Waste for energy production: monitoring and controlling pollutant emissions for sustainable economy.

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1.Introduction

At the United Nations Climate Change Conference in 2023 (COP 23), it was mentioned that the gaps in emissions reductions continue, countries, especially the largest emitters, need to urgently present powerful and ambitious climate plans and seek more efficient public policies to reduce emissions. However, it has not been agreed that the process for different sectors will set new targets for reducing emissions. A positive sign was emphasized by the European Union, which announced and reinforced a reduction from 55% to 57% by 2030 (https://unfccc.int/cop28). The COP action plan to fulfill the pillars of the Paris Agreement included accelerating the energy transition. Governments and non-governmental agencies are researching and implementing actions and incentives to encourage the adoption of renewable energy strategies, so that energy producers use a certain proportion of renewable energy in their energy mix. These sources include geothermal, solar, hydro, wind, and biomass. These are considered sustainable because they release far fewer greenhouse gases (GHGs) and other pollutants that contribute to air pollution and climate change (S.E. Ibitoye et al., 2023). In recent decades the option for technologies with renewable energy has grown significantly, the results of this paradigm shift have shown more economic and efficient processes. Considering the abundance of biomass as raw material in specific countries, it has been generating gaseous, solid and liquid fuels for different applications. The use of solid biomass to generate electricity and biofuels to generate both electricity and transportation fuels are examples of sustainable applications of this energy source. Globally, approximately 7% of total energy consumption comes from traditional biomass, and 2-3% from modern bioenergy (Ravita D. Prasad, et al.,2021).

Biomass conversion technologies have the potential to contribute to zero emission targets due to their ability to process raw biomass and waste (Timsina et al., 2023). Another great advantage of biomass is that it can be used directly, through combustion in furnaces, boilers or other industrial burners (R. Garcia, 2010). Solid biomass fuels can be used to produce briquettes and pellets. These new waste products are generated from compressed biomass. Sawdust, agricultural waste, wood sawdust, coffee grounds, peanut shells, rice husks, coffee husks, elephant grass and even sugar cane bagasse can be used. This waste is compacted with or without binders at high pressure. This new product has advantages such as better storage, low humidity and, above all, higher calorific value and bulk density compared to raw biomass (S.E. Ibitoye, et al., 2023; R.Garcia et al., 2020).

Biomass can be compacted using different processes, the most current being pelletizing. To do this, the biomass must be crushed, dried to the appropriate moisture content and compacted, generating a granular material called a pellet (Magalhães, 2014; Arkom Palamanit, et al., 2023). Pellets are solid biofuels that have consistent qualities - low moisture content, high energy density and homogeneous size and shape (Obernberger; THEK, 2010). They generally have cylindrical shapes with a diameter of 6-8-25 mm and a length of 3.15-50 mm (Hajinezhad; Kianmehr; Nasiri, 2023). Due to its very low degree of humidity, which is around 8% to 10%, the pellet is a product that can have a calorific value of up to 4,800 kcal, while firewood with 30% humidity has a calorific value of no more than 3,600 kcal. It will be important to research the characteristics of these new products for energy generation and simultaneously evaluate the reduction of pollutant emissions and the increase in heat generation and guarantee economic benefits. According to Lijuan Ji, et al.(2023), many agricultural residues have been evaluated as pellets, but little research has been done on the use of peanut shells. The authors evaluated five types of biomasses (various types of wood, straw, peach wood, rice husks and peanut shells) and compared their calorific values. The results showed that peanut shells had the highest calorific value, followed by miscellaneous wood, peach wood, straw and rice husks. Ji, Lijuan, et al., 2023 the emission of pollutants was evaluated experimentally. They concluded that there was a significant reduction in SO_2 and NOx emissions with an increase in the proportion of peanut shells mixed with coal, which was consistent with previous studies. Confirm that mixing peanut shells in boilers can substantially reduce emissions of pollutants such as SO_2, NOx and CO_2 emitted into the atmosphere, contributing to sustainable environmental development. The results of the elemental analysis showed that peanut shells have lower CO_2 emissions compared to coal.

2.Objective: The aim of this study was to determine the emission values of gaseous pollutants and particulate matter emitted by the burning on a pilot scale of biomasses used as fuel, sugar cane bagasse and peanut shell pellets.

3.Methodology

The biomass burning process (sugarcane bagasse and peanut pellets) were performed in burner on a pilot scale and pollutant monitoring described in Costa, M.A.M. et al., (2023). The process of emission control of gaseous and particulate pollutants was carried out using a Venturi scrubber and water as a cleaning liquid. Two liquid flows of

300 and 400 L/h. The burning tests were performed separately for both fuels and maintained the same process variables. Emission data of CO_2, CO, NOx and $PM_{2.5}$, and other pollutant were obtained through online monitoring of the flue gas continuous monitoring system.

4.Results

The results of the elemental analysis of peanut pellets were: composition by mass percentage (%) of dry material - Fixed carbon (19.9 %), Carbon (51.1 %), Hydrogen (6.76 %), Nitrogen (2.7 %), Ashes (5,3 ± 0,8), Total sulphur (0.12 %), Volatile materials (74,8 ± 1,1), Oxygen (34.02 %), Calorific value higher (HCV) MJ/kg (21.07 %), Lower heating value (LCV) MJ/kg (19.61 %) and total moisture (10.07%). Analysis carried out by the Technological Research Institute (IPT) Fuels and Lubricants Laboratory/CQM/IPT. The values of the elemental analysis for sugarcane bagasse can be seen in Costa, M.A.M. et al., (2023). If we compare the HCV values of sugarcane bagasse (18.29 %) and LCV (15.96 %) and peanut pellets, we can see that the pellets show higher results, suggesting better combustion results.

The emission of particulate matter smaller than 2.5 μm emitted by burning these fuels was assessed in different situations, without the use of pollution control equipment and with the use of a Venturi scrubber.

The effect of temperature and the stages of the combustion process affect pollutant emissions. It can be seen that with biomass burning the highest concentrations were of PM less than 1μm. In the flame phase the values in the combustion chamber ranged from 700 to 1200 ºC. Higher temperatures and combustion in the flame phase produce higher emissions of fine particles, in addition to higher concentrations of CO_2 and NOx.

The highest concentrations of PM<2.5 μm were emitted with the burning of peanut pellets, the highest values were above 3307.6 $\mu g/m^3$ for particles less than 0.056 μm. Emissions for both fuels were very high for dp<1.0μm, ranging from 600 to above 3000 $\mu g/m^3$. In this particle size range, these emissions are the most harmful to health and complex for collection in industrial processes. The emitted values of PM were high for both fuels and must be controlled. The tests using the Venturi scrubber in the cleaning of pollutants resulted in high efficiencies. The values of collection efficiency reached values above 90% for diameter around 1.0 to 1.8 μm and 55% for dp = 0.056 μm. The values of gas emissions were higher for burning with peanut pellets. The CO_2, CO and NOx emissions were higher for the higher temperatures of the flame phase for both sugarcane bagasse and peanut pellets. The highest CO_2 emission values were 48065.9 and 88082.2 mg/m^3, for sugarcane bagasse and pellets respectively. Considering CO emissions, the average values of emissions were 400 mg/m^3 for pellets and 200 mg/m^3 for sugarcane bagasse. The highest NOx emissions were 265 mg/m^3 for pellets and 80 mg/m^3 for sugarcane bagasse. The results of the elemental analysis of both fuels showed that the low elemental N value in sugarcane bagasse may be the main reason for reducing the emission concentration of this pollutant. In the pellets burning more oxygen was inserted in the combustion chamber and higher burning temperatures were achieved, this combined effect was positive in generating higher concentrations of CO_2, CO and NOx. In the study by Lijuan Ji, et al.(2023) confirm that mixing peanut shells in boilers can significantly reduce emissions of pollutants such as SO_2, NOx and CO_2 emitted into the atmosphere, contributing to sustainable environmental development. The results of emissions that peanut shells have potentially lower CO_2 emissions compared to coal.

5. Conclusion

The results of pollutant emissions using both fuels were high e these emissions were high and necessarily need to be controlled in industrial processes, even using biomass-based fuel. The use of pollution control equipment in the collection of PM was very efficient for particles smaller than 2.5μm. Emissions of pollutants using sugarcane bagasse were lower than emissions with the burning of peanut pellets. Compared to fossil fuels, biomass energy is an energy source with lower pollutant emissions. The use of biomass energy is a relevant alternative in the energy sector, but these sources must be controlled and monitored in the search for more sustainable processes.

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