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SOLUTIONS FOR POULTRY INDUSTRY WASTE TREATMENT WITH ENERGY RECOVERY

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Abstract: The poultry processing industry is one of the most rapidly growing sectors from food industry chain, with large quantities of waste generated every year. Worldwide there were generated over 10 million tons of poultry residues eliminated in present by incineration. Chicken feathers as poultry processing industry waste represents a source of pollution for air, water and soil affecting also human health and the quality of environment. This paper presents the poultry processing industry waste to assess their potential as renewable energy source. The High Heating Value of chicken feathers is 26000 kJ/kg (dry basis) which recommends them as an energy source. Based on the experimental results, the paper proposes some waste to energy conversion solutions for energetic potential recovery of poultry processing industry waste using thermo–chemical processes. Net electric output generation for a poultry processing unit (86 t/day waste) using some energy conversion solutions can reach 4 MW for completely dried product. This solution is an alternative to incineration allowing the poultry processing industry to become its own energy producer with positive impact on expenses with incineration process.
Keywords: Renewable energy, energy recovery, food industry waste, chicken feathers

1. INTRODUCTION

Energy is one of the important factors with a negative effect on the environment through various ways: increasing emissions of greenhouse gases, environmental pollution by hydrocarbons, long–term storage of nuclear waste, deforestation, etc. By power generation and consumption, it results also some harmful effects on the environment which contributes to climate change, natural ecosystems deterioration and not least negative effects on human health (Jones, J.C., 2010).

Energy activity is responsible for the main pollutant presence in the atmosphere by 50% of methane and carbon monoxide emissions, 97% of sulfur dioxide emissions, 88% of nitrogen oxide emissions and 99% of carbon dioxide emissions (Fuchs, E.F., 2011). Nowadays, mankind is facing with an increase in energy consumption which will lead to the development of new efficient methods of recovering energy from various fuels (Williams, P.T., 2005). The renewable energy sector is distinguished by the possibility of reducing greenhouse gases emissions and pollution, exploitation of local and decentralized energy sources with encourages of new technologies developments in the industry. Based on the limited quantities of primary resources and the negative environmental impact of classic fuels utilization, the use of renewable sources seems a real solution to the 21st century problems (FAO, 2011).

Waste as a renewable energy source represents an option worth taking into account by the enormous increase in quantity and diversity. The everyday generation character coupled with their potentially harmful effects on environment and public health is conducting to the need of methods for safe disposal (Salminen, 2003).

Technologies for recovery the energy from wastes can play an important role in resolving the problems regarding the reduction of the overall waste quantities requiring final disposal. Waste generation rates are influenced by economic development, industrialization degree and population number. Generally, when these figures are high, the greater are the amounts of waste produced (Kantarli, I.C., 2016). Based on the statistics, the poultry processing industry is one of the fastest growing sectors from the food industry chain (Basu, P., 2009). Worldwide there are generated important quantities of poultry processing industry waste, over 10 million tons annually (Corella, J., 2003).

An important and a hard to use waste from this industry is chicken feathers which raises issues regarding safe disposal. Until year 2000, chicken feathers and other poultry processing industry wastes were used in a form of digestible protein feedstuff for poultry. This solution was banned by the European Union because of the risk of disease transmission via feed and food chain. Currently, all the poultry processing industry wastes are disposed by incineration which has some disadvantages in term of the apparent energy loss, air pollution and big expenses (Font–Palma, C., 2012). Therefore, the paper response to these problems by using alternative thermochemical conversion solutions, characterized by high temperature and conversion rates: pyrolysis and gasification. The environmental consequences of the chicken industry's waste disposal have necessitated effective waste management (de Jong, 2007; Marculescu, C., 2012) As a consequence of its availability, chicken waste has been offered as a viable fuel choice for thermal conversion technologies. There is a strong need to assess the current reaction kinetics and its application in modelling pyrolysis and gasification of biomass in fluidized beds and find different approaches to design and operation of gasification plants. Furthermore, fundamental knowledge on the thermochemical behaviour of biomass and waste fuels is still lacking, especially regarding the release of the fuel bound nitrogen. Valuable data can be obtained performing TG–FTIR analysis on the characterization of various mixes of chicken waste, biomass, meat and bone and coal blends (Marculescu, C., 2012; Demirbaş, A., 2001; Nenciu F., 2021).

Based on the experimental results, the paper proposes some waste to energy conversion solutions for energetic potential recovery of chicken feathers waste using two thermo–chemical processes: pyrolysis and gasification. The generation of electricity and heat from chicken feathers by thermochemical processes is a highly waste management solution.

2. MATERIALS AND METHODS

— Waste sample

For the experimental campaign were used chicken feathers obtained directly from the technological line processing of the slaughterhouse. The feathers were not clean, the presence of blood and other poultry residues was observed. The water content was measured by drying in an oven for 24 h at temperature 105 ºC. This revealed a high–water content of about 70%. Then, the feathers were sliced and stored in packed condition at normal room temperature (20–25ºC). The obtained sample was used as a starting material for the experimental part.

— Physical–chemical properties

The complete characterisation of sample consisted in proximate and ultimate analysis. The results revealed high energy content of the sample (Table 1) (de Jong, 2007).

Table 1. Proximate and ultimate analysis of chicken feathers

Volatile [%]	Fixed carbon [%]	Inert [%]	C [%]	H [%]	N [%]	S [%]	O [%]	Cl [%]	HHV [kJ/kg]
92	6.5	1.5	60.6	8.5	8.7	4.8	13.3	2.6	26139

The proximate analysis (volatile, fixed carbon and inert) was determined using a calcination electric heated oven. The volatile content was determined by subjecting the sample to a high temperature pyrolysis process.

The oven was heated to a temperature of 800°C and then the crucible with sample previously weighed was inserted in the oven for 40 minutes. The resulted char was subjected to a combustion process to determinate the fixed carbon content of the combustible materials, respectively the one of inert (non–combustible).

This process took place at a temperature of 1000°C, for about 20 minutes. The volatile content was about 92%, fixed carbon 6.5% and inert fraction of about 1.5%. The volatile high values suggest that the ignition point of the sample is very good; that decreases the excess oxygen demand for the burning process. This thermal–physical characteristic leaded to the assumption that two–stage treatment process can be used for energy conversion chain: pyrolysis as pre–treatment phase followed by combustion or gasification of generated products (gas, tar and char).

Ultimate analysis (elemental composition) of chicken feathers was determined experimentally using an Elemental Analyzer EuroEA 3000 series. The apparatus has a working temperature of 980ºC in the presence of an inert gas such as helium and oxygen. The elemental analyzer used is based on the 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 Detector. It can be observed important amounts of C and H, comparable to those of wood biomass or coal. The high heating value of the dried chicken feathers was 26139 kJ/kg.

3. ENERGY CONVERSION SOLUTIONS

Based on the physical–chemical characterization of chicken feathers, different energy conversion solutions were studied in accordance with the applicability to the product used (Figure 1).

Different humidity content of the product was considered 70% and 50%. The pyro–gasification process was used. The chicken feathers were submitted to the pyrolysis process at a temperature range between (350°C – 500°C). The pyrolysis products resulted undergoes gasification stage at a temperature between 850°C–1100 °C with syngas production. The pyrolysis products formation, properties and quantities depend on process conditions. Consequently, the pyrolysis operation parameters have indirect influence on gasification process (kinetics, syngas composition and properties). Previous works of the authors investigated the influence of pyrolysis temperature, residence time and atmosphere on reaction products (Marculescu, C., 2012; Nenciu F., 2021; Mircea C., 2020).

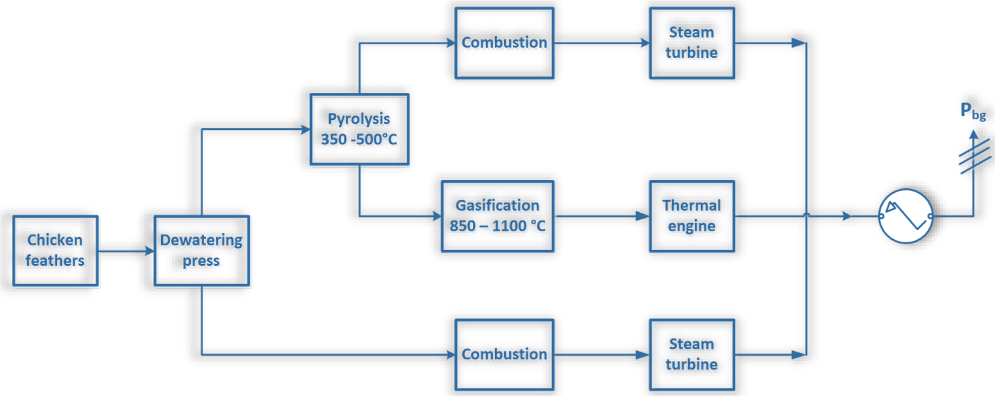

Figure 1. Waste to energy conversion chain

The results were used to assess the waste to energy conversion chain using pyrolysis and gasification treatment sequence for a specific product as it is delivered from poultry slaughterhouse processing line with a capacity of 86 t/day.

4. RESULTS – PROCESS ENERGY BALANCE

Using the experimental results, engineering calculation was performed to establish the energy balance of pyrolysis and gasification stages for representative waste samples. Previous studies of the authors revealed that product humidity can be decreased with minimum energy consumption by a dewatering press.

The energy balance for combustion, pyrolysis and gasification processes was made considering the water content of 70% respectively 50% achievable with the dewatering press and for the case of the humidity varying between 30–10%. In Figure 2 is presented the energy consumption on drying, pyrolysis and gasification processes.

At 70% humidity the biggest amount of energy (heat) is consumed in the drying of the product, approximately 2200 kW followed by the gasification with 1050 kW. For this humidity the pyrolysis process energy consumption is the smallest, about 150 kW. With humidity decrease, the product requires a higher amount of energy to break the solid matrix bounds. Therefore at 50% humidity the drying energy consumption decreases to 1600 kW while the pyrolysis energy consumption slightly increases to 250 kW while in case of gasification is doubled reaching over 2700 kW.

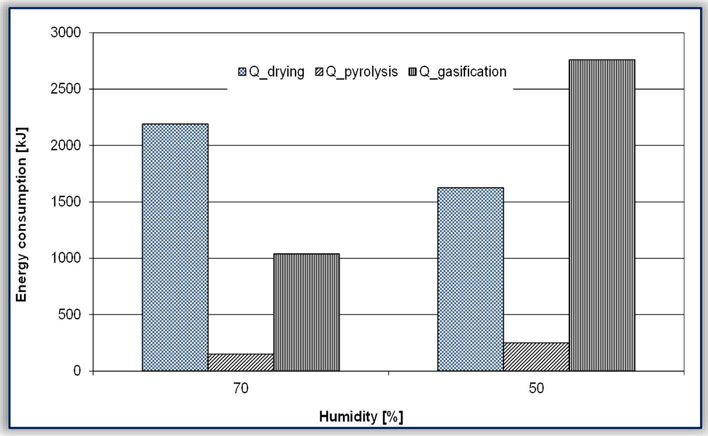

Figure 3. Energy consumption on drying, pyrolysis and gasification

Based on the waste characterisation, net thermal and electric power output was computed using literature process efficiencies (Figure 3).

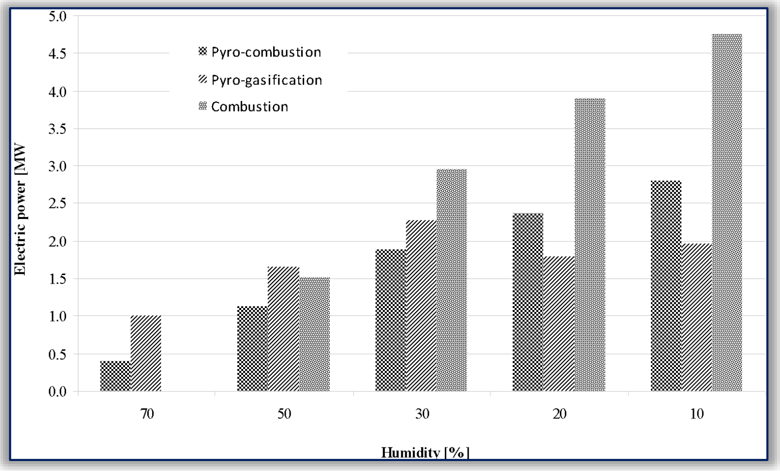

Figure 4. Net power output from chicken feathers using energy conversion solutions

It can be observed the influence of product humidity on power generation. The net thermal power reaches at 70% humidity approximately 1 MW while the net electric power was half of it almost 0.5 MW. This fact can be explained by the low electric conversion efficiency. A decrease of humidity until 50% has an important effect on power generation, increasing the net thermal power up to 2.4 MW. Also, the net electric power is increasing doubling his value up to 1 MW. Considering that 50% humidity is a level easily attained by a dewatering press with low energy consumption the net electric power is less affected by the drying process.

Considering the quality of the feathers resulting from most farms in Romania and a humidity level of 50% (obtained by mechanical dehydration), the best thermo–chemical treatment solution is pyro–gasification. The solution is also based on the maximum level of investment that feather waste producers have in mind in association with the proposed treatment techniques.

5. CONCLUSIONS

High heating value of chicken feathers (dried base) 26139 kJ/kg recommends this waste to thermal treatment processes, pyrolysis and gasification, with energy generation, as an alternative to incineration process. For 50% chicken feathers humidity, based on the calculation can be obtained almost 2.5 MW net thermal power and 1 MW net electric power. Using the waste to energy chain solution proposed in this paper as an alternative to incineration, the poultry processing industry can become its own energy producer. Energy recovery by thermal treatment processes is a promising solution for poultry processing industry waste management. By using pyro–gasification process, an energy unit with good operational parameters can be constructed which improves the overall efficiency of power conversion.

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