ENHANCEMENT OF THE ENERGY DENSITY OF RICE HUSK THROUGH DRY TORREFACTION.

AytenewGetaye[1] M.RaviKumar[2]
Department of Chemical Engineering, College of Engineering and Technology,
Samara University, Samara, Afar, Ethiopia.

Abstract: The objective of this study was to examine the torrefaction process of lignocellulose biomass rice husk produced in Ethiopia through dry torrefaction. Three different torrefaction temperatures 230, 255 and 280^0C with three different holding times 20, 40 and 60 minutes were considered. The result showed that a net reduction of the volatiles content, mass yield, moisture content, bulk density and atomic oxygen content correlate with increasing torrefaction temperature and reaction time, while atomic carbon content, higher heating value(HHV),fixed carbon content and energy density increase with higher torrefaction temperatures and time in both treatment cases. So, torrefaction temperature and holding time had a significant effect on torrefaction process of rice husk. Based on the findings of this study, temperature of 280 with a residence time of 60 min for dry torrefaction and temperature of 280 could be suggested for an effective and proper torrefaction process to recycle the agricultural biomass. The energy density of dry torrefaction was enhanced by 120%. From the thermo gravimetric analysis TGA, torrefaction peaks were observed at temperatures between 200-300^0C.The pyrolysis peaks appeared as a result of the degradation of rice husk. Therefore, the torrefied biomass becomes fuel sources which can be applied to replace with fossil fuel

Keywords: Rice husk biomass, Torre faction, higher heating value,ThermogravimetricAnalysis.

Introduction:

Owing to the increasing impact of traditional energy usage on global climate patterns and the environment, stakeholders are turning their attention to renewable energy sources. Biomass is a primary type of renewable energy, which is expected to be important energy source in the coming years. Of the different non-conventional energy sources available (e.g., wind, solar, tidal, and nuclear), biomass is widely available and is considered to be carbon neutral, in that the net carbon emissions resulting from the burning of biomass are zero[1]. Researchers reported that fossil fuels have been continuously consumed in the 21st century and contributed to the climate change like global warming. Therefore, new energy which can be renewable and friendly with environment is the priority concerned[2]. Biomass is expected to play a major role in the transition to renewable or sustainable energy production [2-5]. Woody and herbaceous biomasses are regarded as lignocellulose biomass, because their major organic mass fraction consists of cellulose, hemicellulose and lignin[6].Bioenergy can be generated in different ways. It can be converted to a value-added liquids and gaseous products such as ethanol, synthesis gas, or bio-oil, or it can generate electricity via direct combustion, or gasification. Bioenergy is produced from organic materials, which are any form of biomass such as food crops, organic wastes, and forestry products[7]. Ethiopia has an abundance of forest resources, and these resources can provide a considerable amount bio-based energy; however, utilizing these sources presents problems. Existing is either adapting this infrastructure to accommodate lower quality Biomass fuel, infrastructure for generating energy uses low moisture and oxygen content fuels, such as coal. The major challenge which can be very costly, or creating a biomass product that can be utilized in a current steam generation or gasification plant. It is for this reason that methods to upgrade the biomass are being explored. The method being researched in this study is torrefaction. Torrefaction is a treatment process for biomass meant to reduce oxygen content and moisture absorption, which increases the energy content. Torrefaction is a thermo-chemical pretreatment process using biomass within a narrow temperature ranging from 200℃ to 300℃[8]. Torrefaction process provides an alternative bioenergy resource since it increases energy density and reduces transport cost. This treatment is carried out under atmosphere conditions in a non-oxidizing environment and for a relatively long residence time[9]. Torrefaction increases the energy density of biomass and stimulates its carbon/oxygen (C/O) and carbon/hydrogen (C/H) ratios. Due to charring of biomass and cracking of volatiles, the amount of fixed carbon in biomass increases after torrefaction[3]. The amount of fixed carbon increased after torrefaction because of conversion of hemicelluloses into more thermally stable compounds[9, 10]. Bergman et al.[11]reported that energy density increases with torrefaction temperature because C/O and C/H ratios increase with rising temperatures. Bridgeman et al.[12]found that torrefaction reduces the ignition time for both char and volatiles. Upon torrefaction, biomass loses various compounds with high oxygen and hydrogen contents such as moisture (H_2O), CH_3COOH, CH_3OH, and CO_2. This is particularly beneficial for gasification of biomass that contains a large amount of oxygen[13, 14].

Materials and Methods:

1. Biomass Preparation

Rice husk obtained from local farmers was air dried to a moisture content of 10-15 % (w.b). The husk was then fractionated to remove the large (>4mm) and smaller chippes (<2mm) with the use of vibrating screen separator. After screening, the husk was kept in dry atmosphere for further analysis. The raw and fractionated rice husk is shown in figure 1.

Figure 1: Raw and fractionated rice husk

2. Raw Material Characterization

Rice husk from rice producing farmers was selected as feedstock for this study since it is the main agricultural crops in Ethiopia. The selection aims among others to utilize these available resources potential by enhancing the energy density using two methods i.e. chemical and dry torrefaction. Proximate analyses of the raw feedstock and the torrefied rice husks were performed according to ASTM standards: ASTM E871, ASTM E872, and ASTM D1102 for moisture content, volatile matter, and ash content, respectively. The ultimate analysis was performed at Addis Ababa University (AAU) Chemistry department. Ultimate analyses of the samples of fuel on dry basis were determined by an“EA 1112 Flash CHNS-O-analyzer”. In addition, the higher heating value (HHV) was calculated according to a unified correlation proposed by (Daya Ram Nhuchhen and Muhammad T. Afzal,2017) .

3. Experimental Setup and Description

All experiments were carried out in a tubular reactor equipped with a hot plate heater (AM-5250A), nitrogen cylinder, a thermocouple and a pressure gauge. A thermocouple for monitoring the reaction temperature (temperature of the sample and the reactor) is connected to the reactor by which the electrical duty of the heater is controlled manually. The reactor is connected to a nitrogen (99.99% purity) cylinder via a valve to create inert atmosphere. After the samples were placed inside the tubular reactor, it was completely purged with nitrogen gas to remove all oxygen. The furnace/torrefied reactor was preheated to the desired temperature set point. Treatment time was said to begin when the furnace reached the desired set point. At the end of the treatment time, the biomass samples were pulled from the furnace and immediately placed in desiccators to prevent from moisture exposer and for further treatment and combustion. Once the crucible cooled to room temperature, the samples were weighed and analyzed with the respective test. The experimental set up for the torrefaction experiments are shown in figure 2 and figure 3 and the general experimental frame work are shown in Figure 4

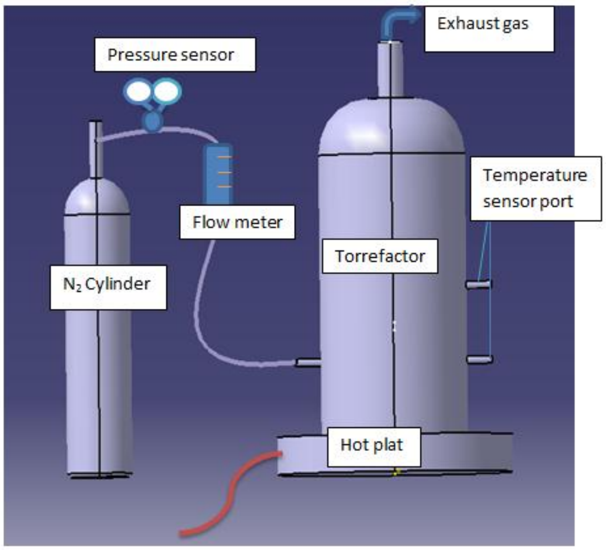

Figure 2: The theoretical experimental set up

Figur 3: The actual experimental set up for torrefaction process

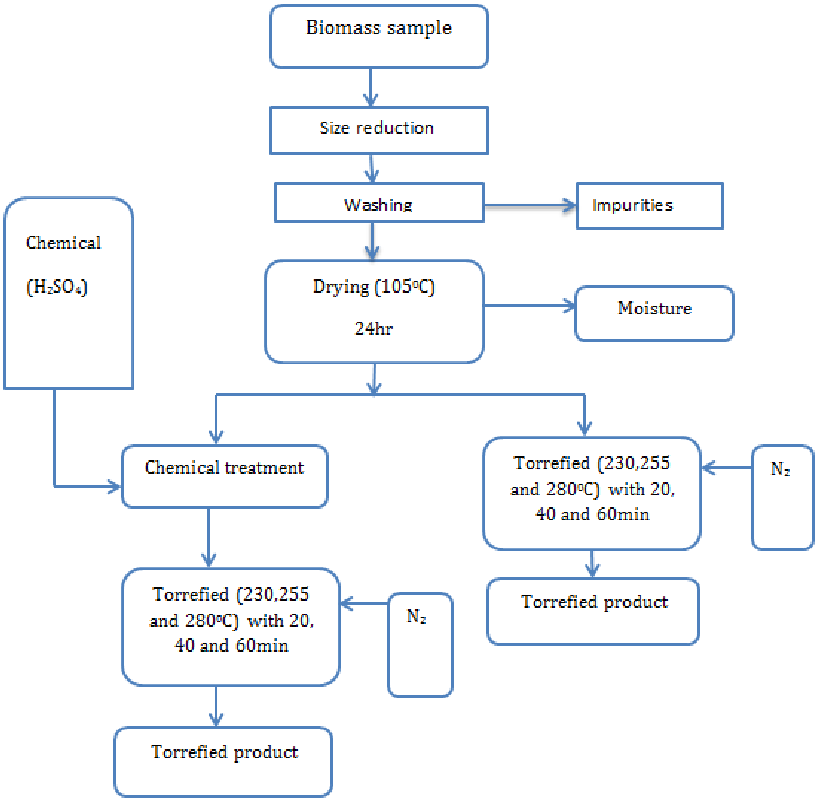

Figure 3: General experimental procedure for torrefaction process

RESULTS AND DISCUSSION:

1. Preliminary Qualitative AssessmentError! Reference source not found. .

Figure 5 shows the surface morphology of fractionated and dry torrefied rice husk. The mass of samples in each of the sample holder were 10g. As can be seen in Figure 5, with increasing torrefaction temperature, the surface morphology of the torrefied rice husk changed significantly, showing a gradually shrinking volume and turning from yellow to brown and then black. The visual difference of the biomass subjected to torrefaction is the color of the samples. Carbonization of the biomass increased with the intensity of torrefaction. Pelaez-Samaniego et.al (2014) reported that changes of color might be occurred due to the oxidation of phenolic compounds and the presence of sugars and amino acids during torrefaction process

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Raw rice husk
TRH-230
TRH-255
TRH-280

Figure 5: Effect of Torrefaction temperature on surface morphology of rice husk sample

2. Mass yield

Figure 6 shows the effect of torrefaction temperature and time on the solid yield of rice husk for dry torrefaction. From the result, it can be concluded that temperature had significant effect on mass yield than residence time. Torrefaction temperature and torrefaction time had significant effect on mass yield. When the torrefaction temperature. was 230^0C and 20 min, the solid yield was 98.663% for dry .As the torrefaction temperature increased the solid yield decreased . When torrefaction temperature is higher than 255^0C, most of hemicellulose was decomposed, and the cellulose started to decompose, so the solid yield decreased quickly, at 280^0C and 60 min solid yield became 74.263 for dry torrefaction. Increasing torrefaction temperature from 230 to 280^0C, the mass yield dropped gradually at the respective treatment time. This illustrates the effect of torrefaction temperature and holding time on the mass yield. This is in compliance with the expected results, since torrefaction involves the loss of both moisture and volatile matter from the sample of biomass.

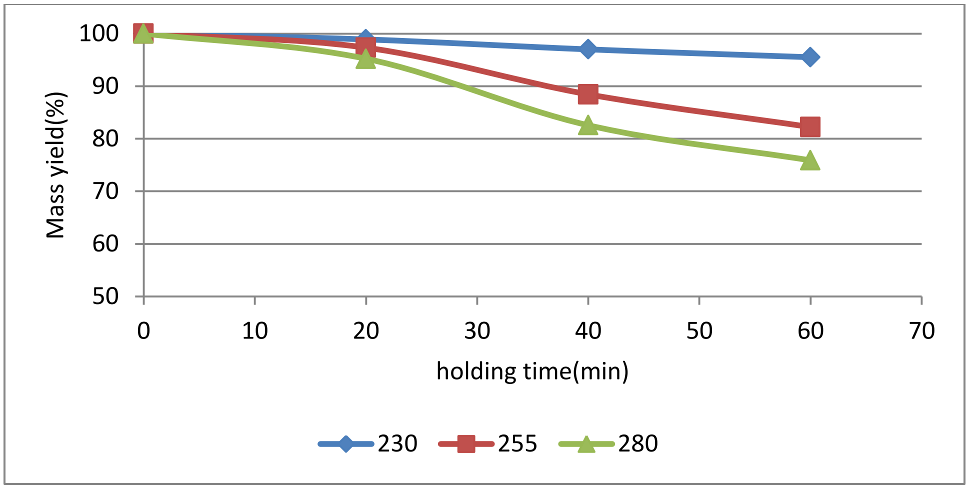

Figure 6: Effect of torrefaction temperature and holding time on mass yield of dry torrefied rice husk

3. Volatile contents

Figure 7 shows the effect of temperature and time on volatile matter contents. As it can be seen in figure 7, volatile content of the torrefaction product shows a noticeable reduction at high torrefaction temperature and time, indicating that high temperature had a noticeable influence on the volatile matter content. For dry torrefaction at lower torrefaction temperature (230^{0}C) and different residence times, the decrease in volatile content in the torrefied biomass was relatively minimal (the maximum decrease was about 1.45% at 60 min with respect to the original value) (Figure 4.5). Increasing the torrefaction temperature to 255 and 280 ^{0}C for the residence time to 60 min reduced the volatile content to about 29.59% and 42.98%.

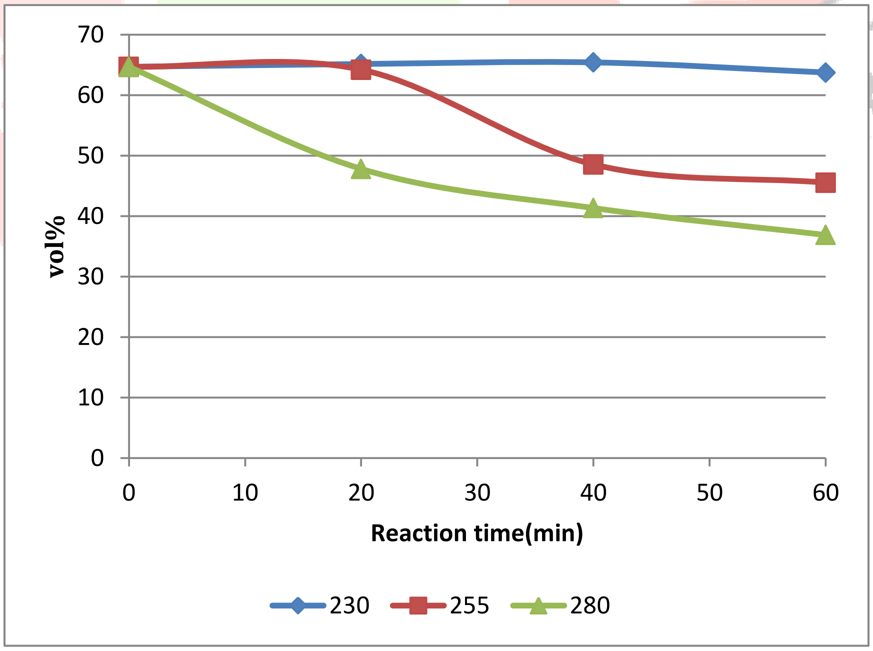

Figure 7: Effect of torrefaction temperature and residence time on volatile contents of dry torrefied rice husk

4. Ash contents

The ash content in the terrified material increased with the increase of Torre faction temperature and time (Figure8). The changes in the ash content are mainly due to breakdown of carbon-hydrogen bonds, resulting volatile loss and further concentrating the ash content in the biomass. The highest ash content of about 29.067 % was observed for dry torrefied samples at 280^0C and 60 min. The increase was about 78% with respect to the original value/raw rice husk

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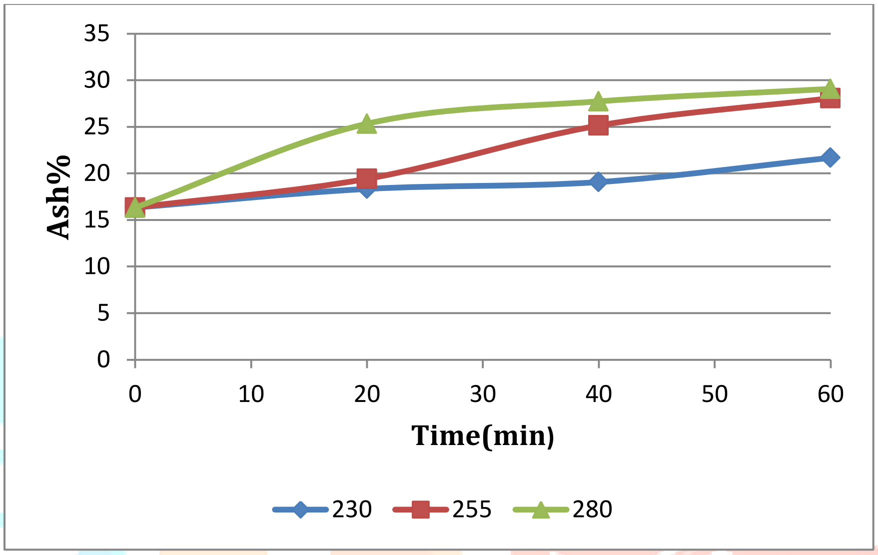

Figure 8: Effect of torrefaction temperature on ash contents of dry torrefied rice husk

5. Fixed carbon

A higher temperature and a longer residence time increased the composition of fixed carbon in torrefied rice husk. The weight percentage of fixed carbon increases significantly with increasing torrefaction temperature due to the carbonization process. The reason behind is that during torrefaction at different temperature, the moisture content and volatile matter removed. So, the composition remained is purely ash and fixed carbon.

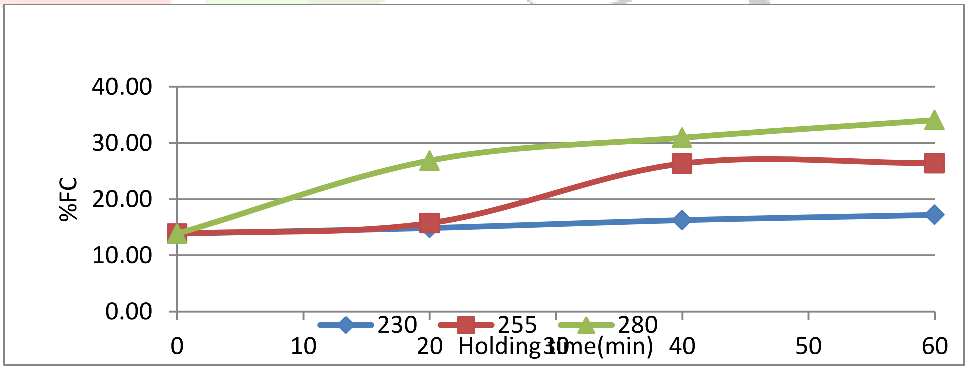

Figure 8: Effect of torrefaction temperature (^{0}C) and reaction time on fixed carbon yield of dry torrefaction

CONCLUSIONS:

Drytorrefaction of rice husk was performed to enhance the energy contents or the bioenergy property. From the results obtained by torrefaction of rice husk, a net reduction of the volatiles content, mass yield, moisture content, bulk density and atomic oxygen content correlate with increasing torrefaction temperature and reaction time, while atomic carbon content, higher heating value(HHV), fixed carbon content and energy density increase with higher torrefaction temperatures and time . A mild torrefaction treatment of 280^{0}C at 60 min and 280^{0}C at 40 min is found to be the optimal torrefaction conditions for improving the heating value, energy density and hydrophobicity characteristics of rice husk.

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References

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Poudel Jeeban and Sea Cheon Oh, Effect of Torrefaction on the Properties of Corn Stalk to Enhance Solid Fuel Qualities. Energies, 2014.
2. Bergman P C A and Kiel J H A, Torrefaction for biomass upgrading. 2005.
3. Batidzirai B , et al., Biomass torrefaction technology: Techno-economic status and future prospects Energy, 2013. 62(1): p. 196-214.
4. Basu P , et al., An experimental and theoretical investigation on torrefaction of a large wet wood particle. Bioresource Technology 2014. 159.
5. Lee W J A comparative study on fuel characteristic and combustion behaviour of biomass fuel types. Journal of Korea Society of Waste Management, 2012. 29(4): p. 421-430.
6. Chen W H and Kuo P C Torrefaction and co-torrefaction characterization of hemicellulose, cellulose and lignin as well as torrefaction of some basic constituents in biomass. Energy, 2011. Vol.36: p. pp.803-811.
7. Chad Lee Carter, Physicochemical Properties and Thermal Decomposition of Torrefied Woody Biomass and Energy Crop. MSc thesis 2012.
8. Du S W , Chen W H , and Lucas J A Pretreatment of biomass by torrefaction and carbonization for coal blend used in pulverized coal injection. Bioresource Technology, (2014) Vol.161: pp.333-339.
9. Pelaez-Samaniego M R , et al., Effect of temperature during wood torrefaction on the formation of lignin liquid intermediates , . Journal of Analytical and Applied Pyrolysis,, (2014) Vol.109 pp.222-233.
10. Chen W H , et al., An evaluation on improvement of pulverized biomass property for solid fuel through torrefaction , . Applied Energy, , (2011) Vol.88 pp.3636-3644.
11. Bergman P C A , et al., Development of torrefaction for biomass co-firing in existing coal-fired power stations “biocoal” ECN Report ECN-C-05-013,, (2005)
12. Bridgeman T G , S.I. Jones J M , and W.P. T, Torrefaction of reed canary grass, wheat straw and willow to enhance solid fuel qualities and combustion properties Fuel (2008) Vol.87 pp.844-856

13. Prins M J Thermodynamic analysis of biomass gasification and torrefaction,. Ph. D. Dissertation Technische Universiteit Eindhoven Netherlands, (2005)
14. Prins M J , Ptasinski K J , and Janssen F J J G Torrefaction of wood Part 1 Weight loss kinetics , . Journal of Analytical and Applied Pyrolysis, , (2006) Vol.98 **;** (pp.3026-3036).