

ENERGETIC ANALYSIS OF MEAT PROCESSING INDUSTRY WASTE

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The paper presents the results of the experimental analysis oriented to the quantification of some physical and chemical properties of meat processing industry residues and the assessment of their potential as renewable energy source. Experimental laboratory analyses were conducted to establish the elemental composition, volatile fraction, fixed carbon and inert content of the products. The calorimetric experiments conducted on representative waste samples revealed the high and low heating value of the product. The results enabled the identification of possible waste to energy conversion solution. Further investigations are in progress for practical applications.

Keywords: biodegradable waste, primary and ultimate analysis, energy potential

1. Introduction

The meat processing industry generates meat and products for human consumption, and also considerable amounts of solid waste and other by-products (skins, fats, bones, offal, etc.) [1, 2, 3]. A significant percentage from the animal remains after processing as waste: approximately 46% of each cow, 48 % of each sheep or goat, 38 % of each pig, 28 % of each chicken [4]. These by-products are a hard to use waste that is produced each year worldwide in millions of tons [5]. The most common method adopted by the meat processing industry to dispose of animal waste is the processing into a meat and bone meal [6].

The Meat and Bone meal (MBM) is produced by processing at 105 °C the animal's offal, blood and bones previously mixed and crushed [7]. Before 1994 in the EU, the MBM was used for feed the ruminants. Because it was found to be the main cause of bovine spongiform encephalopathy (BSE) disease transmission the European legislation has banned the MBM use as feed [8]. Thereby, the safe disposal of meat processing industry waste is necessary to prevent hygienic

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problems and pathologically transmissible diseases. Landfill is not a viable solution because it cannot destroy any potential pathogens.

Nowadays, it is seen that the most potential alternative for disposal of this waste is thermal treatment by high-temperature processes [9]. One option can be the combustion and gasification with energy recovery potential [10]. This paper presents the experimental results in term of physical – chemical characterization of meat processing industry residues (bones) in order to assess their energetic potential as renewable energy source. Based on experimental analysis were identified possible energy conversion solutions.

2. Materials and methods

For the optimum waste processing technology configuration the base of the project consists in the complete product characterization with respect to proximate and ultimate analysis, energy content and physical – mechanical properties. The last criteria is required by collecting, transport, storage and feed-in procedures related to waste treatment / valorization unit.

The samples used for the characterization of waste (mixtures of bones and meat) were collected directly from the meat processing line. The sampling, samples preparation and laboratory experiments / analysis were conducted in order to insure the results reliability.

2.1 Proximate analysis

Proximate analysis delivers the main physical component distribution resulted under controlled heating, in the following order: moisture, volatile matter, fixed carbon, and ash.

The moisture content was determined by sample drying at 105°C for 24 hours. Due to fat based components in the sample the temperature level may induce supplementary weight loss by partial volatilization. Consequently the moisture content may be slightly lower than the measured one.

For determination of volatile matter, the waste was heated to 800 °C for 40 minutes in inert atmosphere; an electric heated oven was used. In Figure 1 is presented the electrically heated oven.

The sample is introduced in a steel crucible with a cap to prevent the oxidization. The mass variation of sample can be monitored with an analytical balance. Volatile matter is the material that will convert to gases. The devolatilization was considered completed when the variation of mass sample stops. The remaining material at the end is char.

For inert (non-combustible fraction) determination, the char was heated in the oven at 1000 °C without the cap for 30 minutes until the complete combustion

takes place. The crucible containing the sample is removed and cooled for 15 minutes before it is weighed, the remaining material is ash.

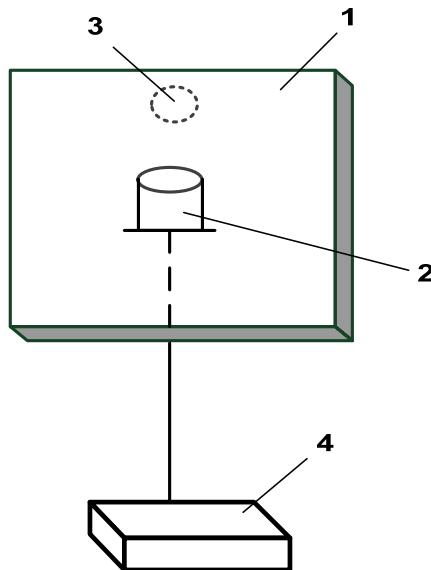


Fig. 1. Electric heated oven
1. Electrically heated oven, 2. Steel crucible, 3. Flue gas evacuation, 4. Analytical balance

The fixed carbon was determined by difference and represents the solid carbon in the sample that remains in the char after the complete volatile release.

2.2 Ultimate analysis

The elemental composition of the waste was determined experimentally using an elemental analyzer. The apparatus uses the principle of dynamic flash combustion and gas chromatography separation of the resultant gaseous species with thermal conductivity detection for measuring carbon, hydrogen, sulfur and nitrogen.

2.3 Energy content

The energy content of a fuel is expressed as higher heating value (HHV) and lower heating value (LHV). The HHV was determined experimentally by a calorimetric system, by burning a representative sample in the calorimetric bomb. The LHV is computed using a correction equation based on hydrogen and water content of the sample [11]:

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

Where W is the percentage of water content in sample, calculated as:

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

where:

W_t – total humidity content,

H – mass percentage of hydrogen

Based on experimentally elementary composition and using semi-empirical formulas, the calorific value of sample was also determined.

The high heating value (HHV) was calculated using Dulong formula [12]:

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

A second formula specially designed by Channiwala and Parikh for biomass based products was used [13].

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

Where:

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

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

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

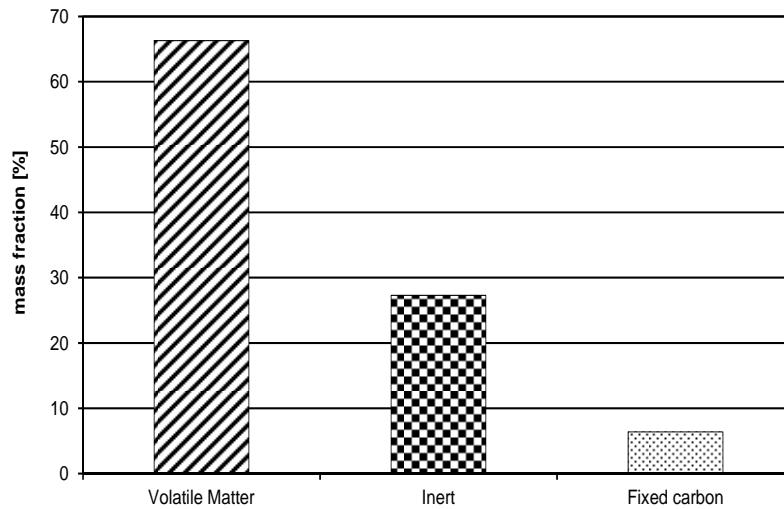


Fig. 2. Proximate analysis of sample

The volatile content of the sample is very high, up to 67% similar to fast biodegradable biomass products. The presence of important volatile matter guarantees a good ignition point and a lower excess oxygen demand for a complete burning process. A specific characteristic of this product is given by high inert fraction (28%) different from common biodegradable waste. This value is similar to coals and municipal solid waste (only for non-selective collection situation) [11].

The presence of high inert fraction may raise residues management problems whatever the waste to energy conversion solution will be applied. Regarding the fixed carbon presence in the product its mass fraction does not exceed 7–8%. Consequently, the specific energy content of the char is very low. The product energy content is concentrated in its volatile matter.

3.2 Ultimate analysis

In Figure 3 is presented the results of the ultimate analysis of pork bones.

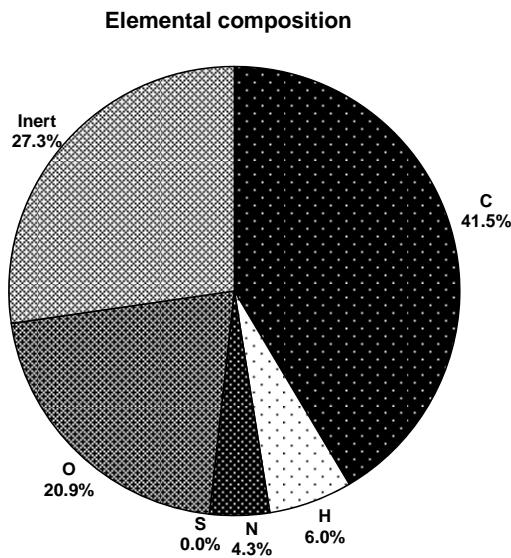


Fig. 3. Ultimate analysis of pork bones

The combustible fraction from the sample, C – 41.5% and H – 6% are high, confirmed by the high calorific value. The sample has also a significant content of N – 4.3%. No sulphur or chlorine elements were detected. The oxygen concentration is similar to biomass based products.

In terms of pollutant sources the product can be considered to be clean suitable for thermal-chemical processing. The waste to energy conversion technologies will require reduce gas cleaning units and lower investment costs.

3.3 High and low heating values

Figure 4 displays the results of the low heating values calculated by the elemental composition and from experimental determination. The calculated values are presented to highlight the importance of direct measurement of HHV in LHV determination. Important errors are introduced by empirical formulas used for HHV and LHV calculation even if correct measured values for elemental composition of the product are used.

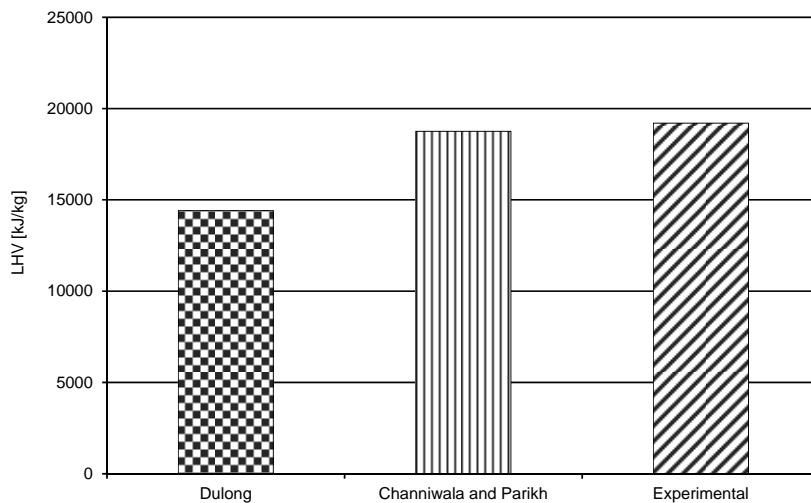


Fig. 4. Low heating value of pork bones waste by calculation and experimental

By calculation using two different formulas the low heating value varies from 14424 kJ/kg with Dulong to 18755 kJ/kg with Channiwala and Parikh. The second formula delivers more accurate results compared to experimental determination (19205 kJ/kg). Nevertheless there is no Romanian standard to certify the results from calorimeter measurements.

For thermal-chemical processing the low heating value and water content of the products represent important data that strongly influence the design and the operation parameters of the waste processing units. In this case lower water content, achievable by pre-treatment or drying, will improve not only the product LHV but also the energy efficiency of the thermal processing. This will lead to higher global efficiency of the conversion chain.

The influence of water content of the product on its LHV is presented in Figure 5. The presence of water in the product up to 40% (in mass) will decrease the low heating value down to 10523 kJ/kg. Even so the value is relatively high in range with medium quality coals. For example the lignite from Oltenia extraction region does not exceed 7000 kJ/kg [14].

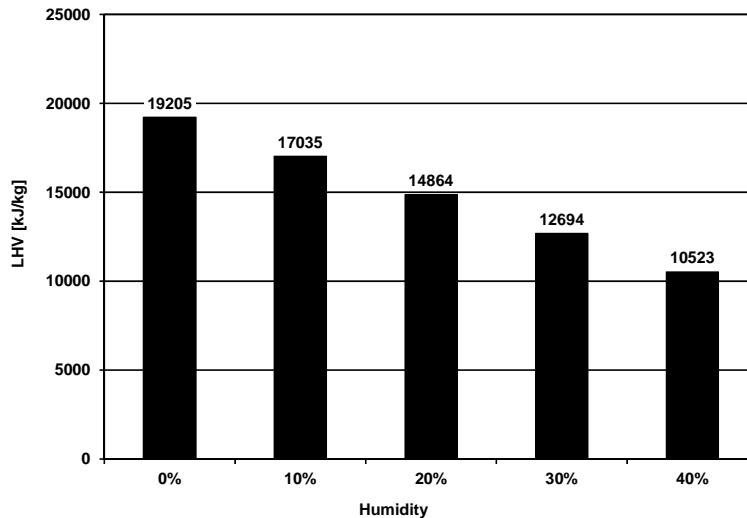


Fig. 5. The low heating value variation function of humidity

Nevertheless the options for moisture removal are limited for this product due to its physical characteristics that are not suitable for mechanical grinding at mesh compatible sizes.

4. Energy conversion

Based on primary, ultimate and calorimetric analysis results a series of waste to energy conversion chains were assessed. The conversion solutions are presented in Figure 6. The first option is represented by direct combustion combined with steam turbine cycle. The waste calorific value and its elemental composition are suitable for this process. Some important aspects related to product properties and in-field conditions limit the applicability of this solution:

- High inert fraction. The presence of important ash fraction and its low melting point will limit the maximum combustion temperature. Consequently the steam parameters will be low and the turbine efficiency will decrease.
- Mass flow. Usually the waste sources have small capacities and the available quantities of waste are reduced with respect to energy sector applications. The Rankine-Hirn cycles are strongly influenced by the scale effect and for this application the global efficiencies are very low.
- Availability. Generated by an industrial process, the waste will not be delivered continuously to the power plant. Steam turbines are designed for a limited start stop procedures. Moreover waste storage is impossible due to its fast degradation properties and high health risk.

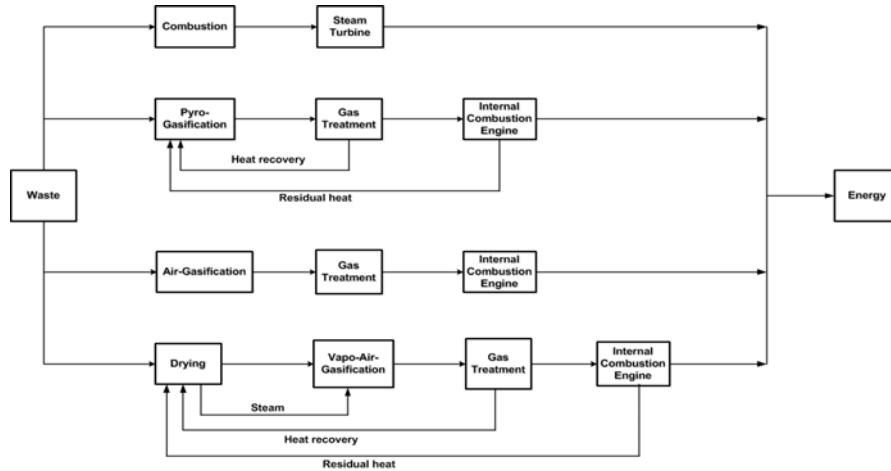


Fig. 6. Energy chain options

The other three options use gasification in different processing configurations. Due to Otto-Diesel cycles flexibility, fast start-up and insignificant scale effect, the gasification provides clear advantages when compared with combustion for this type of fuel and capacity.

Pyro-gasification could be used to solve the moisture problem enabling also the storage of the pyrolysis by-product. Considering the very low fraction of carbon in pyrolysis char the gasification of this product may not produce the required amount of syngas to be used in an internal combustion engine.

The **direct air gasification** could represent a solution but the increased air/fuel ratio required by the important moisture content within partial combustion of waste could decrease the syngas low heating value to engine operating limits. Experimental research is required.

An interesting solution may integrate a partial drying of the waste with **vapor-gasification** processing for high quality syngas production. The separate drying will solve the moisture presence in first gasification stage providing the steam for the second stage where hydrogen formation will be favored. The advantage is given by the significant increase of syngas quality that may fit the engine requirements.

5. Conclusions

The paper presents the results of experimental campaign conducted on the main meat industry residue (mixture of bones, meat etc.) for product complete characterization with respect to combustible properties. The results reveal

important volatile matter (up to 67% in dry basis product) and ash content (up to 28%). The fixed carbon fraction is low compared to biomass and coals and does not exceed 7%. The elemental analysis shows results similar to biomass based products: C – 41.5%; H – 6%; O – 20.9%; N – 4.3%. No sulphur or chlorine elements were detected. The low heating value of dried product is 19205 kJ/kg while the raw product LHV does not exceed 12000 kJ/kg. The results prove that meat industry residues that consist mainly of mixtures of bones and meat could be a renewable energy source with direct in-site valorization. Based on product properties and research team experience in the field of thermal-chemical processing a series of waste to energy conversion chains is proposed.

Acknowledgement

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