Biochar-Based Technologies for Enhanced Productivity and Resilience of Smallholder Rice-Based Farming Communities in the Philippines

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Abstract

One of the proven strategies to help rice farmers to enhance their resilience to climate change is to diversify their production. Hence, PhilRice is popularizing an integrated farming system, popularly called as *Palayamanan,* wherein various farming activities (vegetable production, aquaculture, poultry, livestock, biomass waste utilization, etc.) are integrated with rice production. In this system, biochar from rice husk is utilized in various farming activities. Among others, it is used as animal bedding in poultry and livestock, suppressing foul odor while facilitating urine and manure collection. The excreta-saturated biochar is then applied into the soil as soil conditioner and as additional source of plant nutrients. This paper reports a new system of producing biochar from rice hull. In particular, it reports a carbonization system wherein the heat generated during the process is recovered and used as source of energy in various farming activities for additional income and reduce fossil fuel dependence. Requiring no electricity, this system operates in continuous mode with almost smokeless emission. Various heat recovery attachments were developed for cooking, baking or drying farm products, pasteurizing mushroom fruiting bags, extracting essential oils from medicinal plants and heating poultry houses. Current researches are also being done to make use of this heat as source of energy for household lighting.

Keywords: biochar, carbonizer, integrated farming system, *Palayamanan,* rice-based farming

1. Introduction

The impacts of climate change in the Philippines, being considered as one of the most vulnerable countries in Southeast Asia (Yusuf and Francisco, 2009), are becoming more apparent and devastating. Climate-related natural disasters such as drought, floods, and storms are the principal sources of risk, uncertainty, and losses in agriculture and those heavily affected are farmers who rely on rice farming for a living. A significant number of these farmers are living below the poverty threshold and thus considered highly vulnerable (Eriksen and O'brien, 2007).

One of the proven strategies to help farmers cope up with climate change is to diversify their sources of income through other farming activities (Snidvongs, 2006; Lasco et al., 2011; Tesso et al., 2012; Reddy, 2015), not only relying on the climate-sensitive rice production. At the farmers' level, resiliency can be based on the availability of resources to satisfy their basic needs especially during the time of crisis (Adger et al., 2003). Because of this, PhilRice is extending an integrated farming system, now popularly called as *Palayamanan,* wherein other farming activities (vegetable production, aquaculture, livestock, biomass waste utilization, etc.) are integrated with the rice production (Corales et al., 2004). In the *Palayamanan,* biochar from rice husk is fully utilized in various activities. Among others, it is used as bedding in livestock production, suppressing foul odor while facilitating urine and manure collection. The excreta-saturated biochar is then applied as soil conditioner and as additional source of plant nutrients. Biochar, commonly used in the production of organic fertilizers, has also been globally recognized as a means of combating global warming by holding carbon in soil and by displacing fossil fuel use (Lehmann et al., 2006). Hence, to help popularize the use of biochar as well as enhance farmers' productivity and income, an improved system of carbonizing rice hull and other agricultural wastes was developed (Orge, 2010). Specifically, it is a system that is clean (smokeless emission) and will make use of the generated heat for various applications in the farm (Fig. 1), particularly those applications that would provide farmers opportunities for added income and would reduce their dependence on fossil energy.

2. Development of Rice Hull Carbonization with Heat Recovery System

1) Continuous-type Rice Hull (CtRH) Carbonizer

The CtRH carbonizer is a device developed to process rice hull into biochar (carbonized rice hull). Its development started in 2010 (Orge, 2010; Orge and Abon, 2011) but further improvements had been made (Orge and Abon, 2012) until a working and marketable prototype was developed in 2013 (Fig. 2). Unlike most existing rice hull carbonizers, it can operate in continuous mode with almost smokeless emission and has provisions to recover the heat

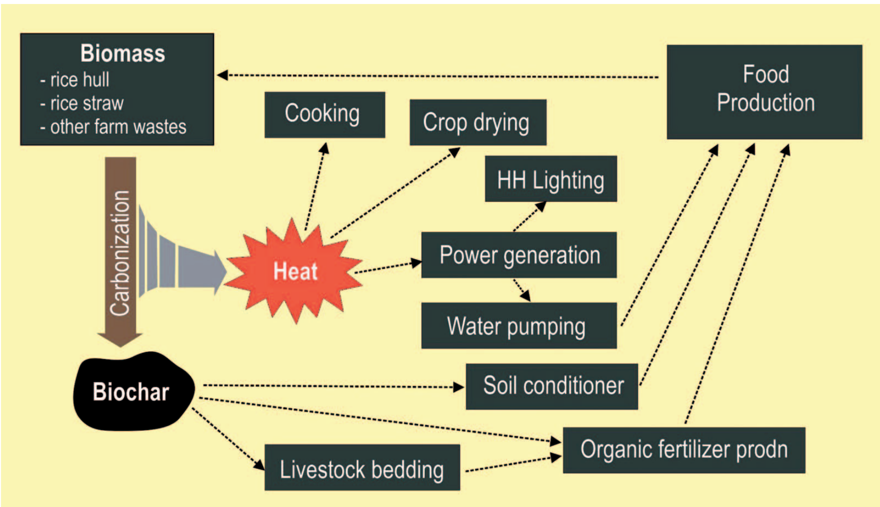

Fig. 1 Potentials of biomass carbonization

Fig. 2 Continuous rice husk (CtRH) carbonizer

generated during its operation. The heat, equivalent to an average of 4.5 kW based from actual water boiling tests, is stable, signifying that it does not require much attention during its operation. Thus, with appropriately designed attachment and while producing biochar, farmers can use this carbonizer for processing high value products for generating additional income. This carbonizer has been tried to carbonize other biomass like chopped rice straw, coconut husk, and wood (Table 1) except that smoky emission was observed hence need some modifications in terms of regulating the amount of air involved in the process, among other things.

2) The Carbonizer-attached High Volume Cooker

The cooking attachment (Fig. 3) was primarily developed for farmers who want to sell cooked products such as boiled green corn, banana, peanut, etc. along the country roads (which is

Table 1 Performance of the CtRHcarbonizer using materials other than rice husk (Orge and Abon, 2012).

Parameter	Rice straw	Coco husk	Wood twigs
Capacity, kg/h	12.00	20.00	32.18
Biochar yield, % w.b.	23.89	17.96	23.98
Ignition time, min	0.87	1.42	2.63
Amount of diesel used in firing, mL	37.0	40.0	113.0
Loading/reloading time, %*	5.6	2.2	2.0
Biochar collection time, %*	5.6	5.3	1.9
Agitating time, %*	0	0	0
MC of raw material, % w.b.	8.15	10.47	6.53

* % of the total operating time

Fig. 3 Carbonizer with cooking attachment (left) and cooked salted eggs (right)

common in the Philippines) and for those that operate food stalls. Few units of it are now in the hands of selected farmers for pilot testing. One is a group of housewives in Aurora province wherein it is used for cooking salted eggs while producing biochar as ingredient of organic fertilizer. It is equipped with a regulating valve that allows the user to control the amount of heat (Table 2) which is needed in cooking rice and other related food processing operations.

3) Carbonizer-attached Baking/drying Oven

This is another attachment developed to recover and utilize the heat generated from the operation of the CtRH carbonizer for adding value to the farm products (Fig. 4). It was designed in such a way that the temperature inside its chamber can be manually controlled so that it can cater to various temperature requirements of the product to be baked, roasted or dried. With slight modification of some parts, it is possible for an electronic device to be installed to automatically control and maintain the temperature. Laboratory tests showed that the

Table 2 Water boiling performance at different settings of the regulating valve (Boyles and Orge, 2015).

Performance parameter	Regulating valve setting			
	¼ open	½ open	¾ open	Fully -open
Boiling time, hr	1.83	1.58	1.12	0.53
Burning Rate, kg/hr	6.72	7.06	9.22	12.45
Thermal efficiency, %	20.71	23.05	27.02	30.29
Overall power, kW	26.66	27.98	36.57	49.41
Useful power, kW	5.52	6.45	9.88	14.97
RH consumed, kg	20.53	19.06	18.02	12.00
CRH percent recovery, %	36.78	38.41	39.73	42.33

Fig. 4 Carbonizer-attached dryer/oven and one of its products (roasted chicken)

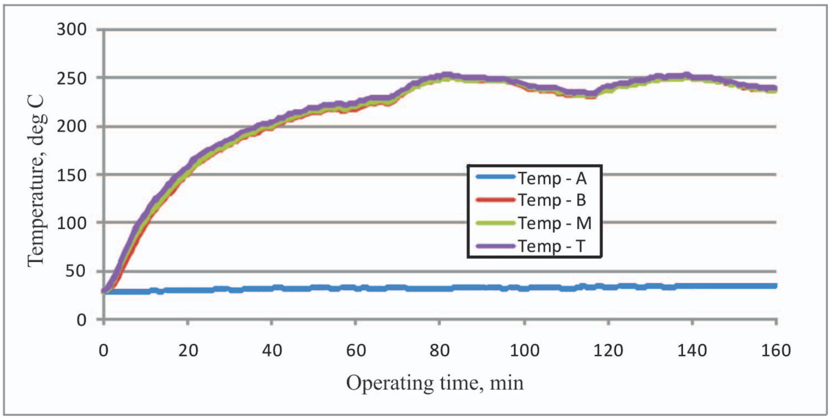

Fig. 5 Temperature profile of inside the oven at two valve settings (Orge and Boyles, 2015)

temperature inside the oven could reach up to 250 °C (Fig. 5). It has been tested and found to perform very satisfactorily on roasting/cooking the following products: roasted chicken, fish, husked corn, banana cakes, and macaroons. Current efforts are geared towards pilot testing it by interested farmers, including a group of farmer-housewives in Zambales province who have signified interest to use it in drying barbeque sticks. Drying of the freshly-made barbeque sticks is a common problem they encounter during rainy season since they only rely on the heat of the sun to dry their products.

4) Carbonizer-based Poultry Heating System

This was developed through a collaborative undertaking with a rice farmer-poultry grower in Nueva Ecija province, who was interested to make use of the heat for heating poultry house. This farmer has two poultry houses, each equipped with automatically-controlled heating system making use of LPG as fuel. The developed carbonizer-based heating system (Fig. 6) was successfully retrofitted in the poultry house. Results of test trials conducted under actual operating conditions showed that the carbonizer can be used as an alternative source of heat for poultry. With it, a poultry grower can significantly save heating expenses while generating additional income from the carbonized rice hull which can be mixed with the co-produced

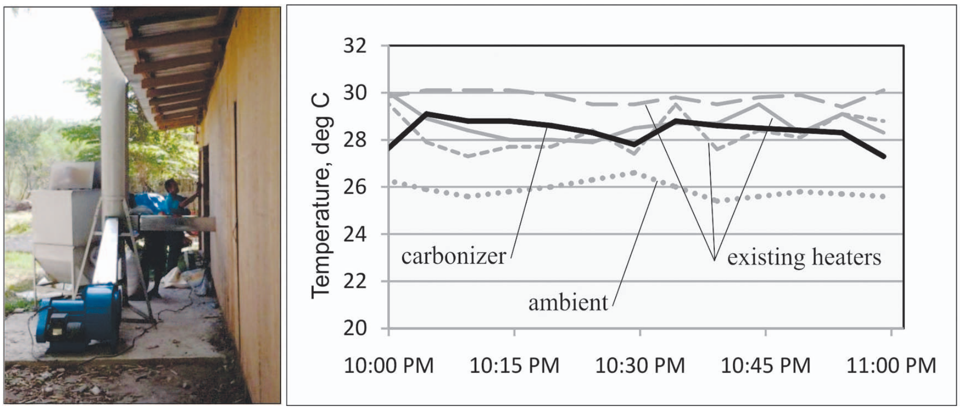

Fig. 6 CtRH carbonizer equipped with a heat recovery attachment for heating poultry. Graph at the right shows the temperature profile inside and outside the poultry house

poultry manure as ingredients of organic fertilizers. Since LPG is being replaced with rice hull, in addition to biochar as by-product, greenhouse gas emission is also prevented thus helping contribute to climate change mitigation.

5) Carbonizer-attached Mushroom Pasteurizer

Mushroom production is an important component of the *Palayamanan*. This heat recovery attachment was developed to further improve the system of producing mushrooms, utilizing the heat generated by the CtRH carbonizer. A working unit is currently being used in the mushroom production at PhilRice-Central Experiment Station in Nueva Ecija province with a batch capacity of 500 fruiting bags (Fig. 7). Currently, PhilRice is producing mushroom as part of its regular income-generating activities. Additional units of this mushroom pasteurizer will soon be established in various PhilRice stations, for use in their respective mushroom production

Fig. 7 Mushroom pasteurizer coupled with a CtRH carbonizer

business, while at the same time monitoring its performance prior to its commercialization.

6) Distilling Apparatus

This is an accessory to the high volume cooking attachment that can be used for the production of essential oils from herbs or medicinal plants (Fig. 8). It can also be used for the production of distilled water for drinking when the supply of potable water is limited, especially during incidence of calamities. Results of exploratory tests also indicate that, with minor modifications, its design can potentially to be used in the production of diesel fuel from plastic wastes.

7) Carbonizer-water Pump System

A proof of concept had been developed showing that the heat generated by the CtRH carbonizer can also be used for pumping water (Fig. 9). It is on the process of further development by improving the method of converting water into steam (which drives the jet pump) to make it much safer to use by farmers. Results of tests showed that, while producing biochar at 9.1 kg h^{-1}, the system could pump water at an average rate of 15.5 L min^{-1} (Table 3).

Fig. 8 Carbonizer-attached distilling apparatus

Fig. 9 Carbonizer-water pump undergoing field test

Table 3 System performance of the carbonizer with and without the pump system (Orge and Abon, 2011).

Parameter	As carbonizer only	As cabonizer-pump system
Amount of rice husk (RH) consumed	40.12	22.7
Amount of biochar produced, kg/h	14.4	9.1
Volume of water pump, L/min	-	15.5
Specific fuel consumption, kh RH/m^3 water	-	25.2
Volume of water pumped/kg RH, L	-	39.7

3. Conclusions

The CtRH carbonizer and its attachments offer a lot of potential in providing opportunities for farmers to be more productive, efficient, and income earner. The cogeneration of biochar and heat would create a more sustainable farming practice since they fit in various activities within the farm. Aside from being a carbon sink (climate change mitigation), biochar helps improve soil condition and fertility which would translate into reduced use of inorganic fertilizers while maintaining higher crop yields and, ultimately, sustained higher income of the farmers. The otherwise-wasted heat, on the other hand, would satisfy the energy requirements of the various processes needed to sustain farming operations and/or create income-generating activities. Research works are also currently being done to utilize this heat for generating electricity for household lighting. By making farmers earn extra income from the same piece of land they till, they can be more financially capable to respond to the various climate-related challenges thus enhancing their resilience.

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