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Factors Influencing the Acquisition and Correct and Consistent Use of the Top-Lit Updraft Cookstove in Uganda

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This study looked at the effects of select behavior change interventions on the purchase and the correct and consistent use of a locally fabricated top-lit updraft (TLUD) stove in Uganda. Behavior change interventions included training of community sales agents and village health team volunteers on household air pollution and correct use, referral of interested community members to sales agents, community cooking demonstrations, information flyers, and direct sales of TLUDs and processed wood. Qualitative and quantitative research methods shaped interventions and were used to understand attitudes and practices related to TLUD stove acquisition and use. Results showed that TLUDs were appreciated because they use wood efficiently, cook quickly, reduce smoke, and produce charcoal. However, the substantial purchase price barrier, combined with the cost of processed wood, effectively eliminated the cost savings from its significant fuel efficiency. This made it difficult for the TLUD to be a meaningful part of most households' cooking practices.

More people are estimated to die prematurely from exposure to household air pollution than from malaria each year (Lim et al., 2012). To date, improved cookstove interventions have largely failed to play a significant role in reducing maternal and child deaths that result from burning biomass (Prüss-Üstün & Corvalán, 2006). As with other consumer products, many factors affect the adoption and correct use of a new cookstove, including awareness, cost, access, knowledge of use, and fit with cooking practices (Stanistreet, Puzzolo, Bruce, Pope, & Rehfuess, 2014; Malla & Timilsina, 2014). The lessons that public health stakeholders learn about these factors can help guide public sector programs to introduce and ensure proper use of new cookstoves. It is, for example, important to have long-term institutional commitment from government, civil society, and the private sector to support policy, education, and regulations that influence and support the introduction of cookstoves. Developing convincing messages is also essential, including messages that go beyond the citation of health benefits which have not been a primary motivating factor for stove acquisition (Mitchell, 2010; Program for Appropriate Technology in Health [PATH], 2012; Thurber, Phadke, Nagavarapu, Shrimali, & Zerriffi, 2014; Thurber et al., 2013). Our study's aim was to understand the effects of behavioral interventions on the adoption and correct use of a top-lit updraft (TLUD) biomass, gasifier stove that is fabricated locally in Uganda. We selected the TLUD stove because of the promising results it had shown in laboratory settings to reduce emissions of health damaging pollutants (up to 95% reduction in $PM_{2.5}$ relative to three stone fires (Biomass Energy Foundation, 2009), yet also posed important challenges to adoption and correct and consistent usage.

In this study, we developed, tested, and evaluated select behavior change interventions related to the acquisition and correct use of the TLUD stove in Uganda. The Ministry of Health was actively engaged in the program planning through the involvement of village health teams (VHTs)[1] in a community-level behavior change communication (BCC) exercise. As a result of the feedback, VHTs were included not only as community educators but also as sales agents. This demonstrated the value of involving different sectors (health and energy) involved in shaping programs that promote the adoption of new cookstoves.

We thus hypothesized that effective behavior change communication approaches can positively affect barriers and motivators to both acquisition and correct and consistent use of a TLUD cookstove.

Method

The study was conducted by PATH, the Berkeley Air Monitoring Group, and the Joint Energy and Environment Projects in Makindye-Sabagabo and Kira Town Council

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[1]Village health teams are individual volunteers at the village level who provide a first point of contact between the community and the health system.

Fig. 1. Charcoal stoves (*left*, metal; *center left* and *center right*, ceramic), and three-stone fire stove (*right*).

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subcounties in the Wakiso district in central Uganda from 2011 to 2013. Of the 50 final household survey respondents, 48% reported owning a bicycle and 16% a car; 82% reported owning a television and 90% a radio. These are urban and periurban communities where a mix of wood, charcoal, and liquefied petroleum gas are used. Charcoal is the most common primary urban fuel in Uganda, used by 70% of households, with wood (~15%) the second most common; liquefied petroleum gas is the primary fuel in only about 8% of urban homes because it is generally too expensive for the majority of household (Ugandan Bureau of Statistics, 2010). Typical charcoal stoves in the study area were simple metal or ceramic stoves, with improved charcoal stoves such as Ugastove also relatively common. The wood stoves in the study homes were almost all three-stone fires (see Figure 1).

We designed a communication strategy and tested the interventions to address important behavioral factors related to cooking. These factors were identified using qualitative methods including focus group discussions, in-depth interviews, and a participatory workshop to identify the factors and design the interventions; as well as incorporating what is known from the published literature. To monitor and evaluate the activities used to introduce the new stove and how the TLUD was incorporated into daily cooking activities, we used qualitative and quantitative methods, including household surveys, focus group discussions, Stove Use Monitoring System monitoring, sales data, and a commercial viability analysis.

Participants and Procedure

Formative Research/Intervention Design

We conducted a formative assessment to inform the design of the interventions. We used qualitative research methods to better understand existing attitudes and practices related to new cookstoves, as well as opportunities and barriers for their introduction, acquisition, and use. The assessment included focus group discussions with mothers, fathers, and community health volunteers, as well as in-depth interviews with key informants (male and female health workers, community/district leaders, and government ministry staff).

We used the AirFOAM framework, an adaptation of SaniFOAM,[2] to identify potential behavioral factors related to acquisition and correct and consistent use of a new cookstove. The key factors were explored during formative research to inform the intervention design. AirFOAM is our adaptation of a framework that was developed to analyze behaviors in the water, sanitation, and hygiene sector, drawing from several behavioral theories (Devine, 2009). During the focus group discussions, we explored the key factors that we had identified in our AirFOAM theoretical framework to inform the design of interventions. By exploring the factors, particularly motivations and barriers associated with a behavior (e.g., for mothers, acquiring and using the improved or TLUD cookstove related to opportunity factors such as availability and access, knowledge, product attributes, and social norms[3]), we were able to identify communities' preferred communication channels and trusted sources of information. We also were able to gather information that helped us to choose the most effective BCC strategies, messages, and supporting activities.

Interventions

A stakeholders' workshop was held to share the formative assessment findings and solicit key stakeholder input. Participants included 28 stakeholders including VHTs, nongovernmental organizations, and key government ministries, such as the Ministry of Health's environmental department; the Ministry of Water, Lands, and Environment; and the Ministry of Energy and Mineral Development. We worked with the participants to apply the findings to develop a BCC strategy to promote the acquisition and correct and consistent use of new cookstoves, using the AirFOAM framework. The flexible, iterative method allowed for adding a supplementary element to the strategy during the intervention to address obstacles related to fuel preparation.

We worked with stakeholders to review the formative findings per target audience (primarily mothers and fathers) against the framework. Together, we developed a communication strategy that included the following: target audience, behavioral factors, strategic concepts, communication channels/intervention, and key messages. For example, to enhance mothers opportunity to purchase and use, findings around mothers not knowing where to purchase the stoves or if stoves were available (knowledge) led to the interventions of training community sales agents and developing promotional brochures. Many findings including mothers not knowing about the stoves, desiring certain stove attributes, and needing to know how to operate the stoves (knowledge, skills) led to the intervention of community cooking

[2]FOAM is defined as Focus on Opportunity, Ability, and Motivation and is a framework used in various consumer-facing sectors to analyze behaviors.

[3]Social norms address people's motivation to purchase an improved cookstove after seeing how it was used and how well it worked when a neighbor used one.

demonstrations. The demonstrations, conducted in community group settings, were also intended to address a number of other findings, including those around social norms.

On the basis of the communication strategy, we designed the following BCC interventions:

- Key educational messages on household air pollution and clean cooking provided by the VHT volunteers during routine visits.
- Community cooking demonstrations with the TLUD conducted by JEEP, a community-based NGO.
- Flyers on household air pollution and the benefits of clean cookstoves distributed by VHTs and sales agents.
- VHT referral to direct sales agents of households interested in purchasing a TLUD.
- Sales agents from the community trained in direct-sales approaches and in the benefits of TLUDs.

We trained 79 VHT members on risks of household air pollution and on key steps in correct use of the TLUD and trained 13 direct sales agents, one in each parish of these two subcounties. VHTs were offered stoves at a subsidized price, and many purchased the stoves; therefore, a proportion of the sales force were also early adopters of the new stove technology and could incorporate the user perspective into promotion and sales.

In the last few months of the intervention phase, two fuel processing interventions were added to address challenges in availability and processing of fuel for the stove, which were identified during monitoring to be the primary barriers to TLUD use. The intervention included encouraging community wood sellers to sell wood that was precut to be the appropriate size for the TLUD and selling saws to a group of participants to facilitate their own fuel processing.

Endline Data Collection and Analysis

A detailed household survey was conducted within the same communities before and after introduction of the wood processing intervention, surveying 50 households with the TLUD stove. The purpose of the surveys was to understand the effects of the behavioral interventions on the adoption and correct use of the TLUD cookstove, fuel use, and compatibility of the cookstove with current cooking practices over time. The sample was selected proportionally and conveniently from the parishes. Stove use monitoring surveys were conducted to assess stove use, perceived health impacts of the stove, perceived safety of the stove, perceived impacts on time and expenditure, nonusers of the stove, fuel measurements, and indoor air pollution (IAP) measurements.

Qualitative data were collected from eight focus group discussions and 10 in-depth interviews with VHTs, and women and men in the communities. This mixed-methods research allowed us to validate data from different perspectives and gain a deeper understanding of the opportunities, ability, and motivations to change cooking behaviors. In addition, the project conducted a commercial viability analysis at the end of the project. This included four components: profit-and-loss analysis; analysis of unit sales including the effect of price, promotions, and other factors; analysis of costs incurred; and, a breakeven analysis for a scenario including microfinance. As this Uganda intervention did not include microfinance, we used relevant assumptions from PATH's successful experience with microfinance-facilitated distribution of household water filters in Cambodia.

Fig. 2. iButton attached to the inside of the handle of a top-lit updraft in Uganda.

Stove Usage Monitoring

Assessing TLUD usage was done by Berkeley Air and their local partner, Center for Integrated Research and Community Development, Uganda, using the Stove Use Monitoring System, which employs temperature-logging sensors affixed to the stoves to determine when the stove is in use (Ruiz-Mercado, Canuz, & Smith, 2011). The sensors (iButton model DS1922T, Maxim Integrated, San Jose, CA; see Figure 2) were affixed to each of the stoves (traditional wood, intervention, and any other stove present) and onto the kitchen wall in a subset of study homes ($n = 29$). The Stove Use Monitoring System recorded the stove temperature every 10 minutes for the duration of the monitoring period, which lasted from April to August 2013. The resulting temperature profiles were then analyzed to determine the frequency of stove use events per day.

Results

Acquisition

A total of 205 TLUDs were sold, from October 2012 through June 2013 (see Figure 3), as per the weekly sales trackers from the direct sales agents. At the start of the TLUD sales in October 2012, we subsidized the price of the stove for the participating VHTs to acquire the stove they were going to promote, as an incentive for their participation. Of the 79 VHTs, 53 bought the stove at this subsidized price of $7.84. When we rolled out the sales to the community (November 2012 to April 2013), we sold it for the full price of $13.73. TLUD sales were dropping through January and February, reportedly due to school fees demands. In May 2013, we the lowered price to $9.80 to increase sales and have a sufficient sampling frame for the study. At this lower price, sales of the remaining inventory began to rise again.

The main motivations to acquire the TLUD mentioned by cooks were fuel savings, speed of cooking, money savings,

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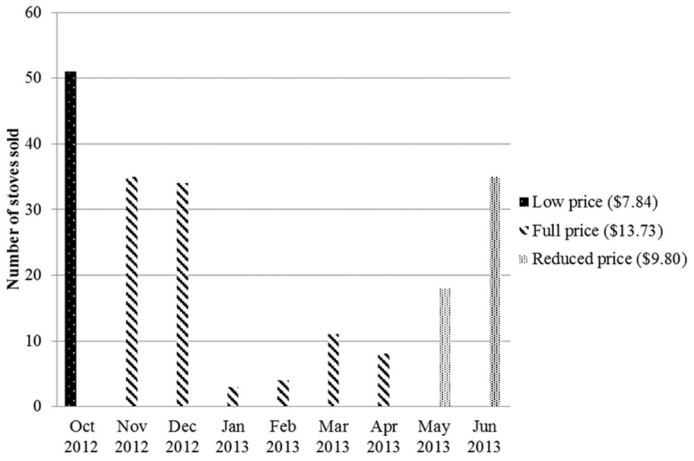

Fig. 3. Top-lit updraft stove sales by month (sales tracking data).

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reduced smoke/health benefits, and the production of charcoal by the stove. Cooks also felt that the clean burning and the increased freedom from not having to refuel the stove contributed to its appeal. Community cooking demonstrations, according to focus group discussion results, were influential and motivated people to purchase stoves, while BCC print materials were perceived as not effective by cooks:

> It [TLUD] saves fuel, cooks very fast, and there is no need to add firewood during the cooking session. (Cook, Kira)

During the formative research, social drivers identified as motivational to buying improved cookstoves included neighbors having a new stove so the potential buyer can first see how well it works and how it is used before deciding to purchase. However, during the household survey, the aspirational (product design features and function that appeal to users and create a demand for a new and improved quality of life, regardless of the product's affordability) or aesthetic features of this stove did not emerge as key factors in influencing adoption.

The relatively high price of the TLUD (40% more than the Ugastove rocket stove, another new cookstove that reduces fuel consumption) sharply limited sales and demotivated many VHTs and sales agents. People were willing to pay the equivalent of US$8 to $10, but most were not willing or able to pay US$14, the TLUD price. Many of the 120 TLUD users, including VHTs, who purchased TLUDs between October and December, were experiencing significant challenges in obtaining and/or processing wood for the TLUD. They may have expressed their dissatisfaction to community members, thereby dissuading other potential buyers:

> The [TLUD] cost is high; when people are told about the cost of 35,000 [Ugandan] shillings, they exclaim. Some people have proposed to buy it between the range of 25,000 shillings and 30,000 shillings. (Cook, Sabagabo Makindye)

> Some people who bought the [TLUD] but did not get firewood have not used the stove because of the difficulty in getting the firewood. (VHT member, Kira)

Data on willingness to pay was collected from the community during community cooking demonstrations and focus group discussions. Second, by offering the stove at a few different price points over the course of the study, we were able to gather "observed willingness to pay." The responses were consistent; people were willing to pay US$8 to $10 for the TLUD.

PATH conducted a commercial viability assessment of the TLUD and sales approach. It was not possible to sell the TLUD in appreciable quantities for as much as it cost to obtain at wholesale from the manufacturer; which resulted in negative gross profit of $873 on the 199 stoves sold, or $4.39 loss per unit. The actual operating loss was far greater ($70,110) because this figure includes sales, general, and administrative costs allocated to the direct sales effort. More than two thirds of the $69,238 cost was incurred during the setup phase before the start of sales ($46,447). After sales commenced, ongoing operating costs ran at a level greater than 10 times that of revenues ($22,791 versus $1,533). The costs were not unreasonable and compare favorably to costs incurred by PATH and partners in pilots of household water filter distribution, which developed a successful model that has been scaled commercially in Cambodia (PATH, 2012). Sales responded primarily to changes in price, fuel availability, and entrepreneurship. To evaluate whether an alternative sales/distribution model for the TLUD in Uganda might be viable, PATH performed a breakeven analysis for a hypothetical microfinance-enabled model featuring consumer-financing with relevant assumptions taken from the aforementioned successful experience in Cambodia. Consumer financing—and especially low installment payments, at a reasonable interest rate—can significantly boost affordability and sales (PATH, 2012). Unfortunately, the breakeven analysis showed that even with microfinance the TLUD model used in this study would not be commercially viable. To achieve breakeven the TLUD would need to be priced at least $18 (46,300 UGX; inclusive of financing charges, which are reasonable and largely offset by selling and distribution efficiencies) and the resulting monthly installments would be around $3.50 (7700 UGX/month) for six months, which compares unfavorably to the price of available substitutes such as the Ugastove (20–25,000 UGX total) and various charcoal stoves (2,000 to 8,000 UGX) popular in the community. This analysis does not factor in the additional cost to the household of pre-processed wood.

Correct and Consistent Use

The practices required to use the TLUD correctly were observed to be used by almost all TLUD users surveyed during the pre and post surveys. The main cooks were provided with firewood appropriately cut for the TLUD and were requested to demonstrate the different steps of stove operation: loading, lighting, controlling the fire, and harvesting charcoal from the TLUD. Most of the household cooks

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demonstrated correct use of the stove at the first survey. All but one of the 29 users who were observed during the second survey were able to perform these steps correctly (see Table 1). Whether these behaviors were consistently used during normal use is unknown, but the participants had the skills and knowledge required to use the TLUD correctly.

According to focus group discussion responses, the most influential factors for purchase and correct and consistent use of the TLUD were community cooking demonstrations (see Figure 4), and training and promotion of stove use by VHTs. The cooking demonstrations provided participants the opportunity to ask questions about the novel stove technology as they observed. More important, the demonstrations allowed community members to witness the process of loading, lighting, and cooking on a TLUD. Communities were able to see its special fuel requirements (i.e., the TLUD combustion chamber needs to be completely filled with appropriately and evenly sized pieces of dry firewood), the stove being lit from the top, intensity of the flames, cleanliness of the burning, speed of cooking, and harvesting of charcoal after cooking. Between 10 and 30 people attended each of the 30 cooking demonstrations and 1 to 10 stoves were sold at the end of each demonstration. Participants reported the stove benefits as motivations for using the stove, including speed of cooking, fuel savings, reduced smoke, and production of charcoal.

The greatest reported barriers to consistent use of the TLUD noted in the household surveys were access to and cost of dry wood (in time and money). Surveys showed a modest adoption of the TLUD stove, with 62% of respondents estimating that they used it at least once during the week before the survey. Also, 27% reported using the TLUD stove 6–7 days per week, and slightly less than half of the respondents reportedly used it only 2–3 days per week.

Results from the Stove Use Monitoring System, which tracked usage with temperature sensors for 18 weeks, suggest a far lower level of TLUD uptake and use compared with that reported (see Figure 5). Traditional wood and charcoal stoves were used for more than 90% of cooking events, while the TLUD stove provided 7% of cooking events. This translates to an average of 0.1 to 0.2 TLUD stove uses per day or approximately one use per week, although some individual homes showed higher usage. The discrepancy between reported and measured stove usage may be due to participants wanting to respond positively questions regarding TLUD usage.

There did not appear to be any substantive change in TLUD usage rates over time. Higher rates in TLUD stove use were not observed just after acquisition, suggesting that the novelty of the new technology was not a factor in at least initial increased usage. Nor was TLUD usage affected during household surveys in these homes (period indicated by the blue shading in Figure 5), suggesting that visits by the enumerators did not influence which stoves were used. Another factor that could have affected stove usage was the physical presence of the Stove Use Monitoring System iButtons on the stoves. However, given their relatively unobtrusive nature (see Figure 2) and the low TLUD usage rates measured using the Stove Use Monitoring System, their presence would be an unlikely cause for increased TLUD use:

> My husband can afford to sit with me as I cook because the TLUD stove does not emit smoke, and we can conduct a discussion. I find this very exciting. (Cook, Sabagabo-Makindye)

TLUD use was limited in part because of incompatibility with some household cooking practices; the survey findings

Fig. 4. Group stove demonstration.

Table 1. Observed correct use of the top-lit updraft stove

Observation of correct use of the top-lit updraft stove	First survey ($n = 22$)	Second survey ($n = 29$)
The fuel used	22	29
How to load the batch	20	29
How to light the stove	20	29
How to control the fire	20	28
When to harvest the charcoal	20	29

Note. Data collected from household surveys.

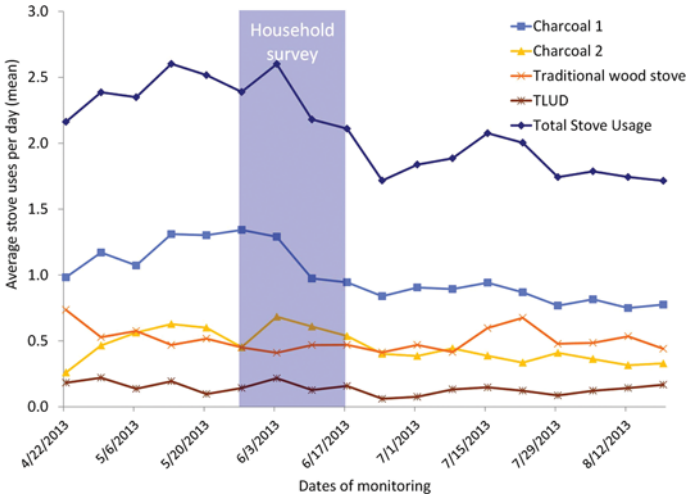

Fig. 5. Household stove usage over time (Stove Use Monitoring System data). TLUD = top-lit updraft.

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showed mixed results for the TLUD's ability to cook important staple foods. Of the survey respondents, 13% reported that a common local dish, *matoke* (steamed bananas), was particularly difficult to cook on the TLUD stove because of issues with keeping the fire at a constant low power for the 1 to 2 hours it takes to cook. With reports showing that these dishes are cooked on a regular basis, some more than five times per week, it suggests that these households were required to use a stove other than the TLUD frequently to meet their cooking needs. All households reported practicing stove stacking, using the TLUD stove in combination with another stove or stoves (see Figure 5). Households used different stoves for different purposes.

During the field visits by the study team and from observing the decrease in stove sales, it became clear that household usage of and satisfaction with the TLUD were generally low due to significant challenges in obtaining and/or processing wood or locating low-cost biomass (e.g., corncobs or nut shells) for the TLUD. The study team decided not to increase the intensity of promoting TLUDs for purchase by low-income households absent a solution to the fuel accessibility/processing problems:

> If we can get someone to cut and sell [TLUD] firewood, most challenges would be solved. (Cook, Kira)

At this point, from March to June 2013, the team focused on interventions to increase fuel availability in two parishes where entrepreneurial and effective sales agents had emerged. The team then tested a lower stove price level in these areas—in part to sell off inventory. At this lower price and with fuel access interventions, stove sales began to increase (see Figure 3 and Figure 6).

Increasing access to processed fuel resulted in a 42% relative increase in TLUD usage among groups that had access to preprocessed fuel or a bow saw for cutting wood (see Figure 7). While the relative increase was notable, the absolute usage level was still low. Moreover, this intervention was time-limited and the numbers monitored were very small.

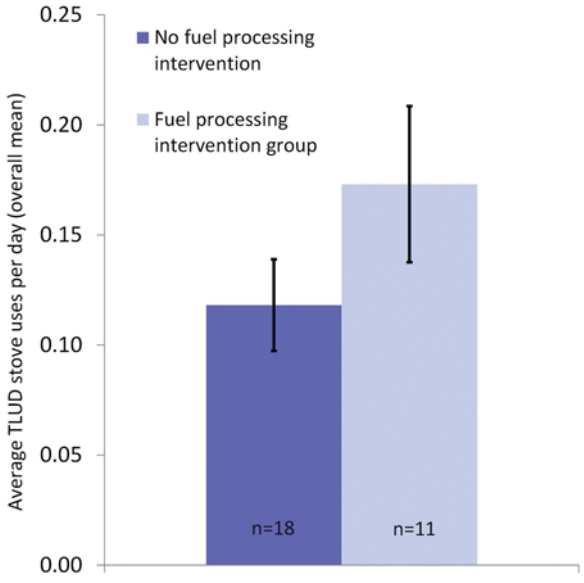

Fig. 6. Top-lit updraft (TLUD) stove use by fuel processing intervention (Stove Use Monitoring System data).

Fig. 7. Top-lit updraft firewood seller chopping wood with machete.

Discussion

Acquisition

Community cooking demonstrations are a powerful strategy to motivate people to purchase the TLUD. Demonstrations lend themselves well to showcasing the benefits of the stove, if people are willing to wait through the process of loading and lighting. Having a person skilled at engaging the audience during this sometimes lengthy process can be useful. Observers become champions when they see the clear flame, lack of smoke, the speed at which food such as beans are thoroughly cooked, and the production of a substantial quantity of glowing charcoal. However, the substantial price barrier to acquire the TLUD combined with the need to spend more time and effort processing wood, or money to purchase a saw or pre-processed wood effectively eliminated the cost savings from its fuel efficiency.

The strategy of engaging VHTs both as information sources and, in some cases, sales agents, played a role in raising community awareness about the risks of HAP, the benefits of improved cookstoves, and where the TLUD could be purchased. Because many of the VHTs had purchased TLUDs at a low price ($7.84) at the start of the intervention phase, they were able to speak from experience about the stove. This could have been a positive or negative in terms of sales, depending on their success with using the TLUD. The highest rate of TLUD sales at full price ($13.73) occurred immediately after the VHTs purchased theirs at a discount.

Sales did not increase until the price dropped again ($9.80) and wood processing interventions were initiated.

The direct sales intervention requires focused technical assistance for at least nine months in order to support the local partners. Stove sales were higher among the several direct sales agents who demonstrated entrepreneurial approaches including providing a financial incentive to VHTs for referring clients who purchased a stove.

The commercial viability analyses showed the TLUD stove used in this project not to be commercially viable in Uganda, with or without microfinance. Ultimately, the relatively high cost of manufacturing the TLUD used in this study rendered it too expensive to sell in this market, even before considering the added cost of fuel. It was notable that the TLUD's price was effectively constrained, in part, by the price point for improved cookstoves already established by the Ugastove rocket stove (20-25,000 UGX)—despite sales messages and cooking demonstrations of the TLUD's superior fuel efficiency. Consumers, VHTs, sales agents, and other stakeholders regularly provided clear feedback that the original price of the TLUD (35,000 UGX) was too high—and suggested the TLUD be priced at no more than the Ugastove's price range of 20-25,000 UGX.

Correct and Consistent Use

TLUDs are a promising technology because they can have excellent fuel and emissions performance, as well as cook quickly, and produce charcoal (Biomass Energy Foundation 2009; Jetter et al., 2012). These benefits, however, are only realized if the stove is used correctly and often, which posed an important behavior change to address. The anticipated behavioral challenges of correct loading, lighting, and cooking with a TLUD were not the primary barriers to use, as virtually all the 29 people observed using the stove were able to complete these steps. The lack of prepared/sized wood was the greatest barrier to use. The stove is sensitive to damp wood and can be difficult to light if wood is not dry. The sensitivity to high wood moisture content is likely to be a major challenge in many settings with rainy seasons.

These stoves are not practical for boiling water or for other shorter cooking events, since the combustion chamber needs to be filled up and allowed to burn out completely before reuse. The stove, however, was reported to work well for certain foods such as beans and some other staple foods, which cook much faster on this stove than on a three-stone fire or charcoal stove. Although this study evaluated a TLUD that was already in the marketplace, the challenges of cooking staple foods such as *matoke* bananas with this stove highlight the importance of codesign with cookstove users (where user behavior and needs are incorporated into the stove design from the beginning). A fundamental requirement is that the product be desirable to the end user in terms of utility, cultural appropriateness, aesthetics, and perceived improvement over the old stove (e.g., see Rehfuess, Puzzolo, Stanistreet, Pope, & Bruce, 2014; Shrimali, Slaski, Thurber, & Zerriffi, 2011; Simon, Bailis, Baumgartner, Hyman, & Laurent, 2014; Stanistreet et al., 2014). This generally requires tailoring the stove design for different target audiences (e.g., see Simon et al., 2014). Overall, the price of the stove and its role as a niche product became disincentives for most users to train other members of the household in the unique set of steps to load and light the stove, control the flame, and harvest the charcoal.

Conclusion

TLUDs are appealing because they cook quickly, use wood efficiently, reduce smoke, and produce charcoal. However, the price barrier to acquire the TLUD, combined with the opportunity costs to prepare wood, and the actual costs to purchase processed wood, effectively eliminate the cost savings from the cookstoves' fuel efficiency. Those who did use the TLUD consistently still used other stoves for more than 90% of their cooking events. The barriers to its purchase and consistent use were difficult to overcome, even with the behavior change interventions, and thus the TLUD did not become a meaningful part of most households' cooking patterns. The TLUD manufacturer might consider product modifications to better meet the cooking preferences and patterns in Uganda, particularly the need to steam a staple food, *matoke* (steamed banana) if they hope to have a more commercially viable/popular product. These modifications would need to be possible, without compromising the improved qualities of the stove.

The TLUD, as it is currently designed, is likely not commercially viable in Uganda. The relatively high cost of fabrication rendered it too expensive for this market, even without the added cost of preprocessed wood. Increasing access to pre-processed wood did increase TLUD usage, though the absolute usage levels remained low. Improved cookstoves should be designed for manufacture at a target cost sufficiently low to allow for sustainable scale-up at an affordable retail price, using carefully vetted assumptions. To assist with the adoption of TLUD stoves, fuel processing technologies are critical, as they ease the work of stove users. These could include motorized saws to split firewood into the recommended sizes. These saws would be set up at fuel supplier's points of sale to increase processing speed and hence delivery of quality fuels to the users.

Despite the challenges presented by the stove, engaging the community from the start is an important model for behavior change. Community members had more awareness of and investment in the project because they helped to design the interventions. VHT volunteers continued to be cited as the reason people knew about the benefits of improved stoves and the dangers of household air pollution. However, it is important to identify and follow selection criteria for direct sales agents, while still considering input from community members. Community members such as VHTs can be supported to become successful sales agents, with sufficient time and technical assistance to build skills.

The community cooking demonstrations are important for both acquisition and correct use of improved cookstoves because they address a number of knowledge, skill and behavioral factors including social norms. The demonstrations effectively convey stove benefits and allow observation of correct stove use. Having a person who is both knowledgeable

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about the stove's attributes and skilled at engaging the audience during this sometimes lengthy process is important. Given a different technology, but with similar performance and lower cost and behavior change barriers, the community engagement model could help facilitate increased acquisition, and correct and consistent use.

Limitations

The study has important limitations to consider for properly contextualizing the results presented. In particular, these data represent snapshots of outcomes and effects that were measured in a limited number of periurban locations among certain demographic groups that are deemed likely to benefit from the introduction of innovative biomass cooking technologies. Their applicability in other contexts would need to be tested before generalizing to wider audiences.

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