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Chapter 9

WASTE RICE HUSK CONTINUOUS CARBONIZERS FOR CARBON SEQUESTRATION AND ENERGY IN RURAL PHILIPPINE REGIONS

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ABSTRACT

This chapter describes a process for eliminating the current practice of dumping unwanted rice production waste, and uncontrolled burning of wastes in the field. Wide-scale rice husk conversion systems remain constrained by limited regionally-specific agronomic research on the efficacy of the resultant carbonised waste biochar on rice yields, fertiliser use efficiency, and stable carbon fractions for reliable and safe soil carbon biosequestration practices, as well as the economic incentives for farmers to integrate waste conversion technologies into rice farms. In this study a carbonizer technology was developed and applied to the rice production systems currently used in rural areas of the Philippines. The carbonizer prototypes were fabricated at the Philippine Rice Research Institute (PhilRice) machine shop in Muñoz Science City, Nueva Ecija, Philippines, and used similar manufacturing techniques commonly used in the local machine shops, i.e., with locally available equipments, skills, and parts. Results from the second refined prototype demonstrated a processing capacity of up to 40 kg hr^{-1} of rice husk into biochar, with around 40% in biochar yield (by mass), and a biochar purity of approximately 99%. The refined prototype has a smokeless chimney emission during operation and carbon monoxide emissions were greatly reduced (431 ppm). The carbonizer enables waste heat extraction using exchangers or microbiolers, with heat produced during combustion available as additional source of energy to partially replace kerosene and firewood currently used. This additional energy source from the use of agriculture waste in carbonizers can play a vital role in protecting the forests in rural Phillipines, whereas population growth and current practices (kerosene and firewood from unmanaged forests) are drivers to illegal deforestation. The adoption of carbonizers can increase carbon sequestration by decreasing firewood demand and avoiding deforestation, (a REDD activity), and the application of biochar for fertilizer further reducing net emissions in the region through soil carbon storage. By increasing aboveground and belowground carbon stocks in the agro-ecosystem, carbonizers can be used strategically for sustainable resource management and as a important tool for reducing emissions as an effective and practical climate change mitigation strategy.

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NOMENCLATURE

Q_a	required air flow rate for carbonisation (kg h^{-1})
Q_{rh}	carboniser's input rice husk capacity (kg h^{-1})
k	stoichiometric air-fuel ratio, air (kg) $fuel^{-1}$ (kg)
ER	equivalence ratio
Δp	pressure head (mm water column)
ρ_a	density of the ambient air (kg m^{-3})
ρ_g	density of the flue gas (kg m^{-3})
h	height of chimney (m)
L	depth of rice husk bed (m)
μ	dynamic viscosity of the fluid (air) (kg m^{-1} s^{-1})
ε	the ratio of the void volume to the total volume of the bed
d_p	particle diameter (m)
ϕ	product of sphericity factor
V_s	superficial velocity (m s^{-1})

INTRODUCTION

The Philippines Renewable Energy Act 2008, and the Biofuel Act 2006 have attracted renewed focus on sustainable development. By improving the methods for disposal of agricultural waste and producing additional heat, the use of rice husk carbonizers can improve environmental sustainability, increase productivity (fertilization effect from biochar byproduct), and help ensure both energy and food security (Dawe et al., 2006; Reyes et al., 2009; van der Meulen Rodgers and Menon, 2010; Borines et al., 2011a; Borines et al., 2011b; Orge and McHenry, 2013). Improving the productivity of Philippine rice systems is a fundamental national food security concern. The introduction of two rice crops per year in the Philippines has driven to the increased need for soil fertilization, mechanization, and cost-effective crop drying technology. For example, an average kerosene batch dryer with a 5 t rice capacity consumes around 80 L when operated for 8 hours, releasing approximately 240 kg of CO_2-e (Haefele et al., 2009). This is an expensive option for many poor farmers, and displacing the common practice of using vehicle roads to dry rice will require the development of cost-effective, portable, and suitable drying technologies. New appropriate drying technologies will reduce the pervasive food contamination risks, avoid some production losses through mishandling, and mitigate associated losses in rice quality and marketability from the existing substandard rice drying techniques in use in the Philippines (Hien, 1993). From a health perspective, the practice of rice residue burning in rural areas is a common cause of air pollution and associated health problems, and from an agricultural perspective the practice leads to large pools of nutrient loss (PhilRice, 2005; Haefele et al., 2009; Orge et al., 2013a; Orge et al., 2013b). The development of local technical solutions that enable parallel reductions in air pollution and greenhouse gas emissions, introduce mechanization alternatives, improve nutrient return and fertilizer use efficiencies, and reduce energy and fuel imports are essential considerations. This is the stimulus behind the development of a cost-effective, simple, but effective, continuous rice husk carbonisers with the capability of retrofitting waste heat recovery technologies (Orge et al., 2013b). However, considering a relatively good farm gate rice prices of around USD320 t^{-1} in the Philippines, farmers are more likely to adopt new carbonisation technologies if they enable rice productivity gains, displace some fertilizer inputs, reduce local agricultural waste disposal requirements, and provide a renewable source of energy for on farm use (McHenry, 2009a; McHenry, 2009b; Ogawa and Okimori, 2010; Zhang et al., 2010; McHenry, 2011; McHenry, 2012; Orge et al., 2013b).

The carbonized rice husks applied to soils (known as biochar) have been shown to increase grain and rice yields in nearby countries (Ogawa, 2007; Laird et al., 2008; Lehmann and Joseph, 2008; Blackwell et al., 2009; Ogawa and Okimori, 2010; Zhang et al., 2010; McHenry, 2011). However, there is little published information to date for the productivity potential in the Philippines. Preliminary research by Zhang et al. (2010) on the application of rice husk biochar (10 – 40 t ha^{-1}) on rice fields in south-eastern China found significant rice yield increases (between 8.8% and 14%) with various levels of biochar additions, reducing N_2O emissions (21-51%), although increasing total CH_4 emissions, both with or without N fertiliser additions. In addition, with the exception of nitrogen, nutrient losses from conversion of rice husk to biochar is relatively low (Haefele et al., 2009; Thies and Rillig, 2009) (Table 1). On-site and portable rice carbonisers, even with a low efficiency heat recovery system, enable farmers to utilise the waste husk component of a volume of rice to dry that same volume, with the resulting biochar returning a sizable fraction of minerals and nutrients to the next crop. At an average rice crop yield of around 5 t ha^{-1}, [(assuming 21% husk by weight, a ~38% husk carbon (C) concentration (Lehmann et al., 2006; Haefele et al., 2009; Lehmann et al., 2006; Haefele et al., 2009)], and a low 30% carbon-to-biochar conversion efficiency (Mochidzuki et al., 2002), a single ha may produce around 0.88 tCO_2-e to be sequestered as biochar annually from the husks alone from two crops grown per year.

Table 1. Elemental constituents of untreated rice husk and carbonised rice husk produced around 500^{o}C. Source of rice husk data: (Haefele et al., 2009).

Material (dry)	**pH**	**C**	**N**	**P**	**K**	**Ca**	**Mg**	**Si**
		(Elements are % by mass)						
Rice husk	6.8	36.2	0.69	0.14	0.45	0.14	0.45	9.5
Carbonised rice husk	8.6	39.8	1.23	0.45	1.03	0.45	1.03	20.4

This research describes an applied project to design a continuous rice husk carboniser operating at the highest possible temperature while minimising rice husk ash production. With the technical compromise between rice husk biochar conversion efficiency and processing capacity per hour exists, the fundamental objective was to design a system that maintained high temperatures sufficient to enable useful heat recovery with minimal user intervention. Therefore, an understanding of the target users' needs, their motivations, preferences, and expectations for a new product is imperative (Christianson and Rohrbach, 1986). For this reason, the new carboniser designs were based on informal user requirements from interviews of selected farmers and researchers with experience of rice husk carbonisation. The user requirements of the carboniser design incorporated improvements to functionality, affordability, manufacturability, and overall user safety of the available carbonisation technologies (Budynas and Nisbett, 2008). The functionality requirements included easy ignition, minimal attention during operation, and minor maintenance needs using unskilled labour. In terms of affordability and manufacturability, local small-scale manufacturing capabilities (mostly limited to welding, grinding, drilling, and cutting equipment) were considered in the design, resulting in easily fabricated and assembled carbonisers. The design aimed to be as simple as possible, used only locally-available materials from the local community, and incorporated only passive draft air fow; in contrast to most other alternative carbonisers which require active electric fans (Orge et al., 2013b). The design also aimed to minimise operator exposures to harmful gases, smoke and particulates, as producing biochar can be hazardous if carbonisers are improperly designed, maintained, or used.

BATCH CARBONISER MODIFICATION FOR CONTINUOUS OPERATION

The conventional batch rice husk carbonizer technology used by farmers was used as a baseline in this study. Whilst the conventional carbonizer is very simple and affordable, the poor functionality and safety concerns were the main drivers in the development of the new technology. Therefore, the continuous carbonizer was designed to be both cleaner and easier to operate than the conventional carbonizer (shown in Figure 1). The main redesign feature was the development of a suitable receptacle for holding the rice husk and a means of removing the biochar (Figure 2). The gaseous products of partial combustion are designed to enter into the central chamber and flow up the chimney, creating a net negative pressure head. The carbonization process requires a strict regulation of air flow and should not exceed the stoichiometric requirement, otherwise complete combustion occurs producing a high ash product (Orge et al., 2013b). From the definition of the equivalence ratio (Basu, 2006), the relationship between the input capacity and the rate of airflow required over time was calculated using Equation 1.

Figure 1. The conventional “open-type” rice husk carbonizer (left) and in operation (right).

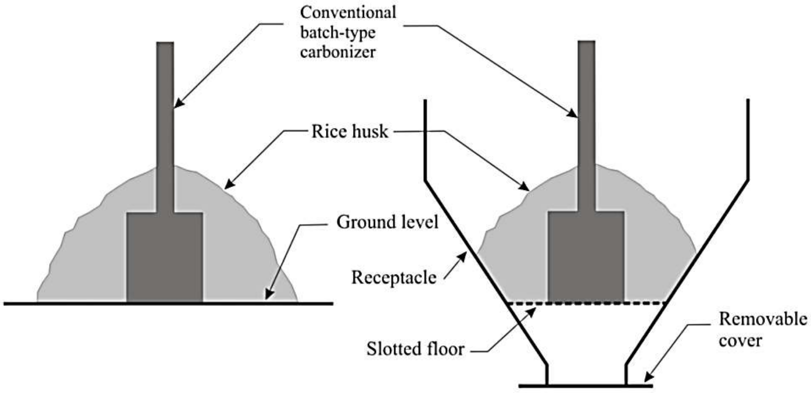

Figure 2. The conventional batch rice husk carbonizer (left) and the first prototype design for a continuous rice husk carbonizer (right).

Equation 1 can be represented in Cartesian form as a straight line with Q_a in the y axis, Q_{rh} in the x axis, $k \times ER$ as the slope, with y intercept at 0 (for various values of ER). Complete combustion occurs at $ER = 1$, and the design is aimed to stay as close as possible to $ER = 1$ to achieve higher equivalence ratios possible at higher temperatures (Basu, 2006). Theoretically, the equivalence ratio could be manipulated by changing either the air flow rate or the input capacity of the carbonizer. Thus the work focused on designs that enhanced passive airflows and minimized complete combustion, high residence times, and small carbonizer capacity. The draft is the pressure head caused by the difference in densities of the ambient air and the flue gas (Equation 2). The pressure head in Equation 2 must be able to overcome the pressure loss when air passes through the bed of rice husk, which influences the design in terms of height of the chimney. The assumption was made that the air needed for carbonization passed through the entire rice husk bed depth of uniform size. The Ergun equation was used to compute the pressure loss relation to the flow rate (Equation 3). Combining Equations 2 and 3, the equivalent length of chimney that would compensate for the pressure loss could be calculated. As Belonio (2005) recommended a 10% allowance to overcome this pressure loss, the final length of the chimney used in the prototype was 1.1 times the computed value of h in Equation 3.

$$Q_a = Q_{rh} \times k \times ER \qquad (1)$$

$$\Delta p = (\rho_a - \rho_g)h \qquad (2)$$

$$h = \left[\frac{L}{\rho_a - \rho_g}\right]\left[\frac{150\mu V_s(1-\varepsilon)^2}{(\phi d_p)^2\varepsilon^3} + \frac{1.75V_s^2\rho_a(1-\varepsilon)}{\phi d_p \varepsilon^3}\right] \qquad (3)$$

TESTING METHOD, MATERIALS, AND PROTOTYPE DEVELOPMENT

Ignition chamber temperatures were determined by two 18 mm diameter and 0.5 m long ceramic lined thermocouple probes and a Yokogawa Portable Multi-Thermometer (model 2423A) data recorder using type K thermocouple wires. The probes were installed at the top and bottom portion of the ignition chamber with tips approximately at the longitudinal axis of the chamber. Temperature readings were taken from each point at five minute intervals, and temperature data in Figure 4 and Figure 6 are averages of these readings. The oxygen (O_2), carbon monoxide (CO), and carbon dioxide (CO_2) content of the exhaust gas were determined using an IMR® 1000 handheld gas analyzer. Biochar quality was measured in terms of the fixed C content of each 500 g test samples analysed at the Analytical Service Laboratory of PhilRice.

The first prototype was fabricated from materials that can easily be purchased at local hardware stores (steel bars, and galvanised iron sheets, pipes and bolts). The prototype resembled a large circular funnel of 1.10 m in height, and 0.80 m and 0.20 m in diameter for its top and bottom openings, respectively (Figure 3). It was designed to be open at the top where rice husks are poured into the carbonizer when filling and refilling, while the bottom is partially closed. Approximately 0.30 m above the bottom opening is a slotted floor where the ignition chamber is rigidly fastened. The ignition chamber is a circular cylinder, 0.275 m in diameter and 0.40 m in height, with a series of 0.03 m diameter holes, and is closed at the bottom. These holes facilitate ignition of the rice hull and provide entry of the gaseous products of partial combustion into the chamber, as air flows up the chimney. The top portion of the chamber forms the seating for the detachable chimney which extends 1.3 m high with an internal diameter of 0.082 m. To start the carbonizer, pieces of paper are placed inside the ignition chamber and a small amount of rice husk is placed outside and around the ignition chamber up to the lid, which is then ignited. Once the exposed rice husk outside the chamber starts to combust, the chimney is installed, and around 40 kg of rice husk is added to the carbonizer hopper to maximum capacity. The biochar collecting container is then placed at the bottom and filled with water. Air movement is created as the flue gas escapes through the chimney.

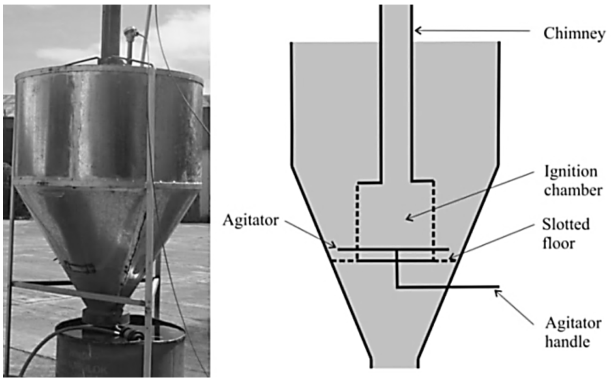

Figure 3. A photo of the first carboniser prototype during testing (left), and schematic (right).

RESULTS AND DISCUSSION OF INITIAL PROTOTYPE TESTING

Testing and re-testing the first prototype after initial modifications demonstrated some enduring technical issues including non-uniform combustion and difficulties in collecting the biochar. The first prototype was modified to overcome these recurring issues, and while the performance seemed adequate by the stable initial temperature recorded by the thermocouples at the side of the ignition chamber, a continuous decline in temperature was observed until combustion self-extinguished (Figure 4). Testing determined that achieving high initial ignition temperatures before the hopper was filled to maximum capacity was critical to sustain carbonization. However, once a sustained temperature was achieved further problems were encountered, particularly in relation to the amount of manual agitation required to maintain partial combustion in the carbonizer. The poor flow characteristics of rice husk, especially when undergoing partial combustion, was a significant design challenge. Conditions like ‘caking’ or ‘bridging’, ‘caving in’, and ‘channeling’ are common problems for rice husk conversion systems (Hien, 1993). As the name implies, channeling is the formation of channels along the depth of the rice husk bed that serve as short passageways for ambient air to enter the combustion zone. If left undisturbed these channels lead to complete combustion of the surrounding rice husks, and the resultant flames can be difficult to extinguish. Caking, on the other hand, is husk conglomerates obstructing gravity flow (Hien, 1993) leading to formation of spaces which can inhibit agitation mechanisms. In the first prototype, there were times when the operator had to stand on an elevated platform to aggressively agitate the husks with a long stick, which increased exposure to dust and smoke. To overcome this, several agitator redesigns were attempted in the first prototype. These included changing the number and the lengths of the agitator fingers, varying their movements from rotary to oscillating, although none proved as effective at removing the char from the combustion zone as manual agitation.

After refinement, the first prototype underwent full testing, determining the average ignition time, the rice husk input capacity (Q_{rh}), the percentage of biochar yield as a percentage of dry weight of the original rice husk, operating times, temperature, and flue gas analysis (dry). The ignition time included the time needed to ignite the rice husk in the ignition chamber using kerosene (300-400 mL). The flue gas analysis included the quality of the flue gas in terms of the percentage (by volume) of CO, CO_2 and O_2. On average, it took approximately three minutes to ignite the prototype and start operation. The complete carbonization of 40 kg of rice husk required an average of 180 minutes, and the average biochar yield was 40.7%. However, major concerns of the performance of the first prototype included the mechanical agitation mechanisms' and inability to overcome the caking, caving, and channeling behavior of the rice husk, and the coexistence of unevenly unburnt husks and completely combusted husks. Simple options such as tapping the sides of the hopper to maintain consistent rice husk flow characteristics were not consistently reliable, especially during carbonization periods when heat appeared to induce additional caking. Furthermore, the sensitivity of the carbonizer to initial ignition conditions, and difficulty of maintaining consistent partial combustion remained significant issues for the first prototype, compounding to an increased emission exposure to users, particularly in windy conditions. Therefore, a second prototype carbonizer was developed to solve many issues arising from the testing of the first prototype.

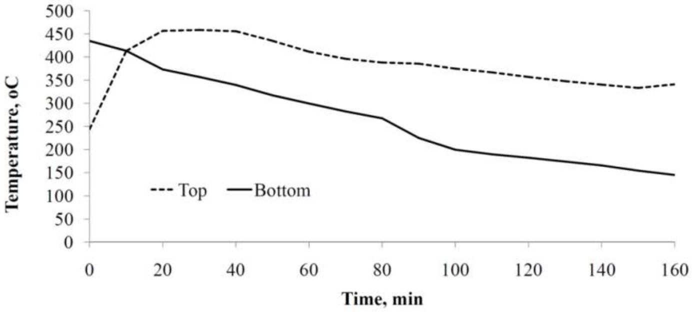

Figure 4. Temperature profile taken during testing of the first prototype.

RESULTS AND DISCUSSION OF SECOND PROTOTYPE TESTING

The most distinguishing features of the second prototype were: no mechanical agitation system (thus avoiding operator emission exposures); the creation of two separate hoppers, and; the inclusion of an additional chamber for discharging the biochar under the ignition chamber (Figure 5). In the first prototype, the simple and direct method of manually pushing the rice husk bed down with the use of a stick was found to be the most effective means of carbonizer agitation. However, users required attaining a high elevation which further exposed them to heat and emissions, often becoming uncomfortable and unsafe. Therefore, the second prototype incorporated a bottom hopper that housed the ignition chamber, and a top hopper that held the remaining rice husks. This created a gap to enable safe and effective user agitation of the husks at a more comfortable height at eye level, enabling even inexperienced operators to effectively agitate the husks (as the appearance of charred husk at the surface was a visually very simple indicator that agitation was required). The creation of this gap also enabled easier ignition compared to the first prototype, and rendered chimney removal and re-installation redundant. In addition, the air intake in the new prototype mostly entered through the hopper gaps as the air intake follow the path of least resistance (Favalora, 1948). The new design maintained a constant flow and operating temperature regardless of depth of the rice husk remaining in the top hopper.

Another redesign incorporated into the second prototype was the larger slots in the floor (0.08 m) which allowed the charred husks to pass through to the bottom chamber. Whilst rice husks are able to fall through these slots when filling the hopper for ignition, this is remedied by simply placing pieces of paper on the slotted floor before filling the hopper. Once carbonization commenced, the paper is carbonized, while the rice husks undergoing carbonization tend to cling to each other such that they would not fall into the bottom chamber unless disturbed by manual agitation. To solve the issue of any unburned rice husk being mixed with the biochar output by manual agitation, the heat of the newly discharged biochar was used to carbonize the unburned rice husk in the newly incorporated chamber beneath the slotted floor.

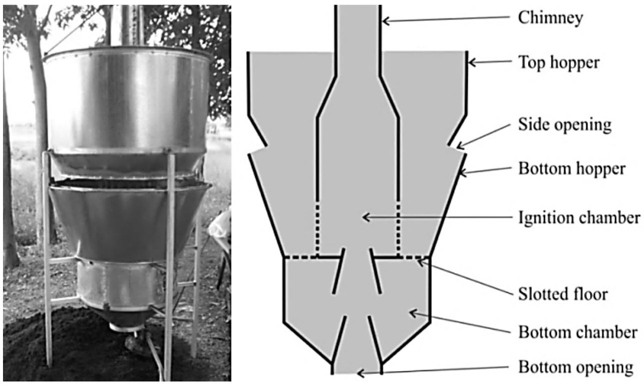

Figure 5. The second prototype of the PhilRice rice husk carboniser (left) and its schematic (right).

The second prototype still exhibited some channeling problems, which are commonly observed in rice husk gasifiers and is difficult to eliminate through design (Belonio, 2005). Despite their occurrence, channel formation at the side opening between the hoppers was easy to monitor and eliminate by manual agitation. However, channel formation was still able to occur in the top hopper, and a cover was designed to prevent the rice husk bed surface from being exposed to the ambient air. A 0.20 m by 0.4 m inlet hole on the cover was developed for loading and reloading the hopper which was closed during operation. Whilst this did not completely eliminate channel formation in the top hopper, the complete combustion of rice husk was successfully eradicated, also minimizing the visual checking at the top of the carbonizer to prevent channeling.

EMISSION REDUCTION DESIGN CHANGES OF THE SECOND PROTOYPE

The second prototype was designed to minimize flame and smoky emissions that were common in the first prototype and the baseline conventional batch carbonizer. Flame emissions from continuous carbonizers when collecting biochar commonly produce an accumulation of combustible gases, including hydrogen (H_2), CO, and methane (CH_4) (Reed and Das, 1988). To address this, a controlled introduction of air into the ignition chamber was developed for the bottom chamber when collecting biochar by two conduits arranged in series, as shown in the schematic of the bottom chamber in Figure 5. The top conduit was fixed rigidly to the base of the ignition chamber, while the bottom chamber was made to move freely along its vertical axis to enable sliding the bottom chamber open and closed. This design introduced a venturi effect, sucking the combustible gas accumulation up the chimney, greatly reducing the occurrence of the bottom chamber overfilling with biochar prior to collection. Aside from a cleaner emission, a higher ignition chamber temperature was achieved, enabling heat recovery (Orge et al., 2013b).

Several test runs were conducted with the second prototype, with consistent performance. Table 2 shows the typical performance test data using rice husks with a moisture content of 9.3% from a rubber roll type rice mill located near PhilRice in Nueva Ecija, Philippines. The second prototype was able to be ignited in less than three minutes, and included filling the bottom hopper with sufficient rice husk for ignition, filling and lighting the ignition pan with 300 mL of kerosene, and a minute to allow the rice husk around the ignition chamber to properly ignite. In the tests, the second prototype was able to process around 40 kg of rice husk per hour with biochar yields of approximately 40%. The impurities that mixed with the biochar was comparable to the open-type conventional carbonizer (1-2%) (PhilRice, 2005). Table 2 shows the decrease in CO emissions from the first prototype (1,503 ppm) relative to the second (510 ppm). A material balance was undertaken to assess the flow and fate of the elements and compounds constituting the rice husk and the ambient air for the second prototype. The calculated emission data for O_2, CO, and CO_2 implied 99.2% of the total mass of the CO produced during the carbonization process was burned at the ignition chamber. In terms of visual appearance, the second prototype produced a clear emission unlike the first prototype which often emitted thick smoke. While biochar yields and purity were comparable to the first prototype, the second prototype increased the rice husk input capacity by ~300%; drastically reducing time required and enabling more efficient heat recovery. The maximum temperature attained was 860°C, an improvement of around 400°C compared to the first prototype maximum temperature of 467°C (Figure 6). Figure 6 shows a consistent slow decrease in temperature during operation, likely influenced by agitation frequency. Agitation was undertaken when charred areas were observed in the rice husk bed between the two hoppers, and each agitation recorded slight increases in temperature at both the top and bottom hoppers. The temperature data recording ceased when the top hopper was empty.

Table 2. Comparison of performance data from the first and second carbonizer prototypes.

Performance Parameter	First prototype	Second prototype	Difference
Approximate ignition time	~3 min	~2.8 min	~0.2 min
Input capacity	13.3 kg h^{-1}	38.6 kg h^{-1}	25.3 kg h^{-1}
Biochar yield	40.7%	39.4 %	39.4 %
Maximum temperature	467 °C	860.1 °C	393.1 °C
Purity of biochar	99.1%	98.8%	0.3%
Emissions			
O_2	4.5%	7.8%	3.3%
CO	1,503 ppm	510 ppm	993 ppm
CO_2	4.1%	6.8%	2.7%

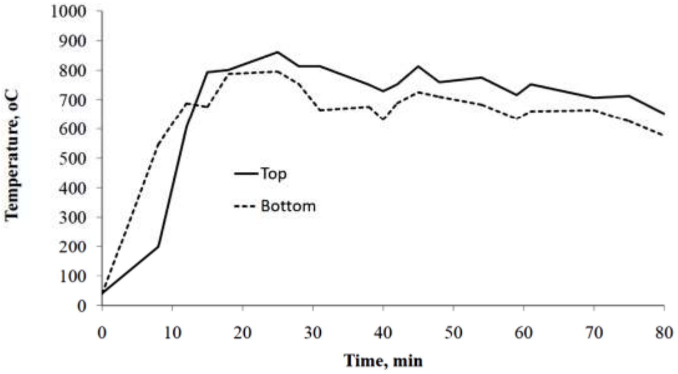

Figure 6. Second prototype temperature profile from two points in the ignition chamber.

CONCLUSIONS AND DISCUSSION

Despite preliminary design issues, the second prototype satisfied the project objectives of producing a continuous rice husk carbonizer, operating at the highest possible temperature (enabling heat recovery) while minimizing rice husk ash production and minimizing health risks to the operator. The two separate hoppers with a side opening for easy manual agitation access, the size of the chimney, and the opening of the ignition chamber all had large influences on operation efficiency and measured performance. The optimum chimney diameter was found to be 0.125 m, combined with an ignition chamber opening within the range of 0.17 – 0.175 m. With a relatively high temperature and an open space inside its ignition chamber, the second prototype design caters for the installation of a steam generator, with minimal modification. Final performance evaluation of the second prototype demonstrated an ability to process around 40 kg of rice husk into biochar in one hour, at around 40% biochar yield, with a purity of approximately 99%.

The second prototype cleanly combusts the gaseous products of carbonization in the ignition chamber, and as a result is cleaner than all other locally available options for small-scale on-site rice husk carbonization. It is also safer to operate (minimizing user exposures to harmful gases); is easy to ignite, filling the hopper is simple, and collection of the carbonized rice husk at the bottom chamber is safe and undemanding. Test results demonstrate passive draft rice husk carbonizers can produce high quality biochars with minimum emissions, with simple and safe operation when compared to existing comparable alternatives (Orge et al., 2013b).

As the collection of rice husks during processing is a relatively simple task, increased availability of cost-effective and reliable rice husk carbonizers may provide an additional venue for increasing rice farmers income by providing the service and or an alternative to disposal option for nearby farmers and in the rice farm community. Within the farm unit, it increases productivity, renewable energy (displacing firewood), reduced emission of GHGs and air pollution, displaces imported fertilizer requirements, efficiently recycles nutrients, increases soil C sequestration, and the heat recovery components can indirectly decrease deforestation (decreased firewood demand), and an overall more sustainable use of rural natural resources (Laird et al., 2008; Lehmann and Joseph, 2008; Haefele et al., 2009; McHenry, 2009b; Ogawa and Okimori, 2010). However, much further research is necessary to determine the specific benefits in terms of net economic, agricultural, and mitigation potential of rice husk carbonization. This includes options for discussing programs and incentives for increasing the adoption of husk waste management for individual farms and collectively for the rice farm communities in rural areas in the Philippines. In addition to technical performance of carbonizers, the positive and negative downstream potential of applying rice husk biochar to soils require further agro-ecosystem wide investigation: refining biological and chemical uncertainties, economics, and safety; elimination of toxic substances emissions from carbonization at high temperatures, and minimizing risks associated in the downstream handling, transport, and application practices of biochars (Lehmann and Joseph, 2008; Blackwell et al., 2009; Joseph et al., 2009; McHenry, 2011; McHenry, 2012).

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