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Performance comparison of charcoal cookstoves for Haiti: Laboratory testing with Water Boiling and Controlled Cooking Tests

Kathleen Lask [a,b,*], Kayje Booker [a], Taewon Han [b], Jessica Granderson [b], Nina Yang [b], Cristina Ceballos [a], Ashok Gadgil [a,b]

[a] *University of California Berkeley, Berkeley, CA 94720, USA*
[b] *Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA*

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ABSTRACT

Charcoal cooking accounts for a large portion of Haiti's energy usage and leads to severe economic, health, and environmental hardships. Organizations are hoping that fuel-efficient cookstoves can help solve the problem. In this study, four charcoal cookstoves intended for dissemination in Haiti were rigorously assessed and compared using Water Boiling and Controlled Cooking Tests.

Due to the poor thermal efficiency of the traditional stove, all improved stoves saved fuel on average over the traditional with the majority also reducing the total emissions released. However, the traditional stove could be difficult to replace because it had the fastest time-to-boil, an important consideration for end users. Through the testing, the number of trials conducted was found to be an important consideration for error analysis. Also, noticeable differences in stove performance were seen between the two protocols, supporting arguments by prior researchers of the necessity to use multiple test protocols for practically useful comparisons.

Introduction

Approximately three billion people use biomass as fuel for cooking and heating worldwide, including most of the ten million people of Haiti (IEA, 2004). It is estimated that 70% of Haiti's annual energy use comes from the burning of solid biomass, primarily charcoal and wood (Nexant, Inc., 2010). Besides being a major human health concern, over the years the unsustainable harvesting of biomass has substantially contributed to rampant deforestation; in 1923, 60% of Haiti was forested, but by 2009 only 2% of the country was forested (Nexant, Inc., 2010; Lim et al., 2012). In cities, a marmite, or the amount of charcoal needed to cook roughly half a day's worth of food, costs 20–25 gourdes (roughly 0.50 USD). The gross national income per capita in Haiti is about 700 USD (UNICEF, 2013). Therefore, families spend a significant fraction of their income on cooking fuel. After the devastating earthquake in January 2010, many organizations, including USAID, the Women's Refugee Committee, and the World Food Program, called for a rapid deployment of fuel-efficient cookstoves to ease the physical and economic hardships in Haiti (Nexant, Inc., 2010; WRC, 2010).

However, cookstove distributors have little or no data on the performance of most charcoal cookstoves developed for Haiti. A few studies in peer-reviewed literature include Haitian stoves as part of a larger study (Bentson et al., 2013) but for the most part, studies evaluating cookstoves do not focus on Haitian stoves (Jetter and Kariher, 2009; MacCarty et al., 2010), except in the gray literature (Nexant, Inc., 2010). This leaves agencies seeking to distribute efficient cookstoves without knowledge of the potential impacts of different Haitian stoves.

We report results from two cookstove testing methods, the Water Boiling Test (WBT) and Controlled Cooking Test (CCT), performed on four charcoal cookstoves designed for use in Haiti. This study aimed to obtain baseline data on the performance of the cookstoves in terms of efficiency and emissions in order to inform the design and help selection of improved charcoal stoves for dissemination in Haiti under the post-earthquake emergency conditions. Results of this work were promptly made available to stove manufacturers, distributors, and funding agencies for use in the knowledgeable dissemination of stoves in Haiti.

Experimental system

Cookstoves tested

Cookstoves that were either readily available in Port-au-Prince or being considered for relief-operations distribution in Haiti were

* Corresponding author at: Lawrence Berkeley National Laboratory, 1 Cyclotron Road Mailstop 90R2121, Berkeley, CA 94720, USA. Tel.: +1 510 486 7435.
E-mail address: kmlask@lbl.gov (K. Lask).

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Fig. 1. Traditional Haitian stove: height: 27 cm; length/width: 11 cm; weight: 2.8 kg.

Fig. 3. Prakti rouj stove: height: 20.5 cm; diameter: 25.5 cm; weight: 4.6 kg.

identified through a field visit by scientists from Lawrence Berkeley National Laboratory (LBNL). Typical traditional charcoal cookstoves were purchased in Port-au-Prince and manufacturers of improved cookstoves were contacted to obtain cookstove units for testing. Based upon their timely availability, the following four stoves were included in both WBT and CCT evaluations.

Traditional Haitian

Haitians typically use simple stoves made locally from scrap sheet metal. These stoves are widely available and have either a square or circular charcoal chamber. The stove tested in this study has a square charcoal chamber with evenly distributed holes along the sides and bottom (Fig. 1). The pot sits directly on the charcoal bed, and ash falls through to a tray underneath which is emptied by turning the stove over.

EcoRecho

The EcoRecho, shown in Fig. 2, is a metal stove with a ceramic liner made in Haiti by D&E Green Enterprises. The pot sits above the charcoal bed on three triangular metal rod supports. A door on the front of the stove can be operated to control airflow and remove ash.

Prakti Rouj

The Prakti Rouj, shown in Fig. 3, is a ceramic-insulated metal stove with a small circular charcoal chamber. The pot sits on raised metal wedges above the charcoal bed and a door on the front of the stove can be adjusted to control airflow. A tray can be removed through the door to empty ash.

Mirak (copy)

The Mirak copy, shown in Fig. 4, is a locally-made, scrap metal stove copied from the Mirak stove designed by the humanitarian agency CARE. It is widely available in Port-au-Prince. The charcoal chamber is hemispherical, and the pot sits directly on the charcoal bed. An opening in the side of the stove allows airflow, but there is no door for airflow control. The charcoal chamber rests on top of the stove body and can be removed to dump out the ashes.

Instructions on using the stoves were not provided by the manufacturers, but several practice tests were conducted with each stove prior to the official tests used for measuring performance. Using the experience gained from these tests, each stove was operated in order to maximize combustion efficiency by adjusting airflow if possible. The cooking pots used for testing were common, traditional Haitian pots purchased in Port-au-Prince, as those would be the same pots used by cooks in the field.

Experimental setup

The test system consisted of a stove platform under an extraction hood which drew gases upward through an aluminum duct (15 cm diameter) using two blowers, shown in Fig. 5. Prior to reaching these blowers, the gases were mixed along a long stretch of duct with stationary fan blades and subsequently sampled for gas analysis. All testing was performed in a well-monitored indoor space at LBNL with initial temperature and humidity data recorded.

Fig. 2. EcoRecho stove: height: 22 cm; diameter: 27.5 cm; weight: 6.2 kg.

Fig. 4. Mirak stove: height: 32 cm; diameter: 30.5 cm; weight: 2.8 kg.