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Integrate and mobile solution for low-cost cooking and power generation for African rural areas

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Aim and approach used. Rural energy needs have been met by biomass for many centuries, albeit in a traditional way, which is associated with high per capita fuel use/low thermal efficiency, health risks (smoke inhalation and fire risks) [1]. In this context, the objective of the LEAP-RE Smart Home Africa (SHE) project is to propose and optimize an affordable smart energy device, flexible in terms of feedstock, that can provide electricity and cook/heat to support grid independence and self-sufficiency.

The proposed device is based on an existing portable micro-gasifier cookstove used with compressed wood pellets, which is currently the best performing cookstove available regarding CO emissions [2]. However, the use of wood as fuel is problematic because of the natural deforestation due to the use of harvested wood as the primary fuel.

The objective of the present study in the framework of the SHE project is assessing the suitability of agricultural residues and perennial energy crops as feedstock for the cookstove, as they are affordable and readily available fuels. The conformity of using alternative biofuels in the cookstove must be checked, particularly in terms of WHO (world health organization) cooking standards related to emissions and efficiency.

For this purpose, three reference biomass (wood, miscanthus and rice husk pellets) will be characterized into detail as reference biomass species. Secondly, agricultural wastes from Western Nile Region will be characterized to determine if they meet ISO recommendations. They will be also compared to the reference biomass species to identify common patterns allowing the prediction of their emissions as a function of their characterization. Then, the reference biomass species will be tested in the cookstove and their emissions will be characterized into detail (permanent gases, tars, water, particle matter).

Scientific innovation and relevance

More than 45% of Africa's population lives in isolated rural communities and over 70% without adequate access to electricity. In addition, the chores related to the use of open fires or inefficient stoves and fuels often disproportionately affect women and children, particularly girls. The use of an optimized portable micro-gasifier with agricultural residues pellets can reduce health risks, deforestation and gender inequalities in South Africa and Uganda.

Preliminary results and conclusion

The cookstove was successfully developed in a previous study using a combined experimental approach and extensive CFD analysis [2]. CO emissions measured using wood in the cookstove were below 200 mg.MJ_{del}⁻¹, which were already below WHO standards (<300 mg.MJ_{del}⁻¹) and were 15 to 20 times below the basic forced draft stove concept [2]. Ongoing experiments will determine the key parameters to optimize the cookstove and the suitability of the selected biofuels, which should meet cooking standards for combustion efficiency (≥40%), safety score (≥86), durability score (<15), fine particle matter (≤62 mg. MJ_{del}⁻¹).

To conclude, around 2.7 billion people worldwide do not have access to clean cooking equipment, which leads to major health problems due to high emissions. This study aims proposing the best fuel to substitute wood pellets, in terms of emissions and efficiency, by considering agricultural residues and energy crops highly available in rural areas. The use of an optimized portable micro-gasifier with agricultural pellets can reduce health risks, deforestation and gender inequalities in South Africa and Uganda.

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Integrate and mobile solution for low-cost cooking and power generation for African rural areas **EXPLANATORY PAGES**

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Material and methods

The proposed device consists of a top-lit updraft gasifier (TLUD) cookstove operated with a fan for forced draft (FD) air supply and designed for pellets. It results in high energy density and homogenized combustion properties of the fuel. The figure 1 shows the operating principle of the cookstove. The stove is operated in batch mode, pellets filling and flame ignition are done from the top. In the developed stove, 4 steps are allowing the minimization of pollutants emissions, (i) drying with water evaporation, (ii) pyrolysis responsible for the conversion of the biomass into volatiles, (iii) combustion of the remaining carbon from pyrolysis oxidation into CO (carbon monoxide) and CO₂ (carbon dioxide), and finally (iv) gasification i.e., cracking of tars molecules to lighter gases, condensable tar and char, and steam.

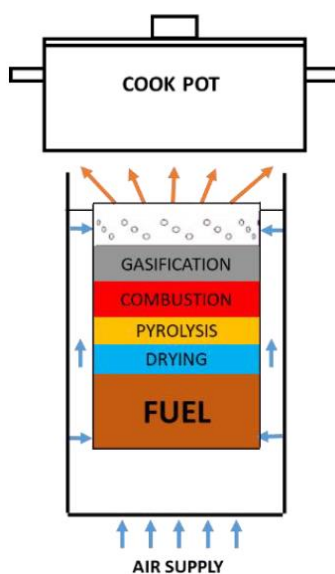


Figure 1: Cookstove operating principle

The aim of this study is to:

- Substitute wood pellets with available agricultural residues and perennial energy crops as affordable and readily available fuels.
- Check the conformity of using the selected biofuels in the cookstove in terms of WHO (world health organization) cooking standards related to emissions and efficiency.

For this purpose, three biofuels will be investigated as reference fuels: softwood, rice husk and miscanthus pellets. They were selected due to their availability, representativeness of the biofuel diversity, namely woods, crop residues and energy crops. The pellets will be characterized in terms of proximate and ultimate

analysis according to standards methods [1], as well as of thermal behaviour using thermogravimetric analysis (TGA).

Agricultural wastes from Western Nile Region (i.e. maize stalks, sugarcane bagasse, coffee husks...) will also be selected to represent the diversity of the local resource. They will be then characterized in the lab so as to compare them to the reference resources and to determine their suitability to be used in the cookstove.

Biofuel emissions evaluation will be performed in the optimized cookstove [2] in terms of fine particles, permanent gases, polycyclic aromatic hydrocarbons (PAHs) and dioxins in water boiling tests according to ISO 19867-1:2018 standards [3]. The Figure 2 illustrates the experimental rig principle.

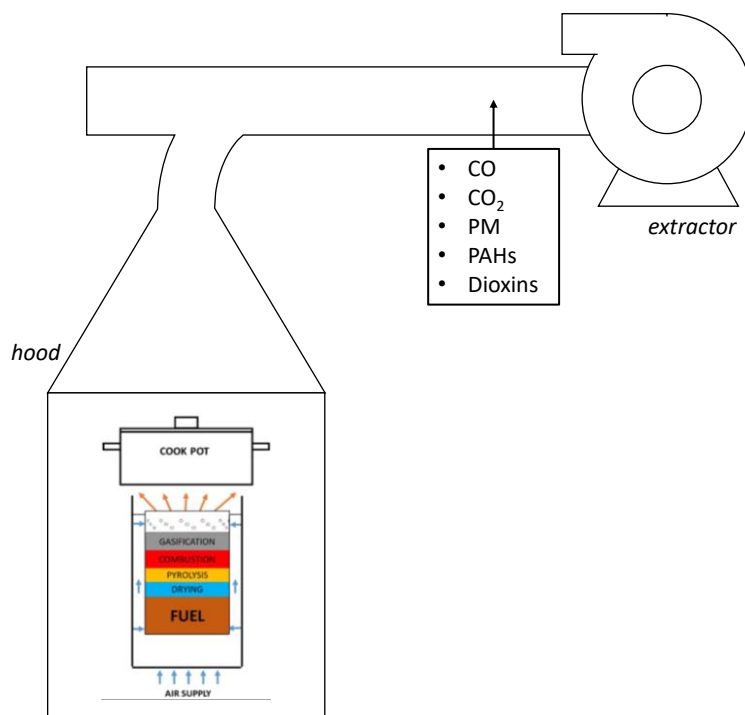


Figure 2: Principle of the experimental rig for gaseous emissions measurement

Preliminary results

Preliminary results from the literature show that wood and miscanthus pellets are in agreement with ISO 17225-6 specifications (Table 1). However, when dealing with agricultural biomass, some parameters may be problematic, such as ash content in risk husk pellets.

Table 1: Average fuel properties and specifications of the ISO 17225-6 standard

Parameters	Wood pellets [2]	Rice husk pellets [2]	Miscanthus pellets [4]	ISO 17225-6 standards [5]
Moisture (%)	7	7.5	8	≤ 10
Ash content (%)	0.5	16.7	2.1	≤ 7
Total Kjeldahl Nitrogen (%)	0.1	0.4	0.28	≤ 0.7
Net Calorific Value (kcal.kg ⁻¹)	4063	3107	3824	3511 to 4538

Future experiments will allow to characterize the selected reference and local biomass and determine if the optimized cookstove and 3 selected biofuels can meet cooking standards, namely combustion efficiency, fine particle matter emissions, safety score, durability score and CO emissions.

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