Poultry litter waste characterization for energy purposes

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Abstract

Poultry litter, waste generated by poultry farming, has its main destination the use in soil as fertilizer, although, the non-controlled use for this purpose can result in environmental impacts. Therefore, the thermochemical conversion of this waste can be an alternative for its final destination, since its products can be converted into energy. In this work the characterization of poultry litter waste was carried out through proximate (moisture, ash, volatile matter and fixed carbon), thermogravimetric and calorific value analysis, in order to use the waste for energy purposes. The results indicated a main devolatilization region between 150 and 450°C for both evaluated fractions (top and base). The high content of volatile matter (69.8% for top and 62.6% for base), as well as the calorific value found (15.27 for top and 17.62 MJ/kg for base) make them attractive residues for thermochemical conversion processes.

Key-words: Poultry litter wastes. Energetic Reuse. Pyrolysis.

Area: 6 – Energy and Renewable Energies

1 Introduction

In recent years, poultry industry has made considerable Brazilian growth rates, primarily due to opening for outer market.

The poultry sector holds the lead in exports and the third position in chicken meat world production since 2011 (RODRIGUES et al., 2014). This position proves the management used by the Brazilian poultry industry, which has one of the most developed aviculture in the world (Avila 2007), but it eventually generates an excess waste, mainly consisting of the litter from poultry that are used and then replaced.

Poultry litter is any material distributed over the floor of the sheds to serve as a bed for the birds (NEITZKE 2010). Poultry litter materials are often made of wood shavings, sawdust, wheat, straw, peanut husks, rice husks, or another type of waste available in the region. According to Costa (2012), the litter is usually comprised of a material, which has a very lignified, part and difficult to degrade. Although it is typically reused, there is little information on their quality characteristics and patterns in different lots of reuse.

According to Silva (2008), poultry litter is a major waste generated by the sector, which leads to poultry production to seek alternatives for use, handling and disposal.

The use of poultry litter as fertilizer can be economically attractive, since it represents an internal resource in farming and it is a residue, which contains a high concentration of nutrients. However, from an ecological point of view, there are major restrictions on its use because it can be a soil, surface and groundwater pollutant (HAHN 2004).

Another possibility for these materials reuse is through thermochemical conversion, since the products generated can be converted into energy. A detailed characterization of these materials is required.

In this work, the characterization of poultry litter waste was carried out through proximate (moisture, ash, volatile matter and fixed carbon), thermogravimetric and calorific value analysis, in order to use the waste for energy purposes.

2 Materials and Methods

2.1. Materials

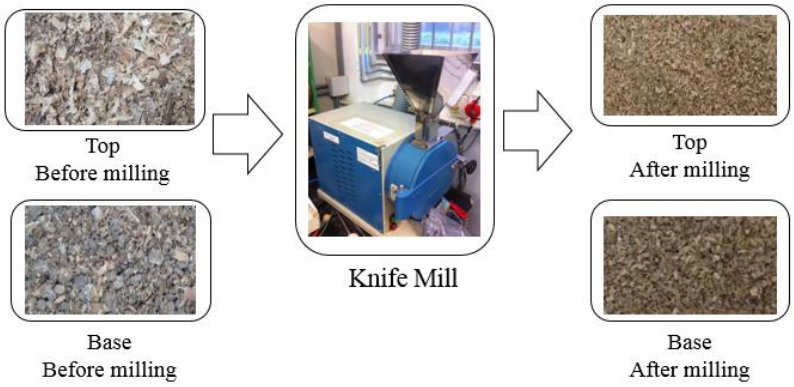
The poultry litter samples used in this work come from a laying poultry farm, placed inside the city of Antonio Prado, located in the state of Rio Grande do Sul, Brazil.

The sampling procedure was performed according to NBR 10007/2004 standard. To ensure the samples representativeness, different sampling points inside the aviary were selected. These samples were allocated in this place for a seven-month period, corresponding to three lots. Afterwards, the quartering procedure was done, which also followed the NBR 1007/2004 recommendations.

2.2.1 Samples preparation

After the quartering procedure, the samples were comminuted in a knife mill, Marconi brand, MA 580 model, 995 724 series. This particle size reduction made possible further analyses (thermogravimetric, proximate and calorific value analysis). A scheme for the preparation steps is shown in Figure 1. Sample preparation procedure was performed in the Polymer Laboratory (LPol) at the University of Caxias do Sul.

Figure 1. Scheme of preparation steps.



2.3 Thermal analysis

The thermogravimetric experiments were conducted in the Energy and Bioprocess Laboratory (LEBIO) at the University of Caxias do Sul, with a samples diameter less than 0.9 mm and initial mass of about 10 mg. The experiments were performed in a STA 449 F3 Jupiter ® thermogravimetric balance from Netzsch brand under inert atmosphere (N_2) at a 50 ml min^{-1}flow rate. An alumina crucible and a 25°C/min heating rate were used. The experiments temperatures ranged from ambient temperature to an 800 °C final temperature.

2.3 Proximate analysis

The experiments to perform proximate analysis were performed in the Energy and Bioprocess Laboratory (LEBIO) at the University of Caxias do Sul, with previously prepared samples, according to item 2.2.1. The analyses were performed based on the D3172-89 (1993) and D3173-87 (1996) standards from American Society for Testing and Materials (ASTM).

Regarding moisture content determination, a Shimadzu brand analytical balance, AUY220 model and a Delio brand stove, A3SED model were used. The volatiles determination was carried out using a Fornitec brand muffle, 1963 model and a Shimadzu analytical balance, AUY220 model.

Ash determination content was carried out using a STA 449 F3 Jupiter ® thermogravimetric balance from Netzsch brand. The analysis was performed with synthetic air atmosphere, samples with diameter less than 0.9 mm and initial mass of about 10 mg. The alumina crucible was used. The heating was conducted from ambient temperature to 500°C (8.33ºC/min rate) and from 500°C temperature to 950ºC (7.92ºC/min rate). These heating rates were used in order to fulfill the standard recommendations (the temperature reached within 1h must be 500°C and the temperature in 2h must be 950ºC). Finally, the samples were maintained at this temperature for 2 h.

The fixed carbon content determination was performed from the ash and volatile matter contents.

2.4 Calorific value analysis

The calorific value analysis of the samples were conducted in the Energy and Bioprocess Laboratory (LEBIO) at the University of Caxias do Sul. A VEB brand, 08 number, 1031 model calorimeter pump equipment was used.

The tablets were prepared using a chrome nickel wire of approximately 13 cm. Firstly, wire weighing and the insertion in the matrix were done. Afterwards, 0.7 g of benzoic acid and 0.3 g of sample (250 µm particle size: ASTM D5865) were weighed. The following procedure was the mixing of two fractions (benzoic acid + sample). Compression was

performed in a matrix. The mixture (benzoic acid + sample) was disposed in a mintage before being placed in the matrix. The samples remained in the matrix over a period of about 30 minutes. After this time, which was necessary for tablets compaction and formation, the removal and weighing were done for later insertion in the calorimeter pump.

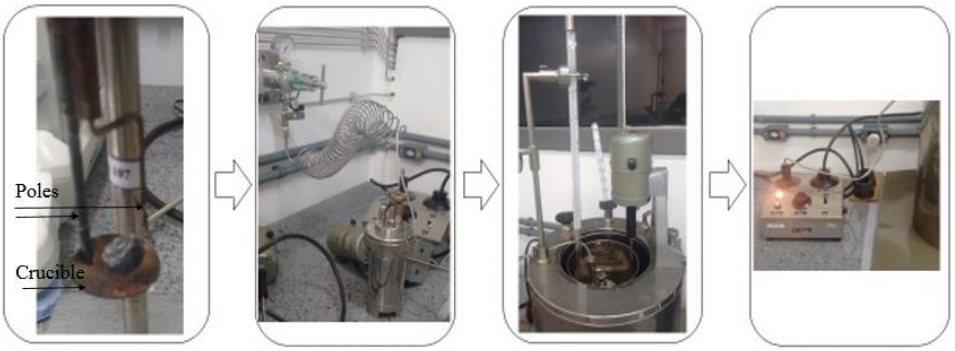
For system preparation, the tablet was fixed at the poles of the pump (Figure 2a), in order to be held by the crucible (Figure 2a), fixing the ends of the wire.

Subsequently, 5 ml of distilled water through a pipette into the pump was introduced. Then, the pump was carefully closed in the manual way (Figure 2 b). An addition of 30-bar-pressure oxygen was done.

The calorimeter pump was inserted into equipment center, for later placement of the stirrer and the Beckmann thermometer. Two litters of water were used in the equipment. Regarding the temperature, it was approximately 1 to 1.5°C below the outer jacket water temperature. Another important issue was related to the thermometer position, as well as the stirrer speed. Both remain constant throughout the experiments. The calorimetric pump and stirrer were connected to the ignition box.

Finally, there was the outer jacket filling with water whose temperature should be equal to the ambient temperature. Figure 2 shows the equipment used for obtaining the samples calorific value analyses with system preparation emphasis.

Figure 2. Equipment used in samples calorific value determination with system preparation emphasis.



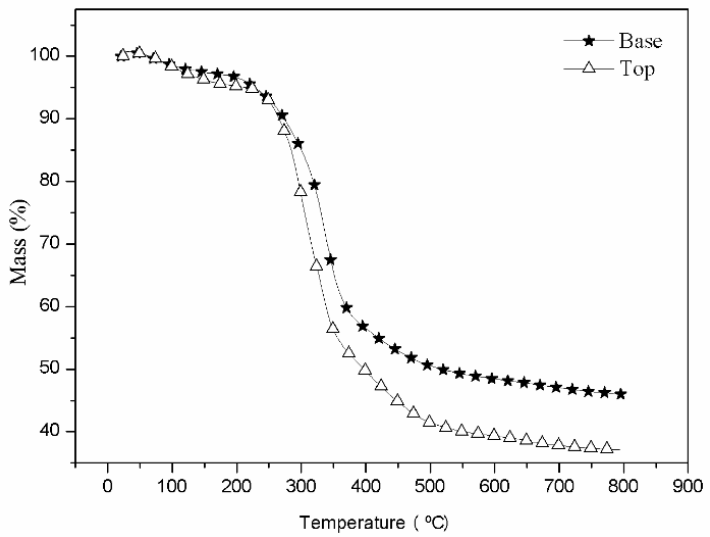
At the end of the system setup procedure, the analysis itself was conducted. At this time, the ignition box was connected to the network, the ignition lamp was lit and the stirring system operation was on. When the temperature stabilized, the ignition button was pressed and it started the combustion. The initial temperature was registered. The data recorded during the combustion were the temperature variations as a function of time. The temperature increase was registered at each minute until the stabilization. The remained wire was dismounted and weighed. For calibration purposes, tests were performed for each sample with 1g of benzoic acid tablets, since the calorific value of this acid is known (2470 kJ/kg). Furthermore, tests were conducted in triplicate for each fraction studied and from this the deviations that will be presented in section Results were obtained. In case of results incoherence, the experimental methodology was repeated.

3 Results and Discussion

3.1. Thermal analysis

Figure 3 shows the thermograms obtained for both poultry litter samples (top and base), at heating rate of 25ºC.min^{-1}. These thermograms provide mass loss curve as a function of temperature.

Figure 3. Thermograms obtained for the two samples.



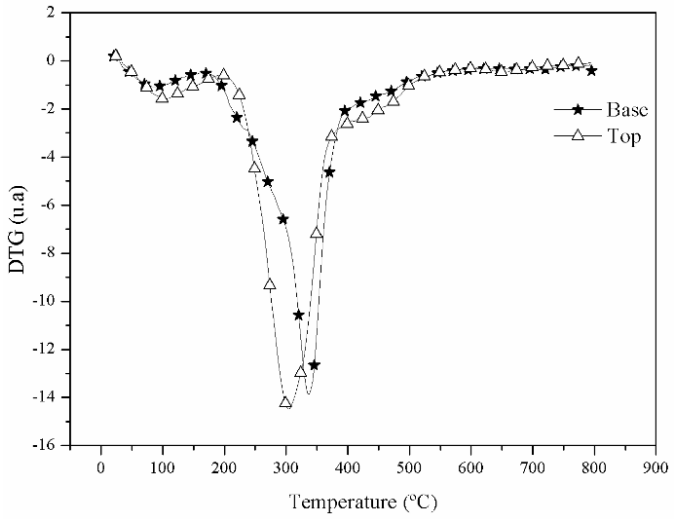
It is possible to observe that both curves have weight loss values at temperatures below 110 °C, where the accumulated water loss happens. The average moisture contents found for these samples were 18.26% for the top and 21.78% for the base.

It also can be observed from Figure 3 that the samples have different residual mass content (mass remaining sample at 800ºC).The highest residual mass was observed for the sample related to the base (46.03%), whereas for the sample related to the top the content was 37.14%. The high residual mass in the sample related to the base is associated with its high ash content, found in the proximate analysis (approximately 26%). Other researchers have reported high levels of ash in poultry litter waste. Kirubakaran et al. (2007) reported a content of 28.8% and Whitely et al. (2006) a content of 26.58%. Neitzke (2010) attributed the fact that the ash content in the litter is greater when compared to timber species, the possibility of the soil particles presence mixed with sawdust, manure, feed, feathers and insects.

The main weight loss region observed occurred between 150 and 450°C. The temperatures where the reaction rate is maximum can be identified in Figure 4 and are 106.4ºC and 304.39ºC (for the top sample) and 88.9ºC and 337.83ºC (for the base sample), respectively.

For a better evaluation of the results, Figure 4 shows the first derivative (DTG) curves.

Figure 4. First derivative for the two samples.



Concerning the curves, it can be inferred for both samples studied that at 200°C begins the degradation process of the hemicelluloses and lignin (SHEBANI 2008 cited JUNGES 2015). Hemicelluloses degrade in the range of 200-350ºC with the cellulose amorphous part, and they show themselves more pronounced as a shoulder rather than a well defined peak in the DTG (KIM, 2006 cited JUNGES 2015). Lignin begins its decomposition process at about 200°C, but the mass loss related to its degradation occurs in a wide range (JUNGES, 2015). The slow lignin decomposition exceeds the maximum temperature degradation and can reach a temperature above 600°C (POPESCU 2011 cited JUNGES 2015). Cellulose decomposes between 280 to 400 °C, but this range is also influenced by the intermolecular bonds fragmentation and aromatic rings condensation, both present in lignin (KIM, 2006 cited JUNGES 2015).

3.2 Proximate analysis

Table 1 shows the moisture, volatile matter, ash and fixed carbon of the samples.

Table 1. Proximate analysis of the samples.

Sample	**Moisture (%)**	**Volatile matter (%)**	**Ash (%)**	**Fixed carbon (%)**
Top	18.26	69.83	7.89	22.28
Base	21.78	62.63	25.99	11.48

The high values obtained for the volatile matter are characteristic of biomasses. According to Netto et al. (2006), the cedar, maçaranduba, sapucaia, timbirana and eucalyptus have volatile values close to 80%. Likewise, it happens with the fixed carbon content. According to Neitzke (2010), the species listed by Netto et al. (2006) have fixed carbon values between 15 and 20%. The high volatile matter content turns the poultry litter samples, both the top as the base, attractive for thermochemical conversion process.

3.3 Calorific value analysis

Table 2 shows the average values obtained in calorific value experiments and the standard deviation for each sample.

Table 2. Calorific value of the samples.

	Average (MJ/kg)	Standard deviation
Top	15.27	0.64
Base	17.62	1.24

The average values obtained for the two samples studied are close to others found by different researchers. Kirubakaran et al. (2007), Reardon et al. (2001) and Whitely et al. (2006) characterized poultry litter wastes and found calorific values between 9.56 and 13.99 MJ/kg.

4 Conclusion

From the results presented in this work it is possible to identify that the thermochemical conversion of poultry litter wastes is an alternative to its disposal, since high levels of volatile matter (69.8% for the top and 62.6% for the base) and calorific value (15.27 for the top and 17.62 MJ/kg for the base) were found.

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