GETTING ENERGY FROM POULTRY WASTE IN JORDAN: CLEANER PRODUCTION APPROACH

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ABSTRACT

Reducing environmental impacts and getting economic benefits, based on the waste utilization, and on the reduction of both energy consumption and organic load, was the driver of the implementation of cleaner production assessment in a poultry industry and its related processes. The main objective of this study is to examine the feasibility of using poultry litter as a source of energy to cover the heating demand of Poultry Company’s slaughterhouse. Poultry litter enters the cooking stage to produce the fat-oil for the fuel burning stage. The results showed that the critical price of poultry litter is 46.7 JOD per ton, below which it becomes feasible to utilize this waste as a source of energy. However, the daily monetary saving was found to be strongly affected by the prices of both poultry litter and diesel. Another revenue can be generated from the fertilizer value of the poultry waste-to-energy ash. However, this depends on several technical and market factors that need further clarification.

Keywords: poultry litter, slaughterhouse, steam boiler, energy, eco-efficiency, cleaner production.

INTRODUCTION

The cleaner production (CP) is an in-depth review of existing operations to increase efficiency of the operation through pollution prevention and energy conservation [1, 2]. The CP is an essential and valuable tool used to: (1) define the specific characteristics of a whole facility or operation that consumes energy and generates waste, (2) identify a range of energy conservation and pollution prevention options, (3) evaluate the options based on a set of criteria, and (4) select the most promising options for implementation.

Facilities should find CP assessment instrumental to systematically identifying opportunities to increase energy efficiency and decrease waste generation. Consequently, this leads to a positive change in the sustainable production and consumption [3 - 6]. It is a well-used and proven approach to identifying cost-saving energy conservation and pollution prevention technologies that enhance the facility’s performance.

The agro-food industry provides interesting opportunities for the application of this concept, in particular, due to the energy and water consumption levels and wastes generated [7, 8].
Jordanian statistics in 2013 indicates the availability of around 2125 chicken farms [9]. Excess biomass is readily available on a poultry operation; this poultry litter is a viable and renewable energy source with heating value average around 9550 kJ/kg [10, 11], at the same time 96 % of energy supply in Jordan is imported [12].

Solid waste management is currently a crucial subject in Jordan. The solid waste generation is expected to increase on account of development activities, population growth, and changing patterns of Jordanian consumption behavior by approximately 3 % per year [13 - 16]. In addition, changes in public awareness will affect it [17].

However, poultry-waste-to-energy has the capacity to increase air pollution and to negatively impact environmental justice and health if environmentally sound management and best practices are not considered [18, 19].

Poultry litter is a mixture of heads, feet, intestines, blood, and feathers. According to literature, the uses of poultry litter as a land fertilizer are constrained due to risks of water pollution (from leachate and runoff), and spread of diseases. On the other hand, pyrolysis of poultry litter by applying thermo-chemical techniques produces usable energy and destroys microorganisms.

The aim of this study is to provide an initial cost-benefit analysis for the efficiency of recovering heat from poultry litter produced at poultry company’s facilities as an alternative source to meet the heating demands of the company’s slaughterhouse. Moreover, it is also examined the feasibility of using the simple pyrolysis technique to produce fat-oil from poultry litter (heads, feet, intestines, blood, and feathers).

MATERIALS AND METHODS

The assessment presented in this paper has been carried out following the Guide to Industrial Assessment for Pollution Prevention and Energy Efficiency in order to facilitate it [20]. In this paper, a poultry factory located in Al-Karak Governorate in Jordan, was chosen as a case study. The company is engaged in the operation of poultry farms, slaughterhouses, breeder and broiler farms, hatcheries, and feed mills. The company manufactures packs, trades, markets, and distributes poultry products, namely eggs and chicken feed. Products of this company are distributed throughout the whole country.

According to its annual report, the factory’s production of poultry meat has experienced a slight increase in year 2014 to reach 30,629 ton in comparison to 30,230 ton in year 2013. Nevertheless, the factory’s annual report for the year 2013 has shown a number of difficulties facing the company, which hamper the company’s growth. Difficulties include rising competition among slaughter shops, fluctuating prices of feeds globally, swamping the local market with imported frozen chicken leading to a higher competition between suppliers, increasing fuel prices globally, and the emergence of new companies in this industry. All of these difficulties have led to an increase in production and drop in prices. Thus, this factory works hard to reduce the cost of production, which eventually could increase its profit.

Several detailed visits were carried out to collect necessary data and establish the material, water and energy flow analyses. The assessment was focused on the slaughterhouse to examine the status of current boiler systems for the future utilization of poultry litter as a source of energy.

All data regarding the daily poultry production, percentage of poultry litter, average daily production of fat-oil, average price per ton of poultry litter, and daily diesel demand were collected and used for calculations. The average diesel price for the year 2014 was 0.685 JOD/L (1 USD equals 0.71 JOD). This number was obtained from the Ministry of Energy and Mineral Resources and therefore it was used as the reference price for diesel.

POULTRY PROCESS DESCRIPTION

As shown in Fig. 1, chickens are normally transported from several farms and delivered in loose boxes (crates) via lorries. During the transportation, the crates, which are made from plastic and have a rectangular shape, are normally contaminated with manure wastes. Consequently, the manure contamination increases the amount of organic effluent produced during the automated crate washing equipment after delivery of the chickens.

Having arrived at the slaughterhouse (killing area), the chickens are hung upside down by their feet on a metallic conveyor which moves them towards the stunning machine (30-40 volt) and the stunned chickens are moved to the killing line. After being killed, the chicken is bled for up to two minutes while moving on the conveyor. The blood is collected in tank, and then it moves through a specific channel.
After bleeding is complete, the chickens are transferred via conveyors to the de-feathering stage, in which they are immersed in a scald tank (56 - 58°C) to facilitate the mechanical de-feathering process. So, the de-feathering stage comprises counter-rotating stainless steel discs with rubber fingers mounted on them, as well as, continuous water sprays are usually incorporated within the machines for flushing-out feathers.

The removed feathers are taken to a collection point via a fast-running water channel located below the machine. The collected feathers are then transferred to a lorry using a conveyor belt. Other feathers, which escape through water, can be collected in the grit chamber in the preliminary wastewater treatment stage.
After that, the chickens are transferred via the conveyors to the evisceration stage (EV stage). In the EV stage, the chicken’s head and feet are cut and removed, and then the chicken is eviscerated automatically whereby the internal organs are mechanically removed using a device which is inserted into the opening and the viscera are withdrawn. Another sucking system is used to take out the lungs and make sure that there are no blood and/or body liquids in the eviscerated chicken body. A water spray system is used to wash the eviscerated chicken internally and externally prior to chilling.

The chickens are unloaded, immersed and moved through a counter-flow current in the pre-chiller followed by screw chiller at temperature less than 5°C. After that the chickens are dried. Rehanging of chickens is manually conducted on moving conveyors which pass through air chilling room to reduce any contamination risk. The chickens are then automatically weighed and classified (fresh and/or frozen chicken, wrapping, partitioning, cutting, and de-boning). After weighing and grading, chickens are usually packed on polystyrene trays and wrapped with transparent film. Then the packed poultry products are cooled, frozen, and stored for shipping.

### RESULTS AND DISCUSSION

The cooked product contains 33 % (wt basis) of fat, 65 % (wt basis) of protein, and 2 % (wt basis) of residual matter, which is finally pressed to produce fat-oil syrup of which 19 % (wt basis) is fat in average. The average production of poultry from the slaughterhouse reaches up to 150 tons/day of which 25 % is poultry litter (approximately 37.5 tons of poultry litter per day). The daily production of fat-oil syrup from the slaughterhouse ranges between 1,800 to 2,000 liters, while the daily quantity needed to meet all heating demands in the slaughterhouse accounts for 4,500 liters. The specific gravity of fat-oil is 0.87 with a heat content of 35.30 MJ/kg (97 % of diesel heat content (36.4 MJ/kg lower heating value)).

### Table 1. Calculation for Fat-Oil Boiler.

<table>
<thead>
<tr>
<th>Fat-Oil Boiler</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Daily Poultry Production</td>
<td>150</td>
<td>ton</td>
</tr>
<tr>
<td>Percentage of Poultry litter (Heads, Feet, Intestine, Blood, and Feathers)</td>
<td>25.00</td>
<td>%</td>
</tr>
<tr>
<td>Daily Production of Poultry litter</td>
<td>37.50</td>
<td>ton</td>
</tr>
<tr>
<td>Average Daily Production of Fat-Oil</td>
<td>1,900</td>
<td>L</td>
</tr>
<tr>
<td>Fat-Oil Production per ton of Poultry litter</td>
<td>50.67</td>
<td>L/ton</td>
</tr>
<tr>
<td>Average Demand of Fat-Oil</td>
<td>4,500</td>
<td>L</td>
</tr>
<tr>
<td>Required Quantity of Fat-Oil (Shortage)</td>
<td>2,600</td>
<td>L</td>
</tr>
<tr>
<td>Required Quantity of Poultry litter (Demanded)</td>
<td>51.32</td>
<td>ton</td>
</tr>
<tr>
<td>Average Price per ton of Poultry litter</td>
<td>25.00</td>
<td>JOD</td>
</tr>
<tr>
<td>Average Daily Cost to Run the Fat-Oil Boiler</td>
<td>1,283</td>
<td>JOD</td>
</tr>
</tbody>
</table>
The average price of poultry litter ranges between 20 - 30 JOD/ton, while the average price of diesel for the year 2014 is 0.685 JOD per liter. Therefore, by assuming that no change occurs on diesel prices it is found that the usage of poultry litter as a source of energy to run the fat-oil boiler will result in a daily saving of 1,114 JOD. Tables 1 and 2 show the findings of the data gathering and analysis for fat-oil boiler and diesel boiler, respectively. Accordingly, the resulting savings of poultry waste-to-energy are calculated as shown in Table 3.

Figs. 3 and 4 show the variation in daily saving vs the poultry litter price and the diesel price, respectively.

Using poultry waste as a feedstock to produce electricity and/or process steam requires specialized equipment, designs, and practices, but is technically feasible using currently available technology. One major drawback associated with any feasible system is capital costs of the technology infrastructure and equipment. Normally, 3 to 5-year return-on-investment (ROI) is makes the project economically feasible. However, currently there is no reported literature of an energy producing system in poultry business and industries that could provide enough adequate energy and would entail a 3 to 5-year ROI.

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**Table 2. Calculation for Diesel Boiler.**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Daily Diesel Demand</td>
<td>3,500</td>
<td>L</td>
</tr>
<tr>
<td>Average Price of Diesel for the Year 2014</td>
<td>0.685</td>
<td>JOD/L</td>
</tr>
<tr>
<td>Average Daily Cost to Run the Boiler on Diesel</td>
<td>2,397</td>
<td>JOD</td>
</tr>
</tbody>
</table>

**Table 3. Saving Calculation.**

<table>
<thead>
<tr>
<th>Saving</th>
<th>Value (JOD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Daily Cost to Run the Fat-Oil Boiler</td>
<td>1,283</td>
</tr>
<tr>
<td>Average Daily Cost to Run the Boiler on Diesel</td>
<td>2,397</td>
</tr>
<tr>
<td>Daily Saving</td>
<td>1,114</td>
</tr>
</tbody>
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Fig. 3. Daily saving vs poultry litter price (at diesel price of 0.685 JOD/L).

Fig. 4. Daily saving vs diesel price (at poultry litter price of 25JOD/ton).
Another economic advantage of using poultry-waste-to-energy is the utilization of the nutrient-rich ash which is expected to have significant value for use in fertilizers. Phosphorus and potassium are the nutrients present in highest concentration. Internationally, the net fertilizer value of poultry waste ash at the energy plant, after accounting for transportation costs and any additional processing costs, will approximately range between $25 and $75 per ton of ash [21].

As to the environmental impact of poultry waste-to-energy process, the sources of emissions from this process include the smokestack effluent, truck exhaust from transport of poultry litter and waste ash, runoff from washing of the trucks, and disposal of the plant’s wastewater. Incineration of organic materials produces emissions, including particulate matter of varying sizes, carbon monoxide (CO), carbon dioxide (CO2), dioxins, nitrogen and sulfur oxides (SOx), heavy metals, polycyclic aromatic hydrocarbons, and others, similar to those of other incinerators that use more conventional forms of fuel [22]. These emissions can individually and jointly impact both the environment and human health [22 - 24]. Hence, the processes and emissions related to alternative energy sources require detailed scrutiny to prevent sacrificing the communities’ health and environment. Moreover, biosecurity measures are required in poultry waste-to-energy projects, and regulations should be set for achieving biosecurity.

It is worth mentioning that the poultry waste-to-energy process is subject to environmental impact assessment (EIA) regulations in Jordan. This is in order to mitigate all environmental impacts that might be caused by such a process. However, previous studies showed comparison of emissions from controlled coal and biomass combustion and poultry litter processes and mainly focusing on the emissions from the smokestack [25]. The results of comparison analysis showed that plants fueled by poultry litter are permitted to produce more carbon dioxide than other forms of fuel and more carbon monoxide than either new or existing coal plants. They are also permitted to produce more NOx than new coal plants, and more SO2 than plants which use new wood or existing biomass to create electricity [25, 26]. Nevertheless, the EIA shall be conducted for such type of processes in order to resolve all potential negative environmental health impacts of incinerating poultry litter for the purpose of energy generation [25].

CONCLUSIONS

This paper addresses a poultry waste-to-energy case that has many properties and attributes that are advantageous for a small-scale poultry litter to energy production system. Moreover, incineration of poultry litter is considered as a solution to the issue of excess waste generation from industrial poultry operations. It was found that it becomes feasible to use the poultry litter as an alternative source of energy if the price of poultry litter is kept below 46.7 JOD per ton, assuming that the price of diesel will stay on the (0.685 JOD/L). Moreover, the daily saving increases with decreasing prices of poultry litter and/or decreasing diesel prices. Other economic viability of poultry waste-to-energy process depends on being able to market poultry waste ash for use in fertilizers because of nutrient concentration and value in the ash.

REFERENCES