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Local rice parboiling and its energy dynamics in Ghana

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ABSTRACT

The study presents baseline data on local rice parboiling process and its energy supply, use and impacts in three communities in the Northern region of Ghana. The process as practiced is rudimentary and time-consuming requiring several hours of soaking and wood collection. Parboiling energy is supplied solely from wood which accounts for 11.9% of the total rice processing cost. The average specific soaking energy per batch of 11 and 40 were estimated to be 16.5 and 8.4 MJ/kg, respectively while that of steaming were 18.3 and 10.3 MJ/kg, respectively. Energy consumption was mostly influenced by the amount of paddy processed and the steaming duration. These results imply that specific energy use in these communities are at least 7 times higher than the average parboiling energy reports in the literature and considerably reduces the income of parboilers. The use of improved stove, utilization of rice husk as an energy source and higher processing capacity are recommended interventions for reducing energy use and cost, mitigating the environmental and health impacts as well as improving rice productivity.

1. Introduction

Rice has become a traditional staple food in most parts of Africa with the fastest relative growth in its demand in the world (Balasubramanian et al., 2007). Ghana, like most West African countries, has more than doubled rice consumption in last decade, recording an increase in per capita rice consumption from 17.5 to 38 kg between 1999 and 2008 which is expected to reach 63 kg by 2018 as a result of rapid population growth and urbanization (Ministry of Food and Agriculture, 2009). This may be due primarily to the ease of preparing rice based food compared to other local delicacies for urban dwellers and the relative higher cost of rice for those living in rural areas. This calls for an increase in local rice production in meeting this demand. Unfortunately, local rice processing is laborious and demand thermal energy from wood with associated environmental and health implications. As part of the local processing method, parboiling, a hydrodynamic process is practiced to enhance rice quality. This process enhances head rice yield and improves nutritional and organoleptic qualities. Generally, parboiling as reported by many scholars is energy intensive. Ahiduzzaman and Sadrul Islam (2009) reported parboiling energy consumption of 1680 MJ/tonne equivalent to a specific energy consumption of 1.68 MJ/kg. Roy et al. (2006) also measured energy consumption for total parboiling (pre-steaming and steaming) and reported 2583, 2758 and 1659 MJ/tonne for vessel, small-boiler and medium-boiler processes, respectively equivalent to 2.58, 2.76 and 1.66 MJ/kg. At the laboratory scale energy consumption in traditional parboiling was also found to be 1400–2441 MJ/tonne depending on the treatment time (Kirubi et al., 2009). All these results have been based on the direct combustion of rice husk which are collected at the milling centres at no cost.

Although, parboiling energy in West Africa is known to be met by fuelwood which are either carried over long distances or purchased from wood vendors and combusted in a three stone fire (TSF) stove (Demont et al., 2012; Kwofie and Ngadi, 2016), there are currently no quantitative reports on energy use at the various stages in the value chain and how the process conditions affect consumption. Therefore, to enhance efficiency and reduce energy cost, a baseline study is required to establish current energy consumption and identify areas where improvement can be achieved. This will provide stakeholders necessary data for rice processing improvement projects.

The objectives of this study are therefore, (1) to assess the current rice parboiling process within three villages in the Northern region of Ghana, (2) estimates energy consumption and examines factors affecting energy use, and (3) evaluates the impact of energy on local rice processing.

2. Materials and methods

2.1. Study location

The study was conducted in three rice producing communities Sishiagu, Nyankpala and Vitin in the Northern region of Ghana. Sishiagu is located in the new district of Sagnarigu is at an elevation of 173 m and

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lies N9° 24.288′ W0° 52.805′. Nyankpala, located in the Tolon District is 168 m above sea level and at N9° 23.378′ W0° 51.527′. Vitin is in the Tamale metropolitan area and lies at N9° 23.133′ W0° 48.356′. The vegetative cover of the selected areas is generally Guinea Savana interspersed with short drought resistant trees and grassland. The soil is mostly of sandy loam type except in the low lands where alluvial deposits are found. Major trees species include the sheanut, dawadawa, and mango. The standard of living in the region is very low as compared to the national average (MoFeP, 2014). The people earn very little as majority of its inhabitants are peasant and subsistent farmers. Agricultural production is the main economic activity offering employment for about 74% (MoFeP, 2014). Most people are into cultivation of food crops like maize, rice groundnuts and yam. The region was selected because of its dominance in parboiled rice production in Ghana.

2.2. Field studies

The study was completed in two visits. The initial planning visit was in February 2014 followed by the second visit in June, 2014. During the initial planning visit parboilers were interviewed and observational data were also collected. Seven rice producing communities within the region were visited: Sishiagu and Sagnarigu in the Sagnarigu district, Nyankpala in the Tolon district, and Nangbu, Vitin, Kasalgu and Lamashegu in the Tamale metropolitan district. During the initial visit three groups of observational data was collected to appreciate the (a) Parboiling equipment and energy supply (b) Factors influencing parboiling energy use (c) cost of energy to rice parboiling. Energy supply data was collected from the different stakeholders in the wood supply chain — wholesalers, retailers, local wood collectors and wood users (the parboilers). Local wood collections points, parboiling centres, milling centres and rice markets were visited.

The objective of the second visit was to measure parboiling energy use and evaluates the factors influencing fuel consumption. Observations from the initial planning visit suggested eight factors may affect parboiling use. These included (a) paddy mass (b) soaking water temperature (c) soaking water mass (d) paddy to water ratio (e) steaming water mass (f) steaming duration (g) wood species (h) wood sizes. The survey information collected during the two visits are shown in Table 1. Since the practices were similar among parboilers in the different communities, only Sishiagu, Nyankpala and Vitin villages were selected for measurement during the second visit. Overall 88 observations were made during the two visits.

2.3. Energy consumption measurements

Measurements of energy consumption was completed at the parboiling centres. Steaming energy in this study was defined as the amount of thermal energy supplied to precook a batch of paddy. Soaking energy on the other hand was defined as the energy supplied to raise the soaking water temperature to the desired temperature before soaking of paddy. A 100 kg Camry two-dial platform scale — model FD100 (Zhongshan Camry Electronic Co. Ltd., China — Mainland) with minimum capacity of 2 kg and readability of 200 g was used for all weight measurement. Quantities of paddy were weighed before soaking, steaming and drying. Water temperature was measured by mercury glass thermometer with range of 0–360 °C and 1 °C resolution (Shiv Dial Sud & Sons, India). Wood consumption was estimated by finding the difference between the initial and final weight of wood. The initial wood weight was the mass of wood planned to be used. The final wood weight was the weight of unused wood, unburnt wood taken from the fire and the charcoal generated. Total distance travelled and time spent in a round trip for wood collection was recorded with Etrex 10 Garmin GPS (Garmin International, Inc., Kansas, USA). This included time spent in exchanges between people collecting wood and farmers working on their farms. Energy from human activities was not included in the study.

3. Results and discussion

3.1. Local parboiling process

3.1.1. Parboiling equipment and material supply

3.1.1.1. Stove. The three-stone fire (TSF) was the main type of stove used in parboiling. 82% (n = 51) of parboilers owned two or more of the TSF. This enables them to run two or more batches at a time especially during the peak of the harvesting season. 35% of parboilers also owned metal crafted coalpot for burning charcoal retrieved from burning wood. Although this was not used in parboiling due to its size, it was used mainly for domestic cooking and heating. The TSF is known to be inefficient with efficiency of 10–15% (Alakali et al., 2011; Bhattacharya et al., 2002; Bhattacharya and Abdul Salam, 2002). This inefficiency and health impact of the TSF have been implicated in deforestation and regional climate change (Bond and Sun, 2005; Manibog, 1984; Ramanathan and Carmichael, 2008). An improved stove with higher efficiency and lower emissions will there be required to achieve energy economy in local rice processing. Improved natural draft brick stoves with higher efficiency of 11–53% have been reported for both domestic and economic activities (Bank, 2011) and can also reduce fuel use by 33%, CO emissions by 75% and particulate matter (PM) emissions by 46%, when compared with the TSF stove (MacCarty et al., 2010).

3.1.1.2. Vessels. Two types of vessels were used in the parboiling process — a smaller vessel (50 L), which can hold up to 50 kg of dry paddy and a 75 L pot. The smaller vessel was used usually for

Table 1
Survey information.

	Observation (POT)	Soaking test (SKT)	Steaming test (STT)
Description	Researcher interview parboilers, wood retailers, millers and milled rice sellers.	Researcher measures the data at the start end of the soaking session	Researcher measures the data at the start end of the steaming session, observe the session and records time-series log of parboilers' activities
Quantitative data	Cost of harvested paddy and milled rice	Initial soaking water temperature	Steaming duration
	Transport cost	Soaking duration	Mass of paddy
	Cost of wood	Mass of paddy	Mass of water
	Rate of wood collection	Initial mass of soaking of water	Initial mass of wood
	Quantity of paddy milled	Final mass of water after soaking	Final mass of wood
		Initial mass of wood (for hot water)	Mass of complementary fuel (rice husk/bran)
		Final mass of wood	Time-series parboiling activity log
Categorical data	Type of stove	Soaking method (warm or cold)	Steaming methodology
	Type of fuel used	Type of soaking vessel	Type of steaming vessel
	Type of wood	Size of Soaking vessel	Type of stove
	Use of rice husk	Time of day	Number of fires
			Wood name
			Size of steaming vessel
			Time of day
			Ignition method