XVII[th] World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

SUSTAINABILTY OF RICE PROCESSING IN RURAL SUB-SAHARAN AFRICA

MOHAMMED BAKARI[1], MICHAEL NGADI[1], ROBERT KOK[1], VIJAYA RAGHAVAN[1]

[1]M. Bakari, Department of Bioresource Engineering, McGill University, 21.111 Lakeshore Road, Ste-Anne-de-Bellevue, Quebec, Canada. H9X 3V9, mohammed.bakari@mail.mcgill.ca
[1]M. Ngadi, Michael.ngadi@mcgill.ca
[1] R. Kok, robert.kok@mcgill.ca
[1] V. Raghavan, vijaya.raghavan@mcgill.ca

CSBE101216 Section VI: Postharvest Technology and Process Engineering Conference

ABSTRACT Energy and environmental sustainability are important considerations for increased rice production. This study examines the energy utilization and sustainability of rice processing in sub-Saharan Africa. The community of Gadan Loko village in the Song local government of Adamawa State, Nigeria was selected as the focus of study. In this community, rice paddy is typically parboiled in small quantities of about 13.2 kg using traditional tripod support stove. Parboiling was the most energy intensive process. Sun dried parboiled rice is milled in local cottage milling stalls operating with single cylinder diesel engines. There were large variations in the quality of milled rice due to lack of consistency in processing parameters. Accumulation of rice husk in the community created important environmental issues. The areas looked at includes: utilizing waste heat from the diesel engines for improved drying and efficient pre-soaking; the utilization of solar energy for pre-soaking; the utilization of rice husks as alternative fuel to firewood; and the optimization and redesign of the stoves and parboiling vessels to minimize heat loss to the environment. The results shows that, the utilization of rice husk as alternative fuel and the redesign of the stoves and parboiling vessels will increase the sustainability of rice processing and can be easily adopted by the community. While solar energy pre-soaking is not economical and the utilization of waste heat from the diesel engines for drying and pre-soaking will be difficult to implement at the rural scale, because most of the parboiling is done far away from the milling stalls. This study shows that research, development of appropriate technology, and education (RATE) of the rural community is an important way of increasing sustainability

Keywords: Rice Processing, Parboiling, Alternative Energy, Heat Recovery, Solar Energy for presoaking rice paddy, Research Appropriate Technology and Education (RATE).

INTRODUCTION Rice is a staple food in sub-Saharan Africa and many other regions of the world. Currently there is an annual increase in demand for rice in the region. The current production, processing and marketing of rice in sub-Saharan Africa in general, is mostly a subsistent one. Even at this subsistent level, large quantity of rice by-product in the form of husk is produced and dumped around processing plants, creating an environmental issue as shown in figure 1. In addition, huge amount of firewood is utilized during rice parboiling, thereby greatly increasing the destruction of trees (see figures 2 & 3). Rice parboiling is a significant step of rice processing. This process involves the temperature and hydration conditioning of the paddy before removing the hulls and polishing the final product through dehusking and milling. This is an energy intensive process that requires manual and thermal energy. The thermal energy for this process comes exclusively from firewood, and one of the most preferred firewood comes from "*Kiriya*" (*Prosopis Africana*). *Kiriya* as it is called in the local Hausa language is very important for farming and pastoralist communities of the West African region. The tree's physical and chemical properties make it attractive for local applications that include medicine, construction, energy, and manufacturing of handles for local tools. Its seeds is also use as food, while is succulent leaves and branches provide food to cattle and goats during the dry season. In addition the trees fix atmospheric nitrogen that improves the soil fertility in the traditional parks and agro forestry system (Weber et al. (2008), Bakari et al (2009)).

Figure 1. Rice husk dumps are environmental hazards to the rice processing communities

Rice production is getting a lot of attention internationally, nationally and locally in recent years, with an accompanying huge amount of investment. In sub-Saharan African, some of the regional governments are putting a lot of resources towards training their rural farming communities and providing fertilizers in order to increase their productivity by 200-500% increase in tonnage. This means that there will be a sharp sustainable increase in rice production, with a concomitant increase in rice processing, and an attending problem of increase in husk production and more destruction of trees used as firewood for parboiling of rice (Bakari et al (2010)).

Figure 2. Truckloads of firewood is consumed by rice parboilers daily

Figure 3. Deforestation as a result of complete reliance on firewood for thermal energy

The parboiling methodology, the type of energy or fuel used, the ability of the rice processors to utilize rice by-product as energy source determines the sustainability of the parboiling process. The scale of the process can also affect the mass and energy efficiencies of the processes. The desired temperature for soaking is usually close to but below the gelatinization temperature of the rice. Bhattacharya (1985) proposed that the soaking shall start at 70 to 75º C and allowing cooling. After soaking, the rice is steamed for a certain period of time to gelatized the starch completely. After the steaming, the rice is dried, dehusked and milled. During parboiling various physiochemical changes occur due to the gelatinization of starch granules of the rice. These changes play an important role in next processing operations. Parboiling requires a specific amount of energy for the starch granules in the rice to be gelatinized, any excess energy supplied during this process is released to the surroundings (Weber et al., 2008). The knowledge of how much energy is required in rice parboiling is important for optimization of the process, especially in the rural sub-Saharan Africa where currently the process is based on traditional methods without consideration given to the exact temperature for gelatinization, heat loss to the atmosphere and the potential energy of the fuel used for this thermal process. Bakari et al (2009) has reported that in the region of the upper Benue river basin which the community of Gadan loko is part of, the thermal energy efficiency of the rice parboiling process is between 21.94 – 44.83% for the small scale rural rice parboilers and 21.09 to 27.89% for the medium scale suburban parboilers. That shows that between 55.17 to 78.06% and 72.11 to 78.91% of the thermal energy that comes from firewood is wasted by heating the atmosphere in the small and the medium scale parboiling processes respectively. This is alarming, when one considers more than 50% of the trees that are being cut for rice processing are wasted by heating the atmosphere and increasing the carbon loading of the atmosphere.

This study investigated methods on how the sustainability of rice processing can be improved in the sub-Saharan African region. The areas looked at includes: utilizing waste heat from the diesel engines that drive the engines that drive the milling machines for improved drying and efficient pre-soaking; the utilization of solar energy for pre-soaking; the utilization of rice husks as alternative fuel to firewood; and the optimization and redesign of the stoves and parboiling vessels to minimize heat loss to the environment.

MATERIALS AND METHODS

Materials

The materials used during this research includes a weighing scale, a measuring tape, thermometer, full-function weather station, digital camera, stopwatch, chain saw, local measuring pan called the" mudu", Kiriya (*Prosopis africana*) firewood, parboiling stoves, designed rice husk burning stove, and local species of rough rice paddy. The Local small and medium scale rice parboiling, drying and milling outfits were used for assessment of viability of the proposed solutions that will increase sustainability. Also a local community based farm skills acquisition centre that is operated by the regional government is used to determined feasibility of utilizing RATE theme for training the rice processing community for adoption of the developed technologies.

RESULTS AND DISCUSSION

Utilization of waste heat from the diesel engine that drives the rice mill

The utilization of waste heat from the single cylinder diesel engines that drives the milling machines is very attractive. The temperature of the hotside barrel can be set to temperature above the gelatinization temperature of the rice. The engine can run efficiently with a hotside temperature of up to 95º C. This energy can be easily harnessed by using a heat exchanger that is fabricated locally from copper tube of ½ inches to provide water for pre-soaking at the required temperature of between 70 to 75º C. The cold-side barrel is at the temperature of 35 to 45 º C this can be used for effective drying of the paddy. Although this option is viable it is not practical at the rural scale rice parboiling level because the parboiling is done far away from the milling stalls.

However for the medium scale suburban parboilers this is highly possible and based on the data obtained. As figures 4, 5, & 6 shows the parboiling and drying is done behind the milling stalls beside the coolant drums.

Figure 4. Diesel engine cooling system consist of two barrels at atmospheric pressure

Figure 5. Pre-soaking of rice beside the diesel engine coolant barrels

Figure 6. A woman using a rake to spread wet paddy that is dried on plastic mats

Utilization of solar energy for pre-soaking of rice

During this study, it was found that active solar heating will be too expensive and less likely to be adopted by the local parboilers. Although the average ambient temperature is about 31.5ºC and the days are usually sunny in the processing season, the parboilers do not consider that the slow solar heating as economically attractive. The conclusions in this case are that the economic drawbacks of such a method, although energetically positive, will make it difficult to implement in this region at this time.

Redesign and optimization of the stoves and parboiling vessels to minimize heat loss

The optimization of the current process will involve enclosing the stove. This will effectively minimize the convective and radiative energy losses to the atmosphere. This simple improvement will greatly improve parboiling efficiency. Another suggestion involves insulating the vessel and also keeping it covered. This will reduce the thermal losses to the atmosphere through evaporation and convection.

Figure 7. Covering the stove minimizes both radiate and convective heat losses

Utilization of rice husks as alternative fuel to firewood

These problems can be turned to the advantage of the whole community through the utilization of rice husk as an alternative fuel. Figures 8a, b, c, & d, show a locally fabricated stove that uses rice husk as fuel. This stove was tested for comparative performance with the conventional tripod and the steel stoves. The only issue that need to be addressed with this stove is the capacity. The best performance was found to be with stove that has the diameter of 30cm or less.

Figure 8a, b. c, & d. Locally fabricated rice husk stove

The best alternative for utilization of rice husk biofuels is by converting it into pellets. The rice husk will be processed into high energy producing pellets using a very simple technique that can be adapted by the local community.

CONCLUSION Rice processing is an energy intensive process. The small and medium scale parboilers in sub-Saharan Africa always overlook the parboiling efficiency, the sustainability and climate change issues that are caused by the current parboiling methods. Valuable trees such as *Prosopis Africana* (kiriya) in the parkland and agroforest are being depleted due to increase in demand for firewood for agricultural processing such as rice parboiling. This paper has shown that with simple adaptable modification of the current process, the energy efficiency of parboiling can be greatly improved. The utilization of waste biomass such as rice husks as alternative fuel can greatly improve the sustainability of the parboiling process. The modified stove that uses rice husk as the key fuel developed in this study is a proof that sustainability of rice parboiling can be greatly improved in the sub-Saharan African region using appropriate technology. Another observation during this research is that skills training of these farmers will be an important step towards increasing sustainability. In summary, the adoption of the concept of RATE (Research Appropriate Technology and Education) will enable the sub-Saharan rural farming communities to increase the production in a sustainable way.

Acknowledgements. WARDA, Yola North Skills Acquisition Centre, Adamawa State Government, Gessedaddo Farms, for their assistance during this investigation.

REFERENCES

Abdullahi, I., Bakari, M., Ngadi, M., Kok, R., Raghavan,V., Diagne,A., 2009 The McGill-Yola North Post-Harvest Rice Processing Project Report.

Akaaimo D. I., Raji A. O., 2006. Some Physical and Engineering Properties of Prosopis africana seed. Biosystems Engineering 95 (2) 197-205

Bakari, M., Ngadi, M., Kok, R., Raghavan,V., Diagne,A., 2009 Energy Analysis for Small and Medium Scale Rural Rice Parboiling in sub-Saharan Africa

NSC. 2001. Injury Facts Online. Itasca, Ill.: National Safety Council. Available at: www.nsc.org. Accessed 17 December 2001.

Waladi, W., B. Partek, and J. Manoosh. 1999. Regulating ammonia concentration in swine housing: Part II. Application examples. Trans. ASAE 43(4): 540-547.

Bhattacharya, K.R. (1985). Parboiling of rice. In. B. O. Juliano (Ed.), Rice: Chemistry and Technology (2nd ed., pp 289-348). St. Paul, MN: American Association of Cereal Chemists.

Islam M. R., Shimizu N., Kimura T., 2004. Energy requirement in parboiling and its relationship to some important quality indicators. Journal of Food Engineering 63 433-439

Weber J C Larwanou M Abasse T A Kalinganire A., (2008).Growth and survival of Prosopis Africana provenances tested in Niger and related to rainfall gradients in the West African Sahel. Forest Ecology and Management 256 (4) 585-592