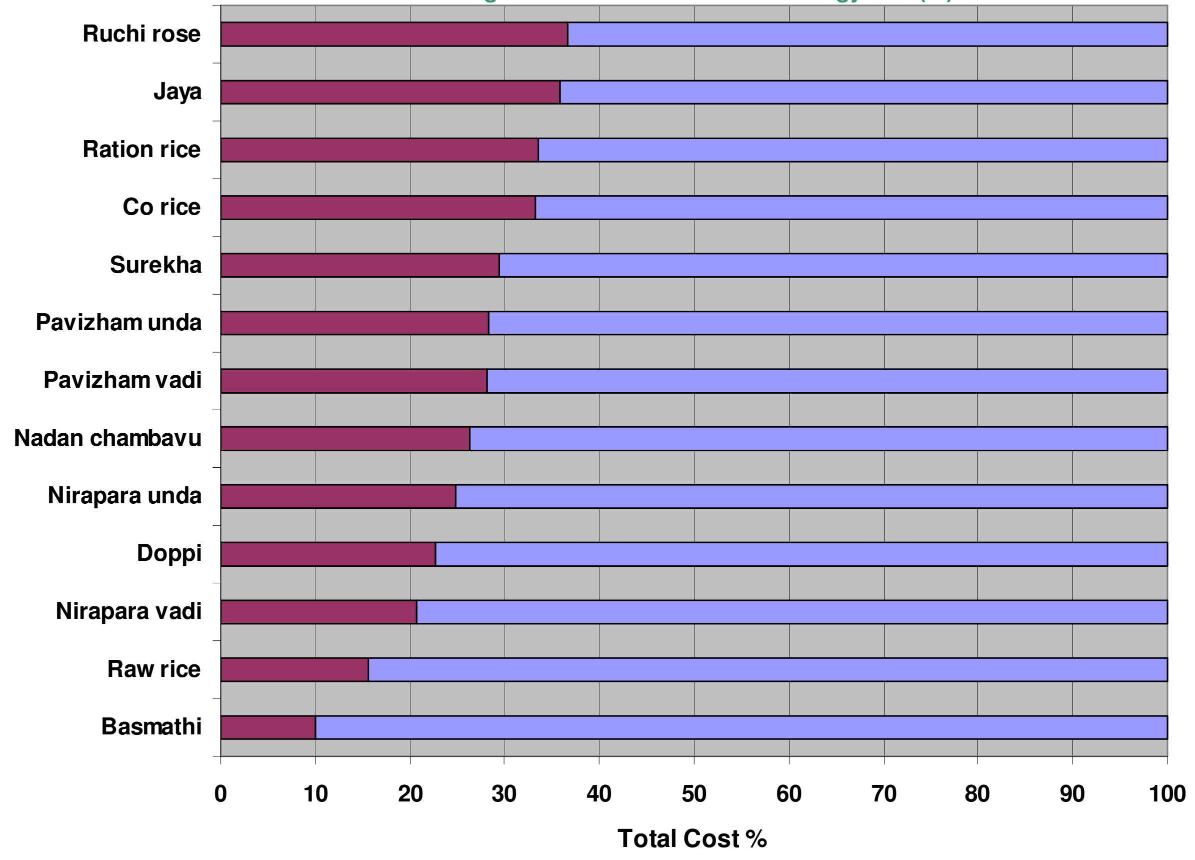
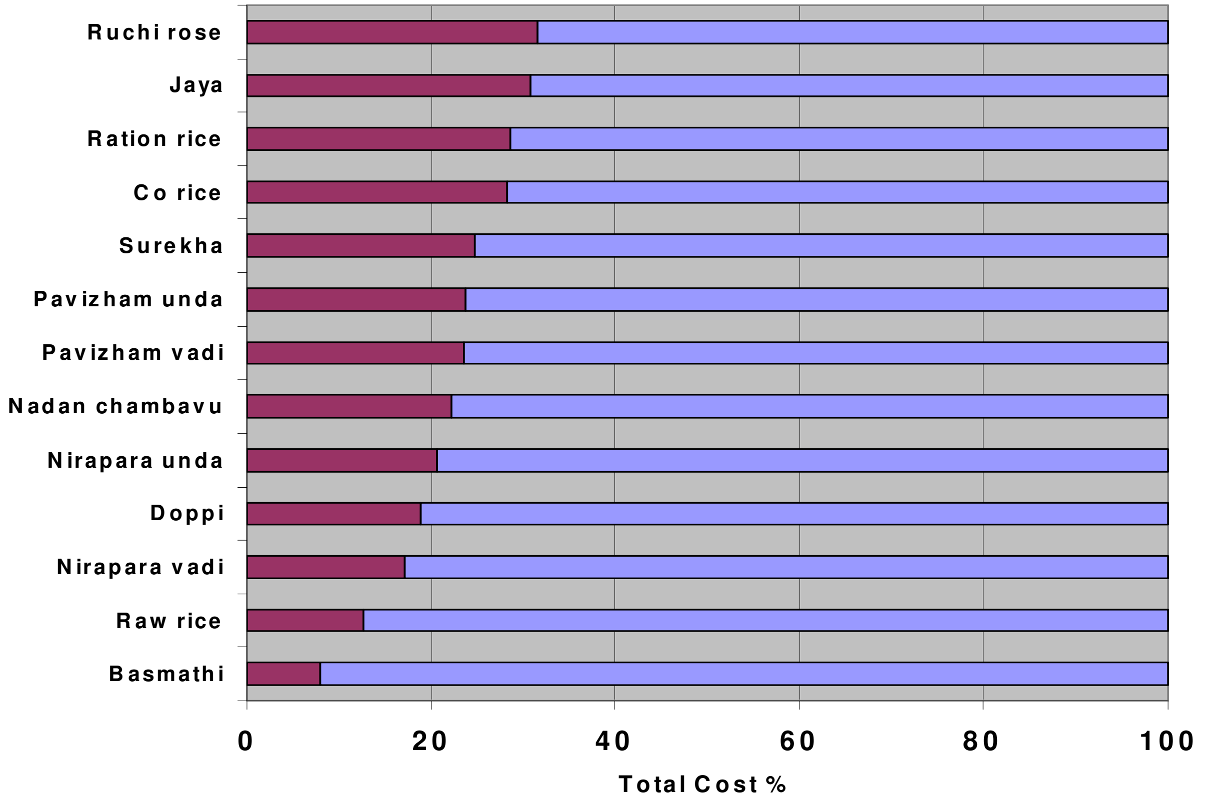


Fig 21 Induction Cooker- Energy Cost(%)



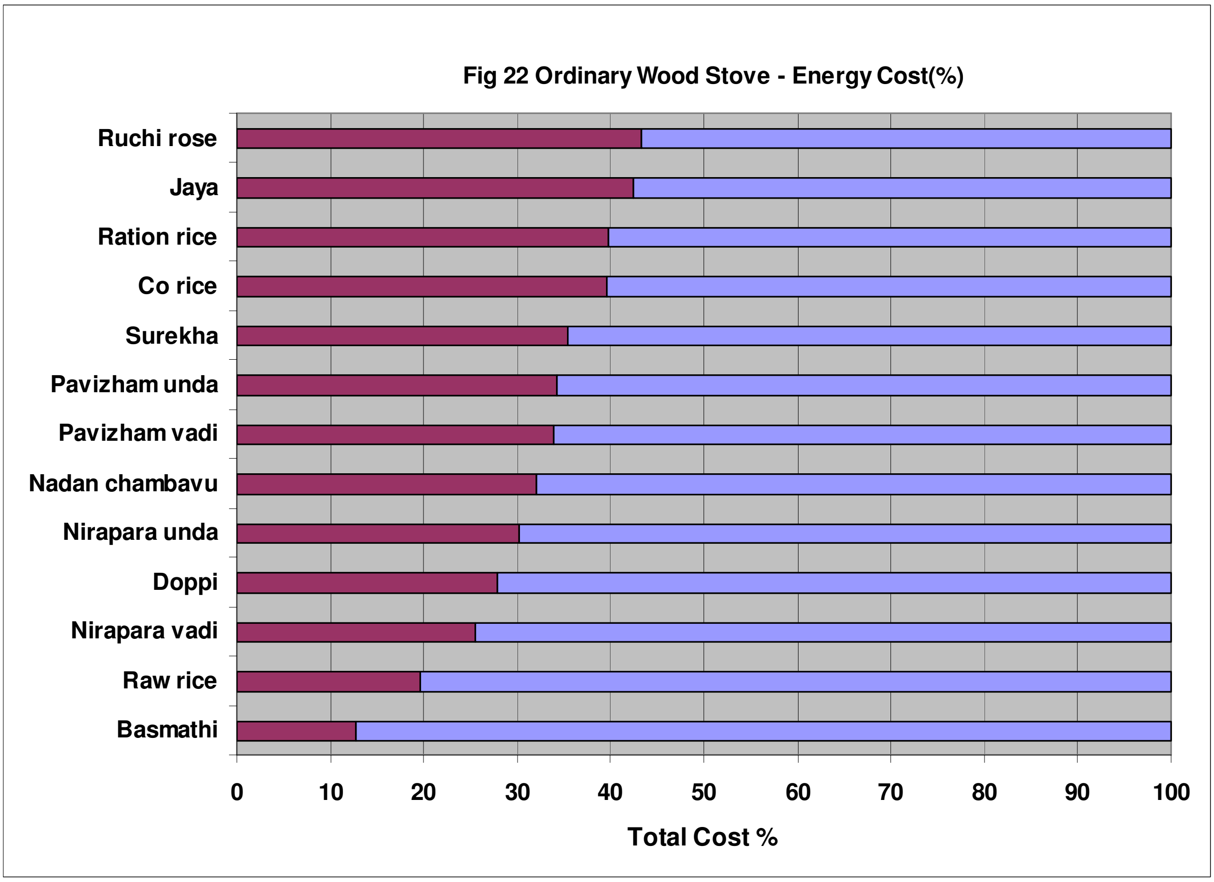


Fig 22 Ordinary Wood Stove - Energy Cost(%)
Ruchi rose
Jaya
Ration rice
Co rice
Surekha
Pavizham unda
Pavizham vadi
Nadan chambavu
Nirapara unda
Doppi
Nirapara vadi
Raw rice
Basmathi
0
10
20
30
40
50
60
70
80
90
100
Total Cost %

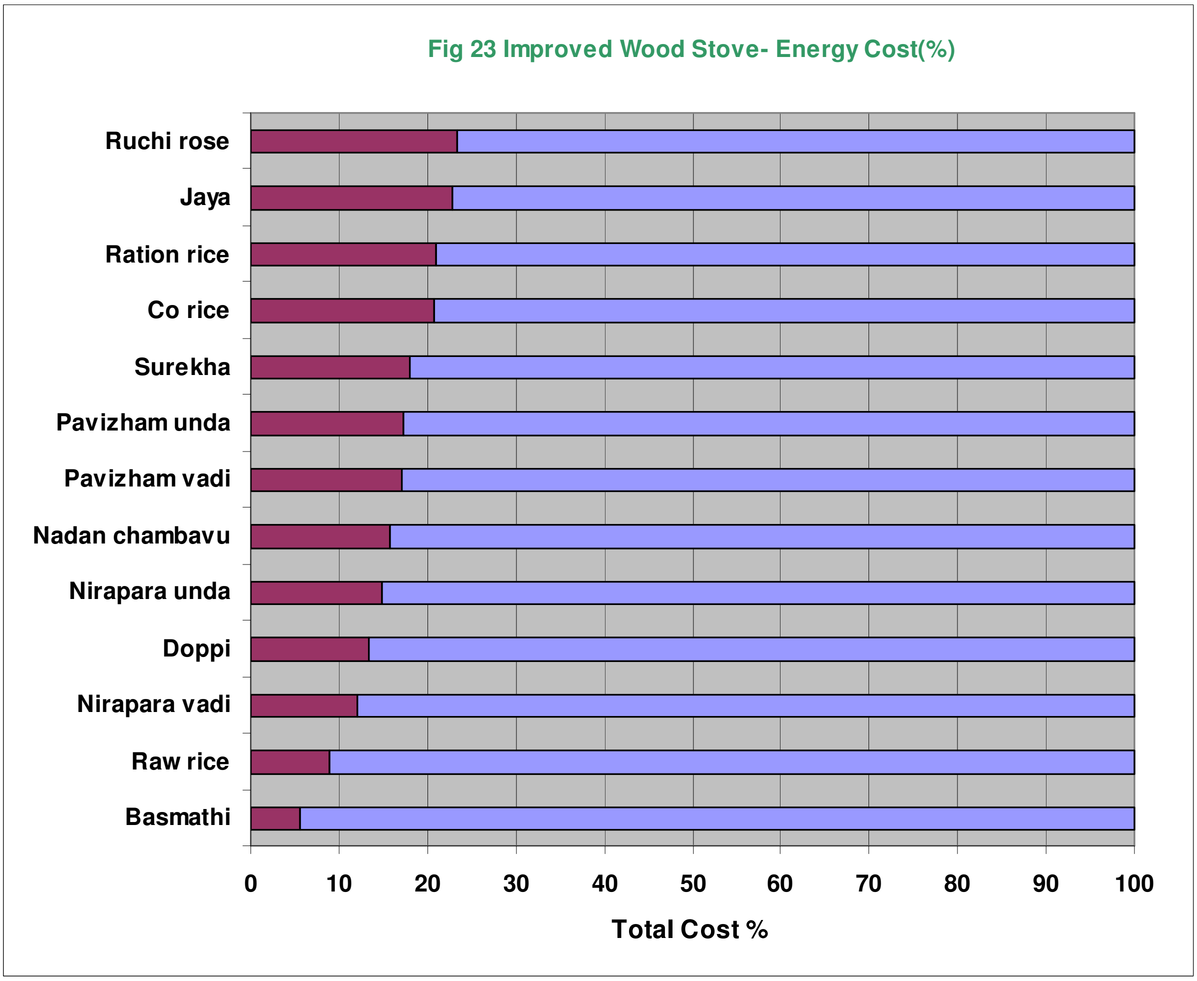
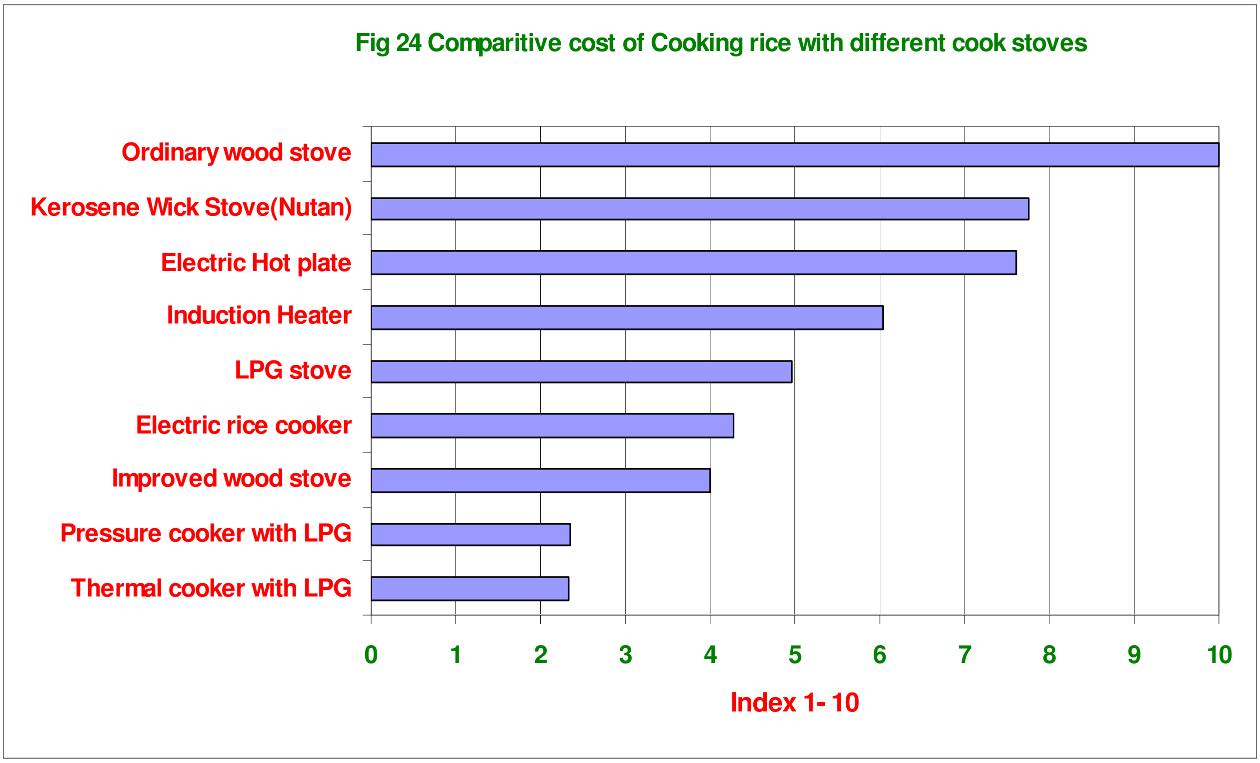


Fig 23 Improved Wood Stove- Energy Cost(%)
Ruchi rose
Jaya
Ration rice
Co rice
Surekha
Pavizham unda
Pavizham vadi
Nadan chambavu
Nirapara unda
Doppi
Nirapara vadi
Raw rice
Basmathi
0
10
20
30
40
50
60
70
80
90
100
Total Cost %



5.4. Quality aspects of cooked Rice.

The quality of cooked rice can be evaluated by some of the important qualities of cooked rice such as the taste , volume yield, nutritional values, volume increase, water uptake or weight gain, gruel loss, cooking time , quantity of fuel required ,cost of rice ,stickiness etc. It will be very difficult compare the best rice variety as most of the above parameters are qualitative. How ever for comparison purpose an overall index is developed considering quantitative factors like fuel consumption , weight gain , volume expansion and the price of rice. For this the final volume and weight yield of cooked rice is calculated in a scale of 1-10 and similarly the index was also calculated for fuel used and the price of rice . The over all index for different rice varieties were calculated and given in Table -10

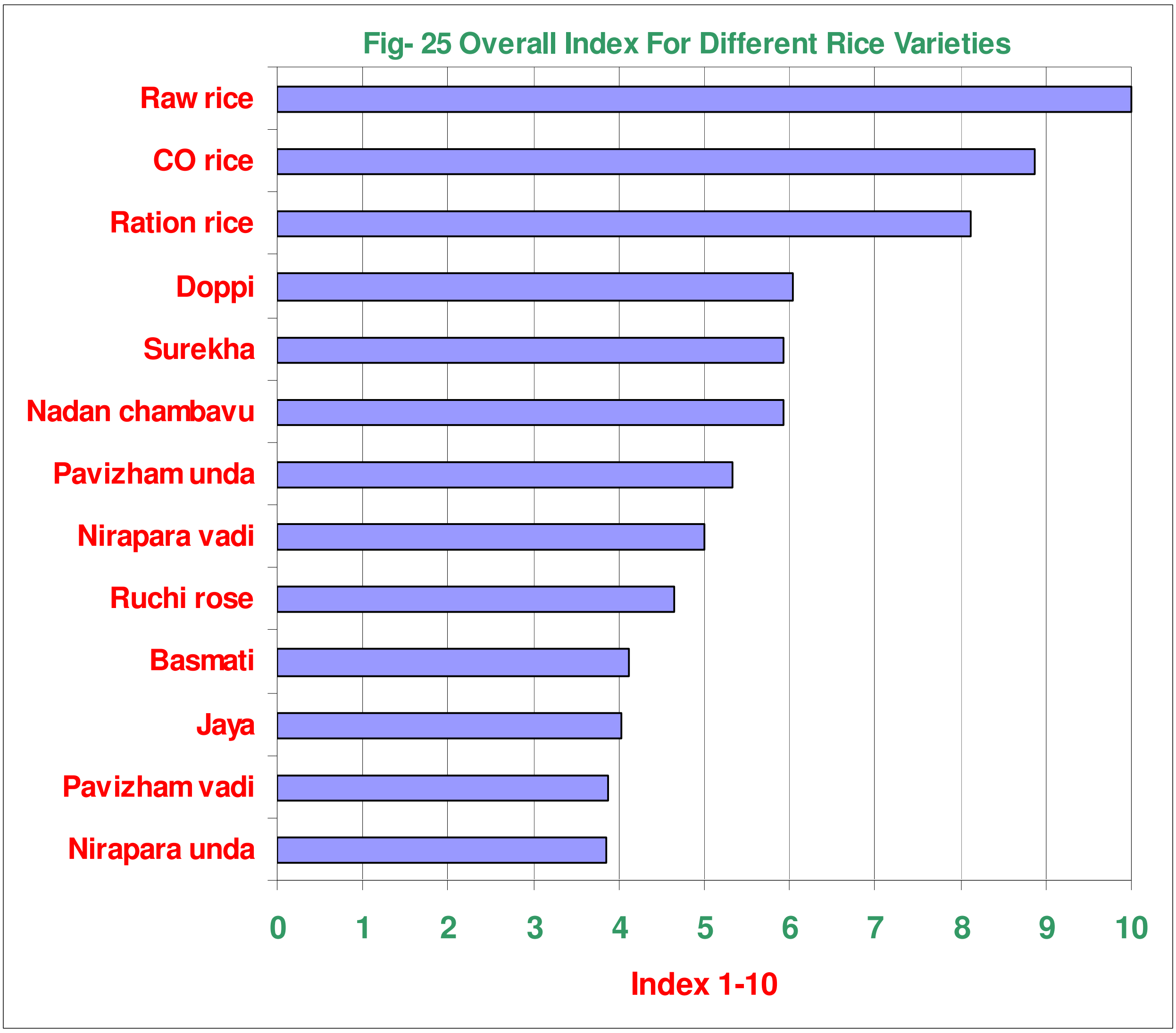
Overall Index = (Weight index x Volume index)/(Price Index x Fuel Index)

The overall index for different varities of rice is shown in Fig 25 in a scale of 1-10.
As per the calculated result the Index is maximum for raw rice and minimum for the *Nirapara Unda*. Among the parboiled varities, the *CO* rice has the highest index value followed by ration Rice , *doppi, Surekha* and *Nadan Chambavu*.

From the various types of rice cooked it was found that *Surekha* and nirapara unda were having high volume yield of more than five times. But leaving the *Basmati* rice, *Jaya* and *surekha* varity was found to be very tasty. With the *jaya* varity consuming the maximum energy for cooking, *CO* , d*oppi* and *Surekha* can be considered as the best ones, taking all the other factors into account.

Table-10 Overall Index for different rice varieties

Sl No	Type of Rice	Price Index	Energy Index	Weight Index	Volume index	Overall Index
1	*Raw rice*	4.57	3.54	8.2	8.40	4.26
2	*Basmati*	10.00	4.61	8.8	9.17	1.75
3	*Doppi*	3.86	4.73	7.5	6.26	2.57
4	*Nadan chambavu*	3.71	5.55	6.5	7.98	2.53
5	*Nirapara vadi*	5.29	5.76	7.4	8.79	2.13
6	*Ration rice*	2.86	6.00	7.1	8.33	3.46
7	*Pavizham unda*	4.14	6.83	7.3	8.76	2.27
8	*CO rice*	3.43	7.11	10.0	9.23	3.78
9	*Nirapara unda*	5.29	7.28	7.2	8.77	1.64
10	*Surekha*	4.29	7.44	8.1	10.00	2.53
11	*Pavizham vadi*	5.00	8.14	7.5	9.01	1.65
12	*Ruchi rose*	4.00	9.66	8.0	9.53	1.98
13	*Jaya*	4.29	10.00	8.3	8.93	1.72
	Average	4.67	7.14	7.83	7.07	2.48



The Table 11 shows the weight and volume ratio of different types of rice. Also the taste range of each brands;

The volume and weight ratio of rice varieties were calculated as follows:
Volume ratio % = (final volumex100)/ Initial volume
Weight ratio % = (final weight x100)/ Initial weight

Table-11 weight and volume ratio of different types of rice in relation to quantity of fuel for cooking

Sl No	Type of rice	Weight ratio %	Volume ratio %	Fuel LPG gm/kg of rice	remarks
1	*Raw rice*	431	461	86	tasty
2	*Basmati*	463	447	112	Very tasty
3	*Doppi*	393	350	115	tasty
4	*Nadan chambavu*	343	393	135	tasty
5	*Nirapara vadi*	387	487	140	tasty
6	*Ration rice*	375	280	146	satisfactory
7	*Pavizham unda*	385	482	166	tasty
8	*CO rice*	526	472	173	tasty
9	*Nirapara unda*	377	505	177	tasty
10	*Surekha*	423	536	181	Very tasty
11	*Pavizham vadi*	392	425	198	tasty
12	*Ruchi rose*	422	507	235	tasty
13	*Jaya*	435	497	243.2	Very tasty
	Average	405.27	448.61	162.09	

5.5. Cooking with Full Power

For saving fuel , it will be better to do cooking at maximum power up to the boiling and thereafter power can be reduced to minimum for maintaining the cooking temperature. To find the fuel wastage and to see any apparent saving in cooking time by opting for cooking with maximum power, a test was also conducted using *Surekha* rice. The results are tabulated in Table 12.

From the study, there wasn't any appreciable reduction in cooking time but the fuel consumption was higher by 100 % in the case of cooking with full power throughout.

Table 12- Effect of cooking with full power

Type of rice		*Surekha*
Qty of rice gms		500
Cooking with reduced flame after boiling	Fuel LPG gms	90.5
	Total Cooking Time min	77.97
Cooking with full power	Fuel LPG gms	188.5
	Total Cooking Time min	77.8

5.6. Induction Cooking Vs LPG Cooking

From the study the average cost of cooking for different types parboiled rice with induction heater was at Rs 4.75 per Kg of rice, as against Rs 3.91 in the case of LPG stove. This was calculated at electricity and LPG cost of Rs 3.00/kwh and Rs320 per 14.2 Kg LPG cylinder respectively. At this cost structure, Induction heating will be economical only if electricity is available at less than Rs2.47/kwh. By depending on Induction cooker for cooking, the monthly electricity consumption will go up. As one cylinder of LPG containing 14.2 Kg is equivalent to 140 kwh of electricity, the total consumption of electricity reaches to expensive slabs. So the claim that these devices are more economical than LPG doesn't hold good, apart from many other reasons, those doesn't favour for electricity use for cooking.

5.7. Cooking With Vessel Open

Cooking the food with vessel closed saves time as well as fuel compared to open vessel. From the water boiling test, the energy consumption increases by 20-40% for vessel with open lids at low power levels but the increase was lower as the stove power increased.

5.8. Normal Cooking Vs Pressure cooking and Thermal Cooking

The table-13 shows comparison of rice cooking using normal cooking, pressure cooking and by the use of a thermal cooker. It takes an average 53% less time to cook in a pressure cooker when compared to conventional cooking. Energy requirement also came down proportionately by 53% in this case. Though there are huge saving both by fuel and time , most of the households in Kerala do not prefer this method due to reasons ranging from poor taste to chances of overcooking, requirement of rice gruel for consumption and other purposes etc.

Use of thermal cooker is quite simple and economical and save fuel almost similar to pressure cooking. But the overall cooking time is more by about 10-15 minutes in the case of a Thermal cooker. Chances of overcooking are also rare in this case. However in case of rice varieties like *jaya* which takes much more time to cook, may require one more round of boiling for complete cooking. Use of thermal cooker are on rise Kerala especially due to fuel saving with no detrimental effect on taste.

There is a potential to reduce the fire wood usage further by $1.76x10^6$ metric tonne per year if every house hold in Kerala using wood stove (ordinary & improved) for cooking rice also uses a thermal cooker or a pressure cooker for further reduction in fuel usage. This saving is additional to the fuel wood saving of $4.45x10^6$ metric tonne per year calculated earlier, by replacing the ordinary wood stove with improved wood stove. This brings the total fire wood saving possible to $6.21\ x10^6$ metric tonne per year , which will reduce the present fuel wood use by about 80%. The total reduction in CO_2 emission from wood fuel for rice cooking will be $8.54x10^6$ metric tonne CO_2 per year. Apart from this , use of thermal cookers or pressure cookers along with LPG and kerosene stoves will reduce 53196 metric tonne of LPG and 7183 kilo litres of Kerosene per year , valued at 138 crores of rupees . The reduction in carbon dioxide from each of these will be $1.6\ x10^5$ metric tonne CO_2 per year and $1.87x10^4$ metric tonne CO_2 per year respectively.

Table-13 comparative advantages of thermal cookers and pressure cookers		
Method of cooking	**Total Time taken min**	**LPG used Gms/500 gms rice**
Normal cooking	67.89	86.50
Pressure Cooking	17.23	41.00
Thermal cooker	80.20	40.50

6. CONCLUSION

As rice is the major staple food in Kerala, a lot of energy is utilized for making it edible. The average annual requirement of rice is about 40.68 lakh tonnes. In this about 70% is used as cooked rice. The amount fuel used for rice cooking alone is equivalent to about 2.9 x10^6 metric tonne of oil equivalent. A vast majority of this energy requirement is being met through fuel wood. So improving the energy efficiency of cooking is very important for conserving our precious forest cover and for sustainable energy use.

Apart from the conventional thinking of improving the energy efficiency in cooking, it is evident from this study that there is a possibility to reduce energy requirement for cooking rice by half ,if we switch over to raw rice from parboiled rice. The savings will be more if we consider the energy requirement for parboiling as well. But this may not be a right approach as people in Kerala has been traditionally using parboiled rice varieties for various reasons ranging from historical and cultural to issues related to nutritional values of parboiled rice.

Among the parboiled rice varieties, the energy requirement varies substantially. For eg. *Jaya* rice which consumes almost 35 % more energy as compared to *Surekha* - which is having a comparable taste.

The poor thermal efficiency of cooking stoves - like majority of Kerallites still using ordinary wood stoves - is a big concern. There must be accelerated efforts for the propagation of improved chullahs as this could save close to 4.5x10^6 metric tonne of firewood per year in Kerala.

It is very important to propagate thermal cookers and pressure cookers among the households in Kerala as the energy requirement can be reduced by half.

Another area for reducing fuel requirement is by popularizing rice cooking without using much water, like steaming etc;, which will maintain higher nutritional values in cooked rice. This is especially important as most of the Keralites now doesn't use rice gruel for drinking purpose these days .

There is scope to optimize the parboiling process for further reduction in cooking fuel usage.

Apart from other considerations for developing new rice varieties, energy for cooking also shall be considered as an important component. We must be developing new rice varieties having lower energy need for cooking, and shall be integrated well with future rice research programmes. For this more dialogues and discussion are essential between agricultural researchers, energy specialists and farmers.

There is potential to reduce the fire wood usage for rice cooking by 80 % and the quantitative saving possible will be 6.21 $x10^6$ metric tonne fire wood per year. This will be possible if every body opts for improved chullah for rice cooking, as well as by adopting an energy efficient cooking aid, either a pressure cooker or a thermal cooker. Proportionately, the CO_2 emission can be brought down by 8.54 $x10^6$ metric tonne of CO_2 per year.

Use of thermal cookers or pressure cookers along with LPG and kerosene stoves, can cut the respective fuel usage by 53196 metric tonne and 7183 kilo litres per year , valued at 138 crores of rupees per year. The total reduction in carbon dioxide from these will be 1.79 $x10^5$ metric tonne CO_2/year. This will bring the gross reduction in CO_2 by $8.72x10^6$ metric tonne CO_2 per year in Kerala , in the case of rice cooking.

For assessing actual quantum of energy used in Kerala for cooking rice , the consumption pattern of parboiled rice varieties need to be known, as the energy requirement for cooking different varieties vary substantially. Also the stove use pattern and other cooking practices for rice cooking also need to be further ascertained through sample surveys. The estimates done in this study largely depended on the cooking fuel use pattern in Kerala, taken from the Census 2001 data. Future policies and programmes for promoting energy efficiency in rice cooking shall be founded on a refinement of this study, based on further inputs from such surveys.

Acknowledgement

We are greatful to Shri. K.M. Dharesan Unnithan , Director , Energy Management Centre-Kerala (EMC) for all the supports for the sucessful completion of this study
our sincere gratitude to Shri. A. Rajagopalan Achari of EMC, Shri. Sunny K. Unni , Asst. Prof; Dept. of Plant Breeding, Dr. Elizabeth Syriac, Dr. Sukumari; Dept. of Agronomy, Dr.Bhaskaran; Dept. of Agricultural Statistics (College of Agriculture, Vellayani, Thiruvananthapuram), Smt. A.N Shyni; Asst Engineer.,Directorate of Agriculture Vikas Bhavan, Thiruvananthapuram also to our training co-ordinator Dr. Sathyajith Mathew.

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