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Clean Cook Stove Technology for Artisanal Palm Oil Clarification and Biochar Production in Ghana

Selorm Y. Dorvlo[ab,*], Ahmad Addo[a], Francis Kemausuor[a], Stephen Abenney-Mickson[b], Jesper Ahrenfeldt[c], Ulrik Henriksen[c], Mathias N. Andersen[d]

[a]*Department of Agricultural and Biosystems Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.*

[b]*Department of Agricultural Engineering, University of Ghana, Legon, Accra, Ghana.*

[c]*Department of Chemical and Biochemical Engineering, Technical University of Denmark, Risø, Denmark.*

[d]*Department of Agroecology, Faculty of Science and Technology, Aarhus University, Tjele 8830, Denmark.*

**sydorvlo@yahoo.com (+233 242786708)*

Abstract

The method of heat provision for artisanal palm oil production in Ghana is riddled with inefficient systems which create unfavourable working conditions (use of spent tyres, smoke filled work tents etc.) for the women who engage in this process. This creates health hazards for the women and sometimes the children they carry along to work. This study, therefore, sought to produce a cook stove that provides a healthy work environment, is efficient, easy to use, and affordable for medium-scale clarification of palm oil. Further it should have a sustainable source of fuel (biomass from processing the palm fruits) and simultaneously produce heat and biochar. The adopted design procedure was iterative and eight preliminary tests were conducted; each an improvement of the previous stove tested. The best stove configuration was adopted for the design calculations and the final stove fabricated and tested. The fabricated stove consisted mainly of a cut out barrel, a chimney and a grate. The stove was insulated to improve its thermal efficiency. Water boiling tests and controlled cooking tests protocols were adopted for the evaluation of the stove. The thermal efficiency of the stove was calculated to be 33 ± 7 % thus representing a 400% increase in efficiency as compared with the local replica stove. The cook stove was able to process approximately 103 litres of press liquor into 35 litres of palm oil within 55 minutes for one cycle of clarification. The quantity of fuel mix used was 9.5 kg with a biochar yield of 5%. A maximum CO emission of 5 ppm was measured. The study showed that the palm oil clarification process with the designed cook stove provided a smokeless work environment, heat and biochar.

Keywords: Cook stove, biomass, CO emission, Palm fruit fibre, Palm kernel shell, bio char.

Contact Address: Selorm Y. Dorvlo, University of Ghana, Department of Agricultural Engineering, Legon, 00233 Accra, Ghana, e-mail: sydorvlo@yahoo.com

Introduction

Palm fruit processing for palm oil is one of the major economic activities engaged in by local processors on both small and medium scale in Ghana. It is estimated that local artisanal processors, of which 80% are females, produce about 60% of the nations' palm oil through varying methods which usually affect their palm oil yield from each processing operation (Osei-Amponsah et al., 2012). On the average, the amount of palm oil extracted from palm fruits range from 11.5 to 29% of oil per fresh bunch weight (Mahlia, Abdulmuin, Alamsyah, & Mukhlishien, 2001; Ohimain, Izah, & Obieze, 2013; Poku, 2002). In Ghana, even though the local processors produce at full capacity and strive to produce more, it is estimated that about 35000 tonnes of palm oil is still needed in addition to the current production quantity of two-hundred and fifty thousand tons of palm oil to meet the local demand for palm oil consumption (MOFA, 2013). One way to achieve this is to enhance the quantity and the quality of the processed palm oil. In a study to assess the oil palm processing industry in Ghana, Osei-Amponsah (2013) found that one of the causes of poor palm oil quality is the unavailability of enough energy.

As such, most local processing centres generally use firewood or wood debris as the main source of heat energy. In extreme cases they resort to spent tyres as a source of fuel. Consequently, it is a common sight to see these processors in smoke polluted structures during processing periods. Such working environments expose the workers to several risk factors including pneumonia, lung cancer, respiratory tract infection, etc. associated with working in such conditions. To make this worse, most of these women are mothers and they occasionally carry their babies as well as toddlers to these sites and they also get exposed to these conditions.

It is therefore necessary to find a solution to this problem since it will inevitably provide the local processors with an efficient and effective means of processing palm oil. The solution will also minimise health related problems. Therefore the provision of a biomass-fired cook stove will address the concerns of the workers within the local palm oil processing centres as well as help draw closer to the attainment of some of the sustainable development goals. Like any other stove design study, there are different aspects which have to be covered; from the design to manufacturing and then its use by the people it was designed for.

This paper is a presentation on the final design and evaluation of a clean cook stove for palm oil clarification and biochar production.

Material and Methods

To ensure that the cook stove is readily accepted and adopted by the local processors, the processing sites were visited and the information obtained helped in developing the stove concept. The stove concept formulation, preliminary tests and final prototype design was conducted at the fabrication workshop of the Department of Chemical and Biochemical Engineering, Technical University of Denmark, situated at Risø-Denmark (Dorvlo, 2017).

Using the final design drawings, the cook stove was fabricated by local artisans in Accra and transported to the processing site at Kade in the Eastern Region of Ghana for evaluation according to the controlled cooking test protocol. 103 litres of a mixture of palm press liquor and water was boiled till the end of the testing period which is signified by the palm oil being ready for scooping from the surface of the boiling press liquor and water mixture. The quantity of fuel used was 9.5 kg and the fuel constitute a mixture of palm kernel shell (PKS) and palm fruit fibre (PFF).

An energy balance was carried out and the thermal efficiency of the stove determined. The CO concentration within the cooking area of the cook stove was measured with a CO monitor (GasAlert Extreme Single Gas Detector).

Results and Discussion

The results of the study are presented in Table 1. The press liquor and water mixture started boiling at 36 minutes. A total quantity of 35 litres of palm oil was scooped off the surface of the mixture by the end of 55 minutes. The average quantity of fuel used was 9.5 kg and the thermal efficiency of the stove was calculated to be 33 ± 7 %. This represents over 400% increase in the thermal efficiency when compared with the replica cook stove used by the locals (Dorvlo, 2017). This can be attributed to the improvements in the design of the stove since the combustion chamber directed the flame to the walls of the cooking pot for high rate of heat transfer.

Table 1. Thermal efficiency data for the Controlled Coking Tests

Parameter	Unit	Test 1	Test 2	Test 3
Volume of press liquor and water mixture	l	70.00	103.50	101.50
Mass of press liquor and water mixture	kg	70.00	103.50	101.50
Starting temperature	°C	19.30	32.50	35.00
Boiling/Highest temperature	°C	100.00	100.20	100.80
Time taken to reach highest temperature	min	25.00	45.00	37.00
Mass of water evaporated	kg	6.00	12.32	11.50
Total weight of fuel put in stove	kg	10.30	9.90	10.00
Total weight of fuel left in stove	kg	0.53	0.40	0.60
Total weight of fuel burnt	kg	9.50	9.50	9.40
Heat Produced	kJ	152.19	152.27	150.67
Heat used	kJ	37.19	57.14	53.92
Thermal Efficiency	**%**	**24.44**	**37.53**	**35.79**
Average Thermal Efficiency	**%**		**33 ± 7**	

The cook stove was also evaluated for biochar production. The stove has a char recovery rate of 5%. A quantity of 0.5 kg of biochar was recovered from 9.5 kg of PKS and PFF mixture.

From the study, it was observed that the stove produced a smokeless working environment when compared with the existing stoves being used by the processors (Figure 1). The newly-designed cook stove had a smokeless environment since the chimney directed the smoke upwards, and the CO concentration within the working environment was measured to be 5ppm. This value when compared with the maximum allowable CO concentration of 9ppm for a typical work environment is low (Maclay, 2004).

a.) b.)

Figure 1. a.) Cook stoves currently used by locals and smoke engulfed work environment with a child wondering around. b.) New cook stove in use with no smoke in the immediate environment.

Conclusions and Outlook

The following conclusions can be drawn from this study:
The cook stove was fabricated and its thermal efficiency was determined to be 33 ± 7 %. It processed 103 litres of the palm press liquor and water mixture to obtain 35 litres of palm oil within 55 minutes using PKS and PFF fuel mix of 9.5 kg with bio char recovery rate of 5 % of the fuel used. Future work on this stove will focus on increasing the biochar quantity and simplification of the stove for mass production.

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