UTILISATION OF EFFICIENT BIOMASS ENERGY TECHNOLOGIES AND BIOFUELS FOR DOMESTIC AND INDUSTRIAL USE IN UGANDA

Technical Report FY 2013/2014
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1.1 Background

Uganda features a high deforestation rate of about 2.2% (Nampewo, 2013) and heavily depends on biomass (over 90%) as energy source (MEMD, 2009). Petroleum which is currently imported accounts for 6% of Uganda's energy consumption (REA, 2011) and the recent discovered oil is expected to last less than 30years (Okupa, 2012). Urban and rural dwellers use predominantly metal charcoal stoves and traditional three-stone stoves, respectively, at efficiency less than 10% (Okello et al., 2013). This puts Uganda's forests and its growing population (3.32%/year) under tremendous pressure. Therefore adoption of improved biomass cook stoves and use of bio-fuels such as *Jatropha oil (Jatropha curcas)* and castor oil *(Ricinus communis)* could conserve energy and reduce environmental degradation.

Jatropha curcas and *Ricinus communis* as energy crops have been found to have the potential for biodiesel production elsewhere (Bonjean & Le-Recin, 2002; Okullo et al., 2012). These two energy crops have however not been evaluated in Uganda. *Jatropha curcas* has rapidly established a niche for itself within the agriculture and energy industry in Uganda, though the current production is not well understood. The private sector entrepreneurs are establishing *Jatropha* plantations in Karamoja and Masindi sub-regions but with no scientific production information in support of the business enterprise. *Ricinus comminis* is also increasingly being promoted for biodiesel due to its high oil yield and relatively low water requirements like *Jatopha*. Castor has many industrial, medicinal, and automotive uses, including: aircraft lubricants, hydraulic fluids, explosives, dyes nylon and many others (Bonjean & Le-Recin, 2002). Castor and *Jatropha* biofuel crops are perceived as not competing with food production because they are inedible (which makes them suitable for pesticides) and can be grown on marginal lands and thrives in waste lands as a potential contribution to the rehabilitation of degraded land (Fitzgerald, 2007). It is therefore, important to understand yield seed provenances, their general agronomic performance, oil quality and quantity and product usage from the bio-materials and plan for their detoxification.

The aim of the study therefore, is to evaluate the utilization potential of efficient biomass energy technologies and biofuels for domestic and industrial use in Uganda. The project specific objectives are to:

i). Determine efficiency and acceptability of improved biomass energy technologies
ii). Determine the physico-chemical properties and energy potential of J. curcas and R. Communis for biodiesel production in Uganda.

1.2 Key activities for FY 2013/2014

i) Strategic random home visits, administering of questionnaires and Key Informant Interviews
ii) Kitchen Performance Test (KPT)
iii) *Efficiency testing: Water Boiling Test (WBT)*
iv) *J. curcas* and *R. Communis* seed collection from Nebbi District.

1.3 Methodology

1.3.1 *Performance testing of coking stoves: The Kitchen Performance Test (KPT) and Water Boiling Test (WBT)*

The KPT is used to demonstrate the effect of stove interventions on household fuel consumption, whereas WBT provides a range of stove performance indicators: thermal efficiency; fuel consumption, and time to boil a fixed quantity of water. Daily measurements of fuel consumption were made in a representative sample of households using traditional stoves and Improved Cooking Stoves (ICSs) over an extended period of time (3-7 days). Because fuel consumption is weighed directly, the KPT was the preferred method of quantifying the ICS's impact on household fuel use.

1.3.1.1 *Study design and sample size*

The study was conducted in Mbale District located in Eastern Uganda, Nebbi and Adjumani Districts located in West Nile. Nearly the entire population in the Districts relies on biomass fuels for cooking, which is typical of rural Uganda. Cross-sectional design was employed in data collection (Figure 1). This design compared fuel use between households with ICSs (n = 25 for Mbale District, n = 20 for Nebbi District and n = 20 for Adjumani District) and households with traditional three-stone stoves (n = 11 for each of Mbale, Nebbi and Adjumani Districts). The sample of households that participate in the test was selected randomly from among the target population in order to obtain unbiased results. Participants in the cross-sectional study had self-purchased the improved cooking stove

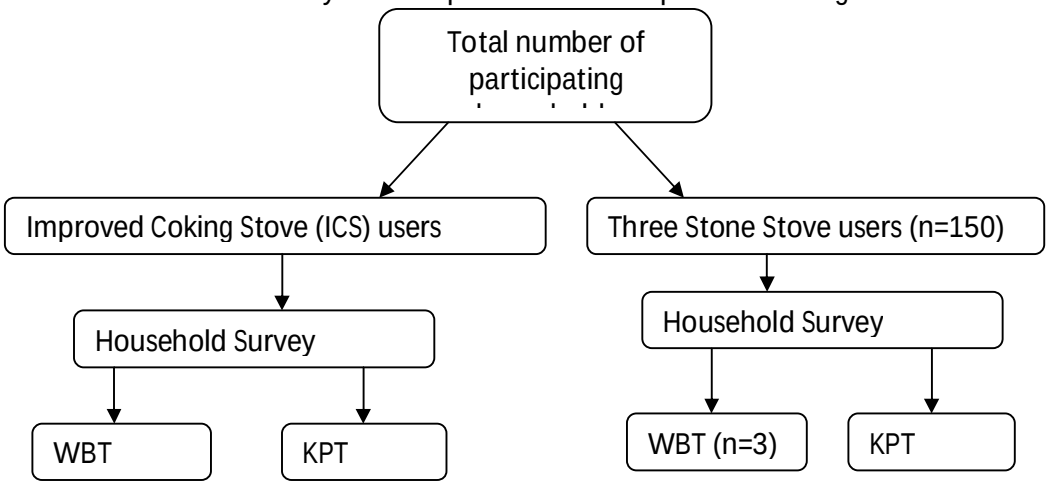


Figure 1: Sampling approach employed in the study.

The KPTs and WBTs were conducted for 6 days in Mbale District, from 3rd to 9th March 2014 and 12 days in Nebbi and Adjumani Districts, from 17th to 29th June 2014. During this period, we also collected baseline information of the study households including demographic, socio-economic, fuel and stove usage patterns using interviewer administered semi-structured questionnaires.

1.3.1.2. Fuel use measurements

Our KPTs were based on two days of repeat fuel use measurements in a relatively large sample size, thereby limiting the influence of inter-household variability. As part of the experimental protocol, participants prepared three batches of fuel enough for 3 days of cooking, based on their typical fuel requirements. On the first day of the tests, the three batches of fuel were weighed on a spring balance. The weight of each batch was recorded, with the third batch serving as a spare batch. We also estimated the fuel moisture content, i.e. the amount of water contained in wood as a percentage of the mass of the oven dry wood. The moisture level was obtained using pin-type electrophysics moisture meter (protimeter Mini BLD2000) with an electronic sensor for wood moisture level, displayed on the instrument's screen upon contact of the pin points with wood. Because wood pieces in the batches were not similar, we obtained an average reading of 3 pieces of wood in each fuel batch. On the second day of the tests, the fuel that remained from the first day was weighed and the difference recorded as the day's fuel consumption. The same procedure was repeated on the second day.

All our analyses were based on fuel consumption in kg per day, obtained by averaging fuel consumption for the 2 days of measurement.

1.3.1.3. Efficiency testing: Water Boiling Test (WBT).

We also conducted the WBT on three stone stove and improved cooking stoves, where the test was repeated three times for each stove using a low power test. In this study, we report two performance indicators that are of particular importance to end-users and stove designers: fuel consumption per unit of water boiled, and thermal efficiency. Specific consumption (SC) is defined as the ratio of the mass of fuel consumed to the volume of water heated for each cooking task (after 45 minutes at, or just below, the boiling point) and is measured in grams (g) of fuel per liter (l) of water; whereas thermal efficiency is the ratio of the work done by heating and evaporating water (at a constant temperature) to the energy embodied in the fuel.

1.3.2 J. curcas seed collection from Nebbi, for oil quantity and quality analysis

Both grown-up yellow and dried fruits of *J.curcas* were collected from 12 accessions from Nebbi district. Fruits/seeds were collected from at least 30 trees in the same population spaced at least 10 to 15 m and randomly selected to ensure unbiased genetic variability. In this study, the accession represented fruits/seeds collected from trees in the same life area or from isolated trees in the same garden or village. Trees were at least 3-6 years old. Accessions were distant each other at least 20-30 km in different sub-counties. Fruits/seeds were labeled to keep identity of each accession. The collection sites coordinates were recorded using the Global Positioning System for point mapping. Fruits/seeds were air dried

at Research Laboratory in Kifu until constant weight under similar conditions of temperature and humidity were realized and kept for Laboratory analysis.

1.3.3 Outputs/Results

Thermal efficiency and energy consumption of 5 commonly used domestic biomass energy technologies (Lorena stove, Molded 1-pot mud stove, trench fire, brick stove, three stone stove) from Eastern Uganda and west Nile were determined using WBT and KPT (Table 1).

Table 1: Performance of Improved cooking wood stoves Vs traditional three stone stove (n = 3)

stove	performance indicators	WBT		KPT	
		Mean	SD	Mean	SD
Lorena stove	Specific fuel Consumption (g/l)	195	25		
	Thermal efficiency (%)	14%	2		
	Fuel Consumption (MJ/cap)			33	5
Molded 1-pot mud	Specific fuel Consumption (g/l)	155	21		
	Thermal efficiency (%)	16%	3		
	Fuel Consumption (MJ/cap)			28	15
trench fire	Specific fuel Consumption (g/l)	227	20		
	Thermal efficiency (%)	13%	5		
	Fuel Consumption (MJ/cap)			37	9
brick stove	Specific fuel Consumption (g/l)	128	19		
	Thermal efficiency (%)	17%	3		
	Fuel Consumption (MJ/cap)			24	14
three stone stove	Specific fuel Consumption (g/l)	310	35		
	Thermal efficiency (%)	9%	1		
	Fuel Consumption (MJ/cap)			53	9

Results show that average performance (thermal efficiency and energy consumption) of brick stove (17%; 24MJ/cap) is better than Molded 1-pot mud stove (16%; 28MJ/cap), 2-pot Lorena stove (14%; 33MJ/cap), trench fire stove (13%; 37MJ/cap) and three stone stove (9%; 53MJ/cap) (Figure 2).

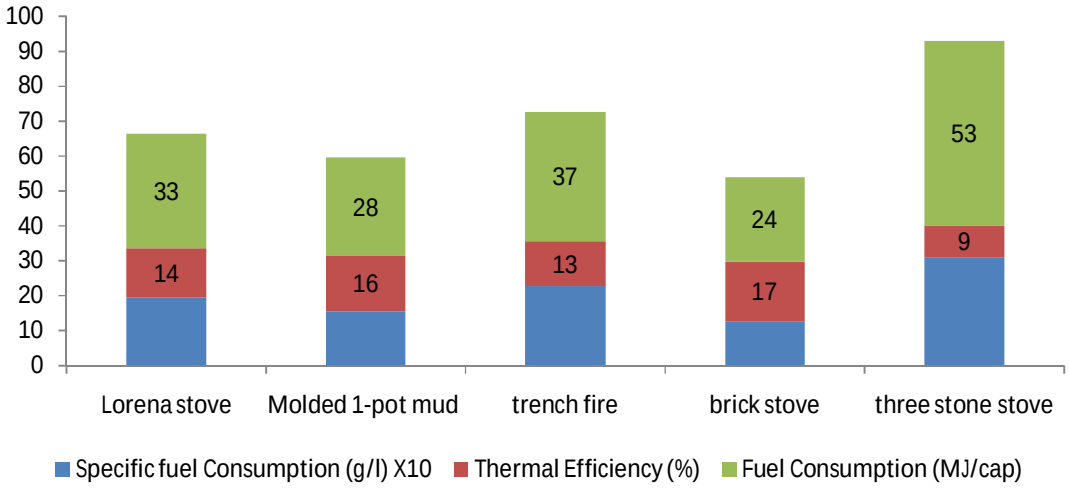


Figure 2: Performance comparison of Improved wood stoves and traditional three stone stoves (n = 3 for each stove)

The level of adoption of improved biomass energy technologies (other than traditional three stone stoves) is 45% in rural households of West Nile and 32% in Eastern Uganda. The study revealed that adoption of improved technologies reduces with proximity to protected areas.

During the FY 2013/2014, about 55kg of J. curcas germplasm from Identified and marked mother trees in Nebbi District was collected for oil quantity and quality analysis. It was observed that J. curcas seed traits depicted a High variability among the accessions. 100 seed weight ranged from 60.44 to 79.43 g (dry weight).

1.4 Gaps

i. The results presented are based on preliminary data analysis. Comprehensive data analysis is still ongoing which will unveil more findings of the study.
ii. Energy saving technologies were not Identifeid and their performance indices not determined in L. victoria crescent and Southwestern AEZ.
iii. *R. Communis* seed collection was not done due to mismatch of harvesting seasons and release of funds vis-a-vis annual work plan.
iv. Oil quality and quantity of *Jatropha curcas* was not analysed for biodiesel production
v. J. curcas and R. communis Seeds were not collected from Western and Southwestern AEZ; Oil quality and quantity not yet determined

1.5 Planned activities/outputs for 2014-15

Quarter 1	Quarter 2	Quarter 3	Quarter 4
1. Efficiency performance indices of biomass energy technologies determined in institutions in Mukono district.	1. Efficiency performance indices of biomass energy technologies determined in agro-based industries in Lake Victoria crescent	1. Efficiency performance indices of biomass energy technologies determined in chemical processing industries in Eastern AEZ	1. Efficiency performance indices of biomass energy technologies determined for domestic use acquired for demonstrations.
2. Atleast 50 kg of J. curcas seed collected from eastern AEZ, Oil extracted	2. Atleast 50 kg of R. communis collected from L. Victoria AEZ, Oil extracted	2. J. curcas and R. communis Seeds collected from Western and Southwestern AEZ, their oil quality and quantity determined	2. J. curcas and R. communis Seeds collected from West Nile, their oil quality and quantity determined

Activities	Activities		Activities
Surveys in industries and institutions; Water Boiling Test (WBT) and Kitchen performance tests; Collect seed, oil extraction (Automatic Solvent Extraction)	Surveys in industries and institutions; Water Boiling Test (WBT) and Kitchen performance tests; Collect seed, oil extraction (Automatic Solvent Extraction)	Surveys in industries and institutions; Water Boiling Test (WBT) and Kitchen performance tests; Collect seed, oil extraction (Automatic Solvent Extraction)	Surveys in industries and institutions; Water Boiling Test (WBT) and Kitchen performance tests; Collect seed, oil extraction (Automatic Solvent Extraction)

1.6 Budget

Output Target Qtr 1	Budget Qtr 1 '000	Output Target Qtr 2	Budget Qtr 2 '000	Output Target Qtr 3	Budget Qtr 3 '000	Output Target Qtr 4	Budget Qtr 4 '000	Source
Efficiency performance indices of biomass energy technologies determined in institutions in Mukono district.	8,500	Efficiency performance indices of biomass energy technologies determined in agro-based industries in Lake Victoria crescent	11,727	Efficiency performance indices of biomass energy technologies determined in chemical processing industries in Eastern AEZ	10,700	Efficiency performance indices of biomass energy technologies determined for domestic use acquired for demonstrations.	12,300	ATAAS
Atleast 50 kg of *J. curcas* seed collected from eastern AEZ, Oil extracted	7,700	Atleast 50 kg of *R. communis* collected from L. Victoria AEZ, Oil extracted	8,800	J. curcas and R. communis Seeds collected from Western and South-western AEZ, their oil quality and quantity determined	7,700	J. curcas and R. communis Seeds collected from West Nile, their oil quality and quantity determined	8,800	ATAAS
	16,200		20,527		18,400		21,100	

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