DEVELOPMENT OF A LOW COST CHARCOAL STOVE

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Abstract. *About 95% of Brazilian households use LPG for cooking. The oil prices increase and the cost of oil products, including LPG, has created a great economic pressure on the low-income population. Aiming to create a cooking alternative for this population, was developed a simple charcoal stove. This stove can be manufactured with a variety of materials, which allows easy manufacturing and low cost. The charcoal for cooking fuel is cheaper than the LPG and alcohol, and is a renewable fuel, have domestic production (mainly local) and reliable use. The lowest flame temperature of the charcoal stove provides other additional benefits, including the retention of food nutrients and better taste.*

Keywords*: Biomass, charcoal , stove, cocking , renewable energy source.*

1. INTRODUCTION

The LPG (Liquefied petroleum gas) use, representing 28% of energy consumption in residential sector and approximately 3.5% of total energy consumption in Brazil. Despite being a small share in total consumption, is a strategic fuel, since the majority of the population depends on it for the daily food cocking.

Table 1. Fuel type used in cocking (million homes)

Localization	LPG	firewood	charcoal	others
Cities	23,1	3,2	1,1	0,4
Rural	1,1	6,2	0,7	-
Total	24,2	9,4	1,8	0,4

Source: IBGE, 1997

According to the IBGE in 2006 of 45 million Brazilian households, 42 million have a gas stove, 6 million wood stove and 3.2 million charcoal stove. The insertion of the gas ranges (gas stoves) in Brazil occurred rapidly over the past 40 years. In 1960 only 18% of the households had gas rangers, in 1970 around 42% and in 2006, 97.7%. At the same time wood stoves decreased: 61%in 1960, 45% in 1970 and around 13% in 2006. Today, only rural and poor urban households use wood stoves, representing approximately 17.4% of residential energy consumption.

This universal LPG distribution occurred in the last 50 years, through the establishment of a network of nationally and locally distributors. The gas distribution through cylinders, exist in all (100%) of Brazilian (more than the post office, electricity, water and sewerage). Petrobras is the only LPG supplier; the LPG is selling by 18 distributors, and these for around 200 thousand retailers throughout the country. This unique home delivery system in the world makes the LPG purchase very easy for consumers. The market is dominated by five companies that control 95% of sales: Ultragaz, SHV Gas, Liquigás (Petrobras) and National Gas Butane group.

Table 2. Market Share Brazilian LPG Distribution Companies (Jan-Mar 2009).

Company	% Market Share	Company	% Market Share
Ultragaz	23.43	Nacional Gás Butano	18.65
Liquigás (Petrobrás)	22.51	Copagaz	7.37
SHV Gás Brasil	22.19	Others	5.85
		Total	100

Source: SINDIGÁS, 2009

Despite the five largest distributors operate nationally; the market share concentration at state level is higher. The Copagaz (7.5% of national market) is the main distributor in Mato Grosso and Mato Grosso do Sul states, and have a significant presence in Goiás and São Paulo. Fogasa and Amazongás form a duopoly in four states of Amazon region, representing only 2.2% of the national market.

The distribution and sale logistics, combined with easy handling, transport, storage and use, became Brazil the fifth largest world LPG consumer (after USA, Japan, Mexico and China), consuming about 6.7 million tonnes per year. About 95% of homes (42.5 million) of all economic classes use LPG for cooking. The high consumption is not all supplied by domestic production, and is necessary import about 21% of total consumption [BEN EPE-2008].

The most common commercialization form is the 13 kg cylinders, intended solely for residential use, which accounts for about 80% of LPG sales in Brazil, through sales points. There are currently circulation in Brazil near 100 million 13 kg cylinders and sold 1,500,000 cylinders daily.

Table 3. Brazilian LPG Production and Consumption (10^3 m^3).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production	6,793	7,333	7,761	8,694	8,940	9,418	9,757	10,848	10,196	10,767
Importation	5,025	5,379	5,097	3,848	3,353	2,040	1,880	948	1,586	1,795
Exportation	-6	-5	-10	-8	-175	-131	-64	-152	-34	-23
Consumption										
Total	11,961	12,493	12,825	12,681	12,125	11,450	11,755	11,655	11,783	12,165
Residential	10,114	10,325	10,342	10,369	10,003	9,345	9,539	9,350	9,345	9,650

Source: EPE-BEN 2008.

The liquefied petroleum gas or LPG is a mixture of liquefied hydrocarbons obtained by primary distillation of petroleum or natural gas fractionation. It contains mainly C_3 (propane, propene) and C_4 (butane, butene) molecules. It may also contain small quantities of ethane and pentane. The composition vary depending on the origin and the treatment process: when coming from natural gas, do not contain unsaturated hydrocarbons, and when obtained from refinery gases, it contains some olefins.

Table 4. LPG types commercialized in Brazil

Type of Gas	Composition
LPG (Propane-butane)	propane and butane mixture
Propane commercial	$C_3H_8 + C_3H_6 > 93\%$
Propane especial	$C_3H_8 > 90\%$, $C_3H_6 < 5\%$
Butane commercial	$C_4H_{10} + C_4H_8 > 93\%$

Source: CNP-02/Rev.3, DOU 4/2/750

At atmospheric pressure, the hydrocarbons of LPG are gases, but at relatively low pressure they became liquid, which promotes the volume reduction, and easily to transportation and use. At atmospheric pressure the propane condensation temperature is -44.5 °C and the butane is +5 °C. At temperature of 20°C the propane vapor pressure is 0.8 MPa and the butane is 0.2 MPa. Therefore, these gases are transported in liquid form in cylinders and bottles at a pressure typically less than 0.6 MPa. The butane and propane gas density is greater than the air. In a leakage situation, they have a tendency to remain in the soil level and produce an explosive mixture with air. As the propane and butane are odorless, an artificial odor is added to the gas (ethyl mercaptan) to produce odor and enable its detection in case of leakage.

In 1994, the final price of the 13 kg cylinders was R$ 4.82, and the total amount of taxes R$ 0.60 (12.44% of the selling price). Over the years, the Brazilian government neoliberal politic take off in December 2001the PPE (part of specific price - known as petroleum account), which acted preventing that prices being affected by external market pressures, and increased gradually the taxes. In January 2009, the same cylinders were sold to consumers at the average price of R$ 33.40, of which R$ 7.69 (23%) are taxes [SINDIGAS, 2009]. Taxes imposed on LPG are: ICMS, PIS / PASEP, COFINS, CPMF and CIDE. The PIS / COFINS are 7% of the product final price. The ICMS varies from 1% in the Amazon state to 18% in Minas Gerais, and 12% in most states. In May 2009, a further increase raised the price of the 13 kg cylinders for about R$ 45.00 (near US$ 24.00) in Minas Gerais.

In 2002 the federal government created the vale-gas, an aid of R$ 7.50 for the low income population buy the gas. Initially, this program had 10 million registered families, but with time, it was incorporated into the Family Grant, which now has about 11 million people benefited, while currently about 600,000 people receive the vale-gas aid.

From a greenhouse effect point of view, 6.6% of emissions due to fossil fuels burning in Brazil come from the residential sector. Almost all residential sector emissions are due to the LPG burning (97%). The other issues are minor role.

2. CHARCOAL STOVE PROTOTYPE

The increase in oil prices and the increasing the taxes are increased significantly the LPG price in recent years, making its use expensive for the low-income population. Furthermore, there isn't the retail sale of this fuel, and for the low income population the cost of one 13 kg cylinders is high (since 2001 is not more allowed the commercialization of 5kg cylinder named *liquinho*). The lack of money to purchase a 13 kg cylinders has led the low income population to use the alcohol in improvised stoves, with a drastic increase of fire accidents at home.

Aiming to reduce the LPG consumption, and create an economic option of cooking for low-income families, has developed a prototype charcoal stove for domestic use.

The charcoal is a fuel with a high calorific value, easy combustion and low smoke emission. It is easy to produce, existing in Brazil a good logistics for production and sale. It is easily found in supermarkets of large cities, and also in rural and small communities.

The design of stove constructed was based on a nineteenth century ceramic charcoal stove, existent in the Museum de Artes e Ofícios - MAO, Belo Horizonte, MG (item 1464, figure 1).

Figure 1. Ceramic Charcoal Stove, XIX Century (MAO – Museu de Artes e Ofícios, Belo Horizonte).

Based on this stove, the prototype (Figure 2) was also constructed in mud (clay) and cooked (burnt) in electric oven at 800 ºC. The prototype was handcrafted by a potter, with the aid of a pottery wheel. It has the form of 2 garden pots, jointed by the bottoms, with the largest vessel in the upper side and lower at the bottom side. The separation wall of 2 pots, make the separation of the combustion chamber and the ashtray. The separation wall was drilled with 35 holes of 1 cm in diameter, to allow the combustion air flow. In the lower pot was a cut elliptical window to allow the air intake. Near the upper edge of the stove was placed a 3 cm fin to allow the support of the cocking pot. A gap between the cocking pot and the stove wall allows the combustion products output. A dish placed below the lower pot collect the combustion ashes. The total stove height is 35 cm, the internal diameter of the upper side 25 cm and total weight 6.5 kg (including the dish ashtray).

Like this stove is a special design "pot", they need some additional operations for their construction, and the potter asked R$ 20.00 (US$ 10.00) for its manufacture. Garden pots of similar size are sold by the same potter for R$ 10.00 (US$ 5.00).

The charcoal is deposited in the combustion chamber and light with an ignition agent (paper). When the combustion is established, the cocking pot is placed in the stove for cocking.

Figure 2. Prototype of the Charcoal Stove (front view and top view)

3. THE CHARCOAL STOVE TEST METHODOLOGY

To determine the stove efficiency, there are 3 standardized tests [Smith, 2009]:
1. WBT: Water Boiling Test
2. CCT: Controlled Cooking Test
3. KPT: Kitchen Performance Test

The stove efficiency was defined as the ratio of pot energy absorbed by the combustion energy. The boiling water test WBT [BAILIS et alii; 2007, HEDON] was used to determine the stove efficiency. In the WBT, a water quantity is heated on the stove in heating and cooking conditions. The water is heated up to boil and maintained at boiling state for 30 minutes. Like is complicated stop the experiment at the end heating stage, it was determined only the total efficiency (heating and boiling). The total evaporated water is calculated, and the remaining fuel in the stove is removed, weighed, and the energy consumed determined. The stove average efficiency was calculated by:

$$\eta = \frac{m_{wi} Cp_w (Te - Ti) + m_{i,evap} H_{fg}}{m_c . LHV}$$

where $\mathbf{m_{wi}}$ is the initial water mass in the pot (kg), $\mathbf{Cp_w}$ the water specific heat (kJ/kg.K), **Te** the boiling water temperature (K), **Ti** the initial water temperature in the pot (K), $\mathbf{m_{w,evap}}$ the evaporated water mass (kg), $\mathbf{H_{fg}}$ the evaporation enthalpy (kJ/kg), $\mathbf{m_c}$ the charcoal net mass consumed (kg), e **LHV** the charcoal lower calorific value (kJ/kg).

The combustion products are taken by a suction probe placed manually in the space between the pot edge and stove wall and analyzed by an infrared gas analyzer Tecnomotor model TM 132 [Tecnomotor, 2009]. The probe was placed at several stove points, and the average emissions (CO_2, CO, HC and O_2) during the test were determined.

The charcoal used in the test was previously dried in an oven at 105±2°C, and stored in an oven at 65°C until the test, to avoid the air moisture absorption.

4. RESULTS

The operating results are shown in table 5, together with others results obtained in the literature. The stove was reliable and easy to operate. The operation cost is several times less than the operating cost the gas stove.

The flame remained stable, and with some practice it can keep burning for a sufficient time to achieve to cocking a complete meal.

Table 5. Cocking efficiency (%) and poluents emission (g/MJ).

	Charcoal [1]	**Firewood** [2]	**Kerosene** [2]	**LPG** [2]
Efficiency	18 %	23 %	50 %	54 %
CO_2	74	305	138	126
CO	1.3	11.4	1.9	0.61
TNMOC*	(HC total = 0.43)	3.13	0.79	0.19
N_2O	----	0.02	0.002	0.002

Source: [1]This study, [2]World Health Organization (WHO). Obs.*Organic components except methane.

The power required for boiling was determined in a previous experiments [PINHEIRO, 1997], in tests with a 4.5 L pressure cooker (widespread use), and a 2 L milk pot, both in aluminum and with covers. These previous experiments showed are necessary 180 Watts for the pressure cooker and 100 Watts for the milk pot, at 26°C room temperature. This stove had sufficient power for cooking.

One of the problems showed in the tests was the necessity in the Brazilian cuisine, to cook more than one hot food at the same time (rice, beans, noodles etc). The development of a stove with more than one burner is necessary. The stove don't was tested with the fried foods, but this will be done in the next step.

In the constructive aspect, the fins that support the pot were fragile, and one was broken during the tests. In a new prototype they should be built a fin more resistant. Furthermore, the fin was placed low, about 7 cm from the edge, which take difficult the use of low pans. The design of the original stove seems better in these aspects

5. CONCLUSIONS

The stove build in ceramic are operated satisfactorily. Based on a nineteenth century design stove, this prototype construction has partially recovered this forgotten cooking technology. The energetic efficiency was similar to the various charcoal and biomass stoves types found in the literature.

Despite their efficiency is lower than that gas stoves, the charcoal low price, and the possibility of the user build your own stove and produce their own charcoal [PINHEIRO, 2009], it makes their use economically feasible.

The basic design of this stove may be copied, adapted and reproduced using a variety of materials (cement, metal, etc.). Although the prototype had cost R$ 20.00, if its production becomes usual, it can be sold for about R$ 10.00/unit. The low cost of the equipment allows its acquisition by the low income population. The cost of using the charcoal stove is smaller than the cost of using LPG or alcohol, and the operation is more reliable that of alcohol stoves.

The alternative fuels use less the pressure on LPG consumption, increasing their supply, and reducing its importation. The charcoal is a native fuel, not being subject to the international market pressure. The charcoal production is handwork intensive, and the increase use would create a rural jobs chain, generating income for the Brazilian society.

This is a portable stove that uses charcoal, a decentralized, renewable and low emission energy source. In addition to the benefits the family level, the spread of this stove can reduces imported fuels dependence. It may become a complementary and auxiliary equipment for the gas stove.

Politic makers often prefer invest in high-technological innovations like the photovoltaic systems, PCH, wind energy, forgetting the investments in appropriate technologies, which directly affect the low-income populations. This is often contrary to civil society needs and the better understanding of the relationship between energy services access, sustainable development and economic growth.

This stove is a route toward ecologically correct technology can be used.

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