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Comparative Studies of Ethanol and Kerosene Fuels and Cook Stoves Performance

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Abstract
Comparative studies of ethanol and kerosene fuels and their performance with household kerosene cookstoves of the same dimensions and geometry were carried out. The authors examined the different sources of domestic cooking fuels such as LPG, kerosene, fuel wood, and ethanol. The overview of the use of bioethanol and kerosene cookstoves in different countries such as Brazil, India, Ethiopia, Kenya and Malawi were also done by the researchers. Simple water boiling test was carried out to determine the boiling time for a specified volume of water. The result showed that kerosene fuel boils water in a shorter time. The study compared the advantages and disadvantages of the two brands of fuels.
Keywords: cook stove, deforestation ethanol fuel, kerosene and performance.

1. Introduction
Ethanol is a clear, colourless, flammable oxygenated hydrocarbon chemically produced from ethylene and biologically from anaerobic fermentation of various sugars. It is used in some countries as a gasoline octane enhancer and oxygenate (blended up to 10 percent concentration). Ethanol can also be used in high concentrations (E85) in vehicles designed for its use (McCracken, 2005).

Kerosene, also an organic compound, is a clear, oily, highly flammable liquid with a strong odour, distilled from petroleum (10 – 25% of total volume). It is a mixture of about 10 different types of fairly simple hydrocarbons, depending on its source. It is less volatile than gasoline, boiling at 140 – 320 °C. It is burned in lamps, heaters, and furnaces and is used as a fuel or fuel component for diesel and tractor engines, jet engines, and rockets and as a solvent for greases and insecticides (Britannica, 2001).

In India, the government subsidized kerosene to keep the price very low (around 15 cents/litre as of Feb. 2007) so as to discourage dismantling of forests for cooking fuel (Bradsher, 2008). Deforestation has been a strong reason behind the global drive for kerosene use. FAO estimates that atleast 90 percent of Africans depend on firewood and other biomass for their energy needs. In Africa, for every twenty eight trees cut down, only one is replanted (Hennig, 2009).

Forests play an important economic role in many African countries. The products provide 6 per cent of GDP in Africa at large, the highest in the world. The consumption of forest products nearly doubled during 1970-1994. The production and consumption of firewood and charcoal rose from 250 to 502 million m^3 during the same period (Hennig, 2009). Projections by FAO estimate that consumption will continue to rise. In India, nearly 90% of the populations depend on some form or the other of biomass fuels to fulfill its energy requirements (D'Sa and Murthy, 2004). Smoke resulting from combustion of wood fuels contains complex pollutants. These are especially harmful when burnt in poorly-designed stoves in unventilated rooms. According to World Health Organization (WHO) estimates, over 1.6 million deaths worldwide are attributable to indoor air pollution resulting from the use of biomass fuel (ITDG, 2004).

These issues enhanced the search for a substitute to wood as a source of energy for cooking. In search of a suitable option, the World Bank started work on kerosene stoves. The pressure stoves were found to be slightly more powerful and more expensive and had greater accident risks (Young, 1993). Due to this and other shortcomings of the kerosene stove such as high GHG-emissions, health hazard, fire risk, non-renewable energy source, etc, it was necessary to find an alternative.

High viscosity, tendency of gumming and formation of soot are the reasons why biodiesel has not been extensively explored as a cooking fuel option. The absences of these drawbacks in ethanol make it a more attractive possibility (Rajvanshi, 2007). The stove which runs on ethanol has lower soot and GHG emissions and is powered by renewable source of energy. Ethanol, also known as ethyl alcohol or grain alcohol, a clear, colourless liquid has been made since ancient times by the fermentation of sugars. All beverage ethanol and more than half of industrial ethanol is still made by this process (Strang, 2009).

2. Ethanol Fuel
Ethanol has been used as a fuel for nearly two centuries, and was one of the first used in the United States to power automobiles at the dawn of the 20th century. But due in part to a $2 a gallon ethanol tax levied by Congress in the late 19th century and Prohibition in the 1920s, gasoline became the motor fuel of choice (Schoen,

2009). Its use re-surfaced as a replacement for petroleum based liquid fuel in the 1970s' when oil supplies became scarce.

Shortly after, its use declined again until world energy demand and environmental concerns heightened, prompting countries like Brazil and the United States to engage in its massive production and consumption. Today, it is considered as the fuel of the future widely regarded as a form of substitute to all forms of fossil fuels.

As the search to find a reliable substitute for wood fuel, charcoal and kerosene cookstoves, several government programs and initiatives were formed to develop an efficient, safe and cost-effective stove that runs on renewable forms of energy.

2.1 History of Ethanol Fuel in Brazil

The history of ethanol fuel in brazil dates from the 1970s and relates to Brazil's sugarcane based ethanol fuel program, which allowed the country to become the world's second largest producer of ethanol, and the world's largest exporter(Daniel *et al*, 2007). Several important political and technological developments led Brazil to become the world leader in the sustainable use of bioethanol(Mitchell, 2010), and a policy model for other developing countries in the tropical zone of Latin America, the Caribbean, and Africa (Hausmann, 2009). Government policies and technological advances also allowed the country to achieve a landmark in ethanol consumption, when ethanol retail sales surpassed 50% market share of the gasoline-powered vehicle fleet in early 2008(Gazeta, 2008). This level of ethanol fuel consumption had only been reached in Brazil once before, at the peak of the *Pró-Álcool* Program near the end of the 1980s (Julieta, 2008).

Table 1: Historical evolution of ethanol blends used in Brazil

Year	Ethanol blend	Year	Ethanol Blend	Year	Ethanol blend
1931	E5	1989	E18-22-13	2004	E20
1976	E11	1992	E13	2005	E22
1977	E10	1993-98	E22	2006	E20
1978	E18-20-23	1999	E24	2007	E23-25
1981	E20-12-20	2000	E20	2008	E25
1982	E15	2001	E22	2009	E25
1984-86	E20	2002	E24-25	2010	E20-25
1987-88	E22	2003	E20-25	2011	E18- 25

Source: J.A. Puerto Rica, (2007).

Sugarcane has been cultivated in Brazil since 1532, introduced in Pernambuco that year and sugar was one of the first commodities exported to Europe by the Portuguese settlers (USGA, 2008). Ethanol is obtained as a by-product of sugar mills producing sugar, and can be processed to produce alcoholic beverages, ethanol fuel or alcohol for industrial or antiseptic uses. The first use of sugarcane ethanol as fuel in Brazil dates back to the late twenties and early thirties of the 20th century, with the introduction of the automobile in the country. After World War I, some experimenting took place in Brazil's Northeast Region (William, 2008), and as early as 1919, the Governor of Pernambuco mandated all official vehicles to run on ethanol (ANFAVEA, 2010).

The first ethanol fuel production plant went on line in 1927, the Usina Serra Grande Alagoas (USGA), located in the Northeastern State of Alagoas (William, 2008), producing fuel with 75% ethanol and 25% ethyl ether. As other plants began producing ethanol fuel, two years later there were 500 cars running on this fuel in the country's Northeast Region.

A decree was issued on February 20, 1931, mandating the blend of 5% hydrated ethanol to all imports of gasoline by volume (ANFAVEA, 2010). The number of distilleries producing ethanol fuel went from 1 in 1933 to 54 by 1945. Fuel-grade ethanol production increased from 100,000 liters in 1933 to 51.5 million liters in 1937, representing 7 percent of the country's fuel consumption. Production peaked to 77 million liters during World War II, representing 9.4% of all ethanol production in the country. Due to German submarine attacks threatening oil supplies, the mandatory blend was as high as 50 percent in 1943(ANFAVEA, 2010). After the end of the war cheap oil caused gasoline to prevail, and ethanol blends were only used sporadically, mostly to take advantage of sugar surpluses, until the seventies, when the first oil crisis resulted in gasoline shortages and awareness on the dangers of oil dependence (William, 2008). Brazil has paid more attention to bioethanol fuel for automobiles than the cook cookstoves.

2.2 African Ethanol Fuel Program

The Millennium Gelfuel Initiative is one of such programs. It was a collaboration between the public and private sector to disseminate an ethanol cooking fuel for use in the African household sector. It involved the use of a low cost Gelfuel produced by adding a thickening agent to ethanol which increased the viscosity of the fuel making it safer for use. A gelfuel factory was set up in Lilongwe, Malawi which had the capacity to produce 1000L/day. Unfortunately, production was halted due to increase in the price of ethanol and changes to tax and duty exemption that made the fuel unaffordable to most people (Hedon, 2005).

Another scheme to develop a stove that runs on a renewable form of energy is the Project Gaia, an Ethiopian based program which has developed an alcohol stove that runs on either methanol or ethanol. The Clean Cookstove is another example of an easy to use and safe ethanol stove under the project Gaia. The stove is designed around the innovative ethanol canister, when the stove is lit, the ethanol evaporates and mixes with air to burn readily, allowing a maximum power of 1.5 kW per burn (Debebe, 2005). Several design modifications were made for the Ethiopian market, as a result of consumer feedback from the initial pilot study and independent performance tests. The pot-stand was redesigned to enable the use of larger and round-bottomed pots, and raised to allow more oxygen to reach the flame. Better guides were provided to locate the fuel canister in the stove body. Handles were added to make the stove easier to carry and to turn over to refill.

Another project of remarkable importance is the mini-pilot study of the SuperBlu stove in Malawi. About 93% of the country's energy source comes from biomass most of which is in the form of wood and charcoal. As a result, the country is heavily deforested (ProBEC, 2009). In the attempt to check deforestation and reduce cases of acute respiratory infections, the Superblu stove built to run on ethanol has been specially designed to burn in an economic, clean and safe way (Robinson, 2006). However more work is required on safety.

In the drive to diversify the energy supply mix of the country using biofuels, the Energy Commission of Nigeria partnered with some stakeholders in the promotion of methanol stove use in Nigeria.

Due to the extremely low value (4.3%) of the lower limit of inflammability, the use of pure ethanol for household purposes is dangerous. This problem can be overcome by the use of ethanol and water mixtures in a suitably designed stove. Tests done at NARI showed that 50% (w/w) ethanol-water mixture was a good cooking fuel (NARI, 2006).

2.3 Performance Features of a Stove

Ethanol and kerosene stoves with their advantages and limitations vary in performance. The performance of a stove is determined by the measure of certain features such as follows:

- Low specific energy consumption at high power.
- Low fuel consumption when simmering.
- Easy power regulation - suitable turn-down ratio.
- No unintended flame extinguishing at low power, even in wind.
- No very hot outer parts.
- Easy placing and removal of pots without getting burnt.
- Good quality combustion - no smoke, smell or emissions.
- Low fuel indicator.
- Easy filling of fuel - even when hot.
- Stable on a variety of surfaces suitable for the type of pots commonly found in the region this usually means that variety pots of various shapes and sizes can be accommodated on the stove. The pot should stand firmly on the stove even when being stirred vigorously.
- Should be easy to ignite and preferably not require a separate starting fuel - it should also be easy to light in a wind.
- Maximum power sufficient for cooking meals in pots of the largest common size.
- Simple instruction for use.
- No danger of fires or spillage even if mishandled.
- Durable - life span of several years

Different methods are used to access certain performance criteria such as the Water Boiling Test (WBT) used to measure thermal efficiency, specific fuel consumption, minimum and maximum power; The controlled Cook Test (CCT) which assesses the stove performance according to local conditions by measuring both the mass of food and fuel used, as well as time taken to cook a typical meal. The test gives a more realistic idea of performance than the WBT; the kitchen performance test is another test that assesses the performance of a stove under real conditions with real food unlike lab tests.

3. Methodology

Varying quantities of water were boiled using kerosene and ethanol stoves respectively. The same size of a conventional kerosene cooking stove of maximum fuel capacity of 0.7 litres was used to boil various volumes of water using the ethanol and kerosene fuels respectively. The kerosene fuel was first tested and later the stove was washed with detergent and sundried. The experiment was repeated with ethanol after replacing the wick under the same condition. The time it took for the water on the stove to boil was recorded as indicated in table 2 and figure 1. The weight of the soot produced is shown in table 3.

4. Results/Discussion

From the results summarized in the table below, it is observed that kerosene generates more heat than ethanol. It also produces more carbon soot than ethanol. It was observed that even though both fuels combust to produce a blue flame, ethanol burns cleanly and does not produce any smoke or smell when blown out. On the other hand, kerosene produces more carbon and greenhouse gases than ethanol and also produces an unpleasant smell when blown out. It was also observed that it took longer time for water to boil using ethanol. This could be due to the presence of water vapour in the combustion zone as a result of the ethanol-water mixture which reduces the maximum heat attained by the burner. It could also be due to reduction in thermal energy because of fewer number of carbon atoms in the molecules of ethanol compared to kerosene.

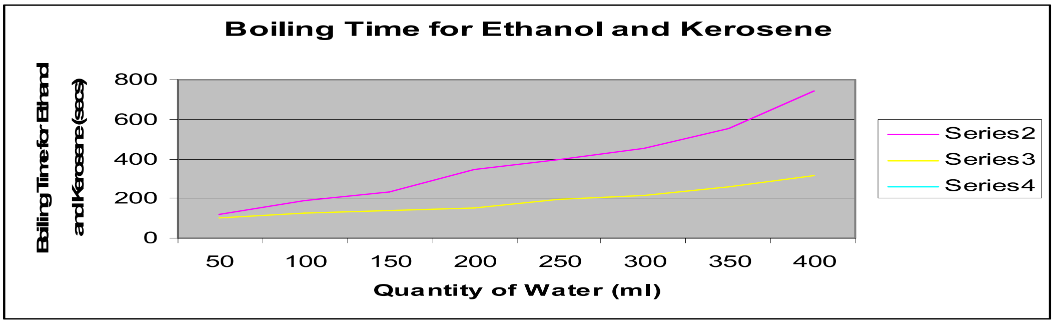
Table 2: Comparative water boiling time for ethanol and kerosene fuels.

Quantity of Water (ml)	Time for ethanol (Seconds)	Time for Kerosene (Seconds)
50	117	98
100	190	126
150	233	140
200	345	152
250	394	198
300	451	212
350	556	261
400	743	312

Table 3: Comparative soot formation for ethanol and kerosene stoves.

Fuel	Flame Colour	Carbon Weight (g)
Ethanol	Blue	0.028
Kerosene	Blue	0.153

Figure 1: Boiling time for ethanol and kerosene



5. Conclusion

Ethanol stove has less thermal efficiency, higher start up cost and less fuel economy but it will provide good returns as a long term investment, it also has less carbon soot, less GHG emissions and promotes renewable energy usage. Though the use of ethanol as a fuel may be slightly more expensive, with the rising crude oil prices and the search for alternatives to contemporary cooking fuels, it can still be seen as a viable alternative in the near future.

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