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Closing the gap between lab and field cookstove tests: Benefits of multi-pot and sequencing cooking tasks through controlled burning cycles

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There is a critical need for developing wood-burning cookstoves lab tests that better reflect their field performance, and that can be used to complement existing standard tests. This is particularly true for Plancha-type cookstove stoves, widely disseminated in Latin America, where existing tests, like Water Boiling Test (WBT) and Controlled Cooking Test (CCT), are either not well suited to these stoves or do not capture the simultaneous and sequential arrangement of local cooking practices –i.e., multi-pot cooking, pre-heating of meals, and use of residual heat. In this paper, we developed a “controlled cooking cycle” or “controlled burning cycle” (CBC) test to study the benefits, in terms of fuelwood and pollutants emissions savings, of multi-pot cooking arising from the integration of cooking tasks. Tests were conducted on the Patsari stove, a plancha-type stove that has been widely disseminated in Mexico and in other regions of Central America. We first used CCTs to evaluate the comparative energy and emissions performance of the Patsari stove relative to a traditional U-shaped open fire (U-type) for the most common cooking practices carried out in the Purepecha Region of Michoacan. We also compared results from the CBC multi-pot cooking with results from simply conducting the cooking tasks in series. All the CCTs and CBCs were carried out in a simulated kitchen at GIRA facilities in Patzcuaro, Michoacan, Mexico with two local cooks who performed all the cooking tasks in the traditional/typical manner of the region. Results from CCTs showed Patsari benefits relative to the open fires, in terms of fuelwood consumption and CO and $PM_{2.5}$ emissions savings, vary among cooking tasks and range from negligible to 63% depending on the parameter and the task. The sequential cooking and integration of these tasks in a CBC result in average savings of 65% for CO, 65% for $PM_{2.5}$ and 35% for fuelwood relative to the U-type, and of between 30% and 44% savings with respect to simply conducting the cooking tasks in series in the same stove. The CBC fuelwood savings obtained here are comparable with field results from Kitchen Performance Tests (KPT) conducted regionally by other authors. The results confirm that multi-pot cooking and a smart sequential integration of tasks developed by local users are key to achieve the maximum benefits from plancha-type stoves, and need to be much better reflected in standard lab tests.

Introduction

Reliance on fuelwood for cooking and heating is very high in many Latin-American countries, particularly within rural areas. Wood is mostly burned in open fires, which require vast amounts of fuel and produce very high indoor air pollution (L'Orange et al., 2012), leading to several health effects (Rumchev et al., 2007), and environmental problems (Smith et al., 2010). To cope with this problem, plancha-type improved wood-burning cookstoves have been widely disseminated in several countries across North, Central and South-America such as Mexico, Bolivia, Peru and Honduras with >1 million stoves installed (I Seminario Taller Latinoamericano., 2014). In rural Mexico, the Patsari stove, a multi-pot

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Fig. 1. A. Stoves tested. Left to right: Patsari stove and the U-type. B. Different in-field simultaneous cooking of several dishes on Patsari stoves observed in Purepecha Region of Central Mexico.

plancha-type stove,[6] has been well accepted due to its effectiveness to cook tortillas, but also is used to cook beans and rice, heat beverages, and to fry eggs as reported by Ruiz-Mercado and Masera, (2015).

Many studies have emphasized the need to develop standard lab and field tests that better reflect in-field conditions (Arora and Jain, 2015; Adkins et al., 2010; Bailis et al., 2007). This is particularly true for Plancha-type cookstove stoves, because Water Boiling Tests (WBT) are not well suited to these stoves, as a large fraction of the heat that is transmitted through the "plancha" is not captured by the pot filled with water that is placed on top of it. Adaptations to the standard Water Boiling Tests (WBT) such as the "*comal-olla*" or *"plancha-olla"* (Medina et al., 2017; ISO TC 285., 2015) or the "Mylar pot" (ISO TC 285., 2015) have been proposed to better estimate the actual heat transfer from the combustion of fuel to the plancha (Medina et al., 2017). But these adaptations, while important to have more realistic estimates of the stoves actual energy efficiency, are not aimed at giving feedback on their in-field performance.

Controlled Cooking Tests (CCT) were developed to give more insights on the stoves performance for the most relevant cooking practices within a region (Bailis et al., 2007). While CCTs have proved very valuable –and have not been used to the extent they should as a complement to WBT- they also present shortcomings. In fact, evidence from the field shows that local cooking tasks more than being a simple collection of isolated events, are usually performed following specific arrangements, which can be thought as daily "burning cycles "-or "cooking cycles"- (Johnson et al., 2010).

Here we argue that the combination of specific cooking practices carried out locally as well as the simultaneous and sequential arrangement of these practices in burning cycles –i.e., multi-pot cooking, and use of residual heat for pre-heating meals and water, or for keeping food warm, see (Ruiz-Mercado and Masera, 2015), could be used as a starting point for developing new standard tests that could help to better assess the actual field performance of improved stoves. These tests, simulating regional cooking cycles, can be viewed as a complement to standard tests, such as WBT and individual CCTs.

To test these hypotheses, we first conducted a series of CCTs for the most common meals (or cooking tasks) prepared in the Purepecha Highlands, Central Mexico and compared the relative performance of Patsari improved stoves to traditional open fires for each task. We then integrated the different cooking tasks in a Controlled Burning Cycle (CBC) and re- assessed the energy and emissions performance of Patsari stove relative to both traditional open fires and to itself for the whole cycle and for a theoretical cycle consisting of the simple additions of conducting the individual tasks in series.

Methods

Controlled Cooking Test

Stoves. Fig. 1A shows the cookstoves tested: Patsari stove and a traditional fire: the U-shaped open fire (U-type). **Patsari:** the body of Patsari

[6] Plancha-type stoves are characterized for having a large flat griddle, named "plancha" or "comal" that covers the upper part of the stove, avoiding the direct contact between the fire and the pot and also allowing the smoke to exit the house through a chimney. The griddle is usually made of metal, and the stoves could be metallic or made of local materials, like bricks, mud, and cement.