THERMO-PHYSICO-CHEMICAL ANALYSES AND CALORIFIC VALUE OF POULTRY PROCESSING INDUSTRY WASTE

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The paper presents the experimental results for the complete characterization of poultry processing industry waste. The experimental campaign consisted in physical-chemical properties determination of poultry feathers as waste from the poultry slaughterhouse processing line. For the complete characterization, the chicken feathers were analyzed as elemental composition, primary analysis and calorific value. In this paper we investigate the combustibility properties of some residues from the food industry for best energy recovery efficiency. Further investigations are in progress.

Keywords: poultry waste, low heating value, elemental analysis, thermo-chemical analysis.

1. Introduction

Disposal of poultry processing industry waste is becoming a major problem in poultry industry because of environmental pressures and health concerns. Land application and incineration which are currently the major disposal methods are under pressure because of the environmental pollution [1].

These wastes are generated in considerable amounts each year by slaughterhouses, primary due to high consumer demand for poultry meat.

An average weight of a mature chicken is 1.8 – 1.9 kg and 5 – 7% of this weight is represented by feathers. Based on these, the entire quantity of chicken feather waste produced can be estimated. Today the poultry processing industry is developing in high rates and worldwide produces over 5 million tons of chicken feathers waste [2, 3].

A very small amount from the total quantity of waste feathers generated is used for clothing, insulation and bedding [4], producing biodegradable polymers [5] and enzymes [6].

Chicken feathers are made over 90% of keratin protein, 8% of lipids and 1% water [7] and because of this are a difficult substrate to a biological process

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like anaerobic digestion, producing some by-products which are toxic and inhibitory to anaerobic microorganisms in high concentrations [8].

This paper analysis the thermo-physico-chemical properties and the calorific value of the poultry processing industry waste for a complete characterization in order to see combustibility properties of this waste and the energy that could be recovered.

2. Materials and methods

Different analyses were performed: proximate analysis, elemental analysis, high and low heating value determination.

2.1 Primary material

The material used in the experimental campaign is chicken feathers from a local slaughterhouse. Raw feathers were in a mix with blood and other slaughterhouse residues, with the humidity of 70%.

2.2 Methods

2.2.1 Preparation of chicken feathers waste

The feathers were submitted to the drying process in an oven for 24 hours at temperature 105 ºC. After the drying process, they were sliced into smaller pieces, packed and stored at normal room temperature (20–25 ºC). The dried material was used in the experimental campaign.

2.2.2 Volatile Solids (VS %) measurement

For the Volatile Solids percentage (VS %) determination of chicken feathers an electric heated oven working at a nominal temperature of 1100 ºC was used. The sample inserted in a crucible with cap was putted in oven at temperature of 800 ºC for 40 minutes in inert atmosphere. The resulted product is char and the mass difference is the volatiles liberated. The general scheme of the electric heated oven is presented in Fig. 1.

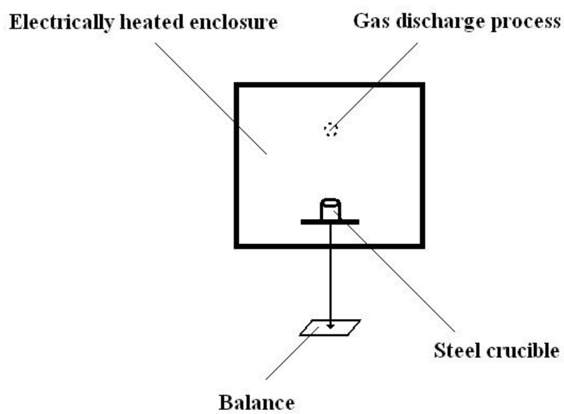

Fig.1. General scheme of electric heated oven

2.2.3 Inert measurement

For inert (non-combustible) measurement, the char was introduced in the electric heated oven at 1000 ºC for 30 minutes. The crucible is without the cap, to permit air (oxygen) necessary for combustion to enter in contact with the sample.

2.2.4 Direct measurement of calorific value using calorimeter

We burned in the calorimetric bomb a representative sample of product, obtaining the high heating value (HHV). Low heating value (LHV) is obtained by a correction factor, calculated according to relationship [9]:

$$LHV = \left(HHV - 5{,}83 \times W\right) \times 4{,}18 \qquad \text{[kJ/kg]} \qquad (1)$$

where:

LHV – low heating value,

HHV – high heating value,

W – percentage of water weight of the material taken for test.

The percentage of water in material weight collected for sample is calculated as:

$$W = W_t + 9 \times H \qquad [\%] \qquad (2)$$

where:

W_t – total humidity content,

H – mass percentage of hydrogen.

2.2.5 Determination of calorific value by calculation

For the elemental composition of chicken feathers an Elemental Analyzer EuroEA 3000 series was used. The analyzer is based on the well-established Dumas principle of Dynamic Flash Combustion followed by gas chromatography separation of the resultant gaseous species (N_2, CO_2, H_2O, SO_2) and Thermal Conductivity Detection in the presence of helium as inert gas and oxygen.

The calorific value of sample was determined based on experimentally elementary composition and using some semi-empirical formulas.

First the high heating value (HHV) was calculated using Dulong formula [9]:

$$HHV_{dry\ product} = (7831*C) + [35932*(H - O_2/8)] + (1187*O_2) + (578*N) \quad (3)$$

Because the Dulong formula is not taking into account the inert fraction, a second formula was used, Channiwala and Parikh [10]:

$$HHV_{dry\ product} = 349.1\times C + 1178.3\times H + 100.5\times S - 103.4\times O - \\ -15.1\times N - 21.1\times A \quad (4)$$

where:

C, H, O, S, N - is the percentage of these chemical elements in the composition of the sample.

Once the high heating value (HHV) was obtained, the low heating value (LHV) is calculated with formula (1) considering that the product is completely dried.

3. Results and discussions

3.1 Proximate analysis

Fig. 2 presents the values obtained for the volatile content, fixed carbon and inert of the sample.

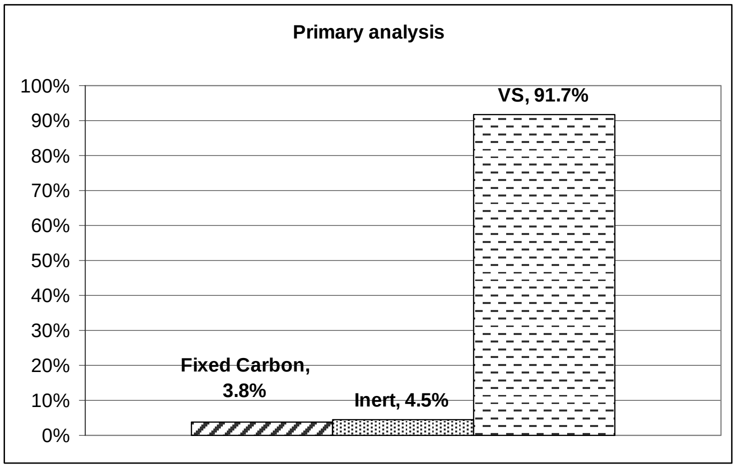

Fig.2. Primary analysis of sample

The volatile content of the sample is very high (91.7%), this shows that the sample have a good ignition point removing the excess oxygen demand for a complete burning process.

3.2 Ultimate analysis

In Fig. 3 is presented the results of the ultimate analysis of chicken feathers.

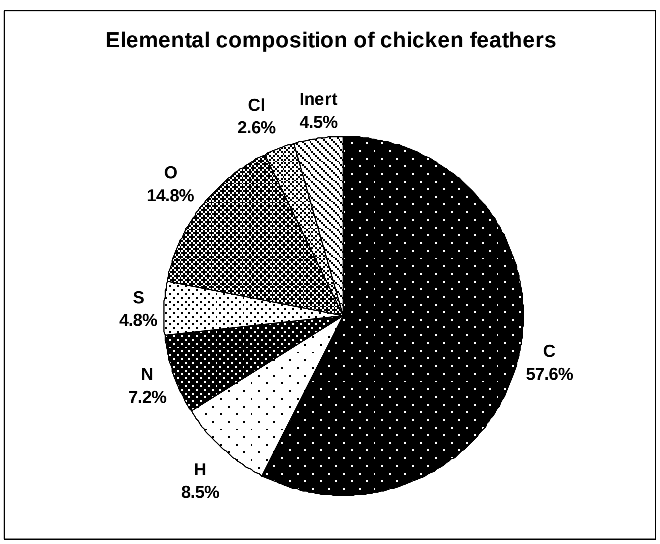

Fig.3. Ultimate analysis of chicken feathers

The combustible fraction from the sample, C – 57.6% and H – 8.5% are high, and because of this it is expected that the calorific value will be very good.

The sample has a high content of N – 7.2%, S – 4.8% and low content of Cl – 2.6%. The presence of N can be explained by the fact that the feed of the chickens is rich in nitrogen. The feathers were not clean, because of the presence of blood and other residues can be explained the sulphur content.

3.3 High and low heating values

Fig. 4 displays the results of the low heating values calculated by the elemental composition and from experimental - calorimeter.

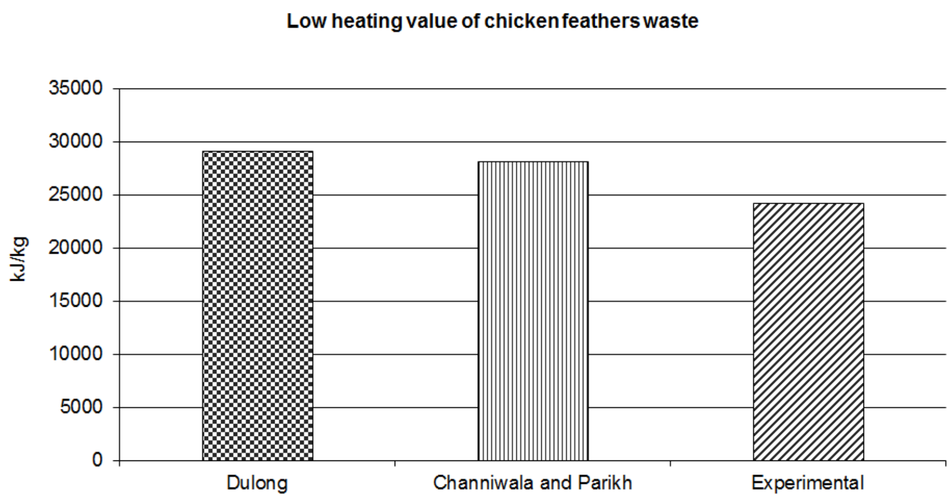

Fig.4. Low heating value of chicken feathers waste by calculation and experimental

By calculation using two different formulas the low heating value varies a little, 29000 kJ/kg with Dulong and 28000 kJ/kg with Channiwala and Parikh. Though, the experimental determination of low heating value with calorimeter is more accurate than the one resulted from the elemental composition of chicken feathers, even if the latter has a better result, 24000 kJ/kg. There is no Romanian standard to certify the results from calorimeter measurements.

To see the improvements made by the drying process of the chicken feathers, Fig. 5 presents the low heating value calculation of the primary derived material with the humidity of 70%. The low heating value was calculated with formula (5) considering that the initial mass of feathers is 1 kg:

$$LHV_{wetfeathers} = \frac{LHV_{driedfeathers} * m_{driedfeathers} - \lambda * m_{wetfeathers}}{m_{feathers}} \quad (5)$$

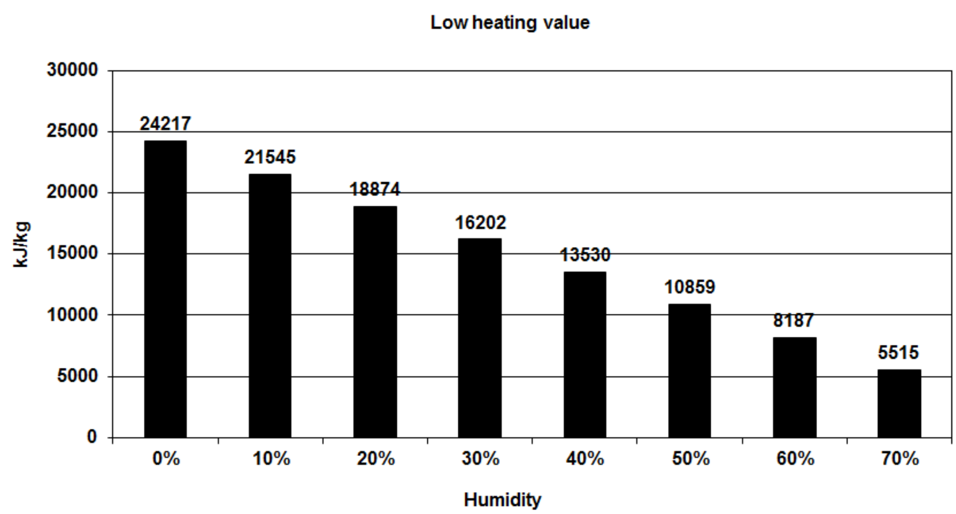

Fig.5. The low heating value variation function of humidity

The low heating value varies from 24217 kJ/kg for dried sample to 5515 kJ/kg for sample with humidity 70%. At this humidity the sample cannot ignite. Drying the feathers in the oven is considerably increasing the calorific value up to almost five times.

4. Conclusions

Because of the increasing quantity of waste feathers and the good low heating value from elemental composition of sample, almost 25 MJ/kg $_{\text{dried feathers}}$ the potential of poultry feathers derived like waste for the energy sector can be a viable solution for the future. The high value of volatile solids content can self-sustain the ignition of the product and removes the excess oxygen (air) demand for the burning process.

Because incineration is a technique not so environmental friendly with carbon dioxide emissions into atmosphere and an apparent energy loss, the solution could came from the pyrolysis or advanced gasification like the proper technique for thermal destruction of these waste. With this solution we can neutralize 99.99% of waste with low emissions in air; obtain recoverable energy and technically products: char, syngas, and possibility to increase the global energy efficiency by solving some technological and operation problems.

Acknowledgement

This work was supported by POSDRU, project number POSDRU/88/1.5/S/61178

R E F E R E N C E S

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