Ingeniería e Investigación
ISSN: 0120-5609
revii_bog@unal.edu.co
Universidad Nacional de Colombia
Colombia

DOI: http://dx.doi.org/10.15446/ing.investig.v36n1.52567

Supplying the energy demand in the chicken meat processing poultry with biogas

Suministro de la demanda de energía en el procesamiento de carne de pollo con biogás

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ABSTRACT

The main use of electrical energy in the chicken meat processing unit is refrigeration. About 70 % of the electricity is consumed in the compressors for the refrigeration system. Through this study, the energetic viability of using biogas from poultry litter in supplying the demand for the refrigeration process was found. The meat processing unit studied has the potential to process about a hundred and sixty thousand chickens a day. The potential biogas production from poultry litter is 60,754,298.91 $m^3.year^{-1}$. There will be a surplus of approximately 8,103 MWh per month of electric energy generated from biogas. An economic analysis was performed considering a planning horizon of 20 years and the discount rate of 12 % per year. The economic analysis was performed considering scenario 1: sale of all electricity generated by the thermoelectric facility, and scenario 2: sale of the surplus electricity generated after complying with the demands of the refrigeration process and all other electrical energy and thermal energy use. Economic indicators obtained for scenarios 1 and 2 were favorable for the project implementation.

Keywords: Waste of poultry, slaughterhouse, ammonia absorption refrigeration, distributed generation.

RESUMEN

El principal uso de la energía eléctrica en unidades de procesamiento de carne de pollo es la refrigeración. Alrededor del 70 % de la electricidad es consumida en los compresores para el sistema de refrigeración. Por medio de este estudio, se comprobó la viabilidad energética de la utilización de biogás producido a partir de gallinaza en el suministro de la demanda del proceso de refrigeración. La unidad puede procesar a unos ciento sesenta mil pollos por día. El potencial de producción de biogás a partir de gallinaza es de 60.754.298,91 $m^3.año^{-1}$. Habrá un superávit de aproximadamente 8.103 MWh al mes de la energía eléctrica generada con el biogás. Se realizó un análisis económico considerando un horizonte de planificación de 20 años y la tasa de descuento del 12 % por año. El análisis económico se realizó teniendo en cuenta el escenario 1: venta de toda la electricidad generada por la planta termoeléctrica, y el escenario 2: la venta del excedente de electricidad generada después de satisfacer a todas las demandas de energía eléctrica y energía térmica. Los indicadores económicos obtenidos para los escenarios 1 y 2 fueron favorables a la ejecución del proyecto.

Palabras clave: Residuos de la avicultura, matadero, refrigeración por absorción de amoniaco, generación distribuida.

Received: August 20th 2015
Accepted: January 31st 2016

Introduction

Current trends indicate growing electricity costs in Brazil, above the inflation rate. The majority of the hydroelectric potential of South, Southeast and Midwest regions were already being explored. In the North region, that concentrated the remaining hydro potential, a major environmental impact of large hydroelectric projects exists. The decentralization of electricity generation in Brazil has increased along the years. Over 28 % of the Brazilian primary energy matrix is firewood, sugar cane energy products (alcohol and bagasse) and other biomass sources such as agriculture residue. The hydropower energy corresponds to about 13 % of the country's primary energy matrix, and around 87 % of the electrical energy consumed in Brazil (EPE, 2014). The renewable energy in Brazil is

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How to cite: Ferrarez, A. H., Oliveira, D., Lacerda, A. F., Costa, J. M., & Aparisi, F. S. (2016). Supplying the energy demand of the meat processing poultry with biogas. *Ingeniería e Investigación*, 36(1), 118-121
DOI: http://dx.doi.org/10.15446/ing.investig.v36n1.52576.

already around 44 % of the primary energy, and it has a great potential that should be explored much further.

The region of Zona da Mata is a major center of poultry production in Minas Gerais State. The poultry industry has a key role in the economy of small towns of the region, creating many jobs in the service sector. The activity contributes prominently to the region's economy, allowing the inclusion of approximately 600 farmers, 95 % of these classified as family farmers. The improvement of family farms is directly linked to public policies that promote access to new technologies. The farms are located around the plant for meat processing in the municipality of the Visconde do Rio Branco in Minas Gerais State. Most of such farmers are in a distance around 45 km from the meat processing unit. The poultry industry directly influences the economy of at least 34 municipalities of the region. The population of all municipalities involved is estimated around 647,000 inhabitants (Avizom, 2012).

The poultry production chain is characterized by a number of unit processing operations which bind through a technical net, and which in turn depends on the design and technology utilized. The meat processing unit is an important part of the production process (Silva, 2014).

In poultry slaughterhouses there is a need of large volumes of air and water at low temperatures, as well as of steam, that is used in several processing steps. Low temperatures are required for cooling environments (10 °C), for cooling hygiene water (4 to 5 °C), for meat storage rooms (-30 °C) and for meat freezing tunnels (-40 to -35 °C) (James, 2005).

Due to process automation, electrical energy is used in all stages of meat processing. Electric motors are the main end use, since they spend most of the energy in a slaughterhouse. About 70% of the electricity is consumed by the electric motors of the compressors for the refrigeration system. Therefore, in order to propose solutions based on the rational energy use and energy saving it is fundamental to reduce costs and to increase competitiveness of this activity (Bueno , 2008).

The by-products in this production chain have a great potential for power generation, which is mainly composed by poultry litter (Kelleher , 2002). Through the process of anaerobic digestion, poultry litter could be transformed into biogas, which should be used in cogeneration, i.e. CHP or Combined Heat and Power generation/ trigeneration, i. e., the simultaneous generation of electricity, heat and refrigeration (Santos and Lucas Jr., 2002). Hence, the use of waste heat from cogeneration to produce cold, characterizes the process of trigeneration. Less than 10 % of the electricity required in the refrigeration process by compressors is demanded in the trigeneration process. The generation of cold occurs by absorption of ammonia in the refrigeration cycle. This process is important for reducing emissions of carbon dioxide (CO_2) and other greenhouse gases. The absorption refrigeration is described as a system that operates mainly with waste heat. In large industrial applications absorption equipment by ammonia and water is used. In these cases, ammonia is used as a refrigerant fluid and water as a liquid absorbent (Muhle, 2000).

It is important to point out that ammonia (NH_3) is already the refrigerant used in most of the industrial sectors worldwide.

Table 1 shows the characteristics of an absorption refrigeration system using ammonia as refrigerant fluid.

Table 1. Main characteristics of the system by absorption of ammonia

Parameters	NH_3 – absorption
Effect (Stage)	Simple
Cooling capacity (kW)	20 – 2,500
Thermal COP	0.6 – 0.7
Equipment cost (US\$ TR^{-1})	1,760 – 2,640
Electrical energy rate for selling	0.09 US kWh^{-1}
Electrical energy rate for buying electricity	0.12 US kWh^{-1}

Source: (Muhle, 2000)

Table 2 shows the comparison of the thermal and electrical energy consumption of mechanical compression systems and ammonia absorption systems with their service temperatures (T_s). It also shows the minimum temperatures of the heat source that generate the required refrigeration.

Table 2. Comparison of energy consumption in refrigeration systems compression and absorption systems for condensation to +35 ºC in 1 hour for 1,160 kW of refrigeration (TR 329.8)

Refri gerated temperature, T_s(ºC)	Electricity consumption of the compressor (kWh/h)	Heat consumption of installation absorption (kJ x 1000)	Minimum temperature of the heat source (ºC)	Electricity consumption of the solution pump (kWh/h)
0	229	6,997.2	107	18
-10	306	7,812.42	120	21
-35	526	11,831.4	162	31

Source: (Cortez, 1998).

The aim of this work was to propose energetic solutions for the meat processing unit by the use of biogas from poultry litter. The specific objectives were: (i) to evaluate the electrical and thermal loads of the meat processing unit of poultry; (ii) to estimate the electrical power generated from biogas of poultry litter by using gas turbines; (iii) to estimate the cold generation using absorption refrigeration system; (iv) to evaluate the possibility of the meat processing unit of poultry to become energy independent; and (v) to carry out an economic analysis of the options studied.

Methodology

The study was conducted by collecting data of the poultry meat processing unit, located at the municipality of the

Visconde do Rio Branco, Minas Gerais State, Brazil, and in the Energy Laboratory of the Agricultural Engineering Department, Universidade Federal de Viçosa.

The slaughtering and processing capacity is around 160,000 birds per day. The processing unit works in three shifts a day. The survey to evaluate the electric loads (e.g., electrical motors of the compression refrigeration systems, lighting, etc.) and thermal loads (e.g., steam demanded for cleaning and in the meat processing) was done through technical evaluations at the factory and by interviews with the energy department engineer head.

Table 3 shows the total electric power installed by sectors in the processing unit.

Table 3. Total electric power installed by sectors

Sector	Electric power installed (kW)
Reception of birds	45.03
Stunning/Bleeding/Scalding/De-feathering	83.03
Evisceration	63.22
Cutting/Processing	777.74
Sorting/Wrapping/Labelling	93.29
Refrigeration (Engine Room/Cold Storage)	4,423.02
Others	926.51
Total	6,411.84

The average consumption of electricity was 2,385.43 MWh per month in the period from January to July 2009.

Calculations were performed to estimate: (i) the potential of biogas production from residue in the productive chain, (ii) the electrical power that could be generated from the gas turbine, and (iii) the amount of heat to be recovered from the electric power generation. The relationship between the thermal energy and cooling capacity for different temperatures for refrigeration was calculated, since in the meat process different temperatures are required. The calculations were carried out to estimate the residual heat in kWhth and cold in tons of refrigeration (TR).

An economic analysis was carried out aiming to identify the project's economic feasibility. Two different scenarios were analyzed: (i) Scenario 1: Sale of all electricity generated by the thermoelectric unit, and (ii) Scenario 2: Sale of only the surplus electricity generated after complying with the demands of the meat process unit (refrigeration and other electrical and thermal energy use). The following indicators were used in the economic analysis: Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PP). The discount rate was considered to be 12 % a year, typical value for Brazil. A planning horizon of 20 years to the project was also considered.

For the purpose of loan analysis a line of financing of the National Bank of Economic and Social Development (BNDES) called alternative energy was considered. This program aims to promote the diversification of the Brazilian energy generation mix and its sustainability. The interest rate considered was 10.65 % per year, with a grace period of 6 months after the starting of plant operation and a 16 year term for the loan payment.

Results and discussion

Table 4 presents the results for the potential of biogas production, electric power generation from the gas turbine, heat recovered from the process of generating electricity and the equivalent of cold produced in tons of refrigeration (TR).

Table 4. Potential for biogas production, electric power and energy generated, heat recovered from exhaust gases and tons of refrigeration produced

Item	Values
Potential biogas production (m3.year^{-1})	60,754,298.91
Electric power generated by gas turbine (kW)	14,367.88
Electricity generated by gas turbine (MWh.year^{-1})	125,862.65
Thermal power recovered from the process of generating electric power (kWth)	22,640.04
Thermal energy recovered from the process of generating electricity (kWhth.year^{-1})	198,329,035.00

Table 5 shows the input data for the analysis of the economic feasibility of the use of biogas for the 14,367 kW thermoelectric located beside the refrigeration unit.

Table 5. Input data for analysis of economic feasibility of using biogas for 14,367 kW rated power generation by a thermoelectric located beside the refrigeration unit

Equipment	Total Price (US$)	%
Thermoelectric generator	8,979,925.00	24,2
Heat Recuperator	2,155,182.00	5,8
Plant Refrigeration	7,574,957.10	20,4
Deployment Costs	18,335,862.82	49,49
Total	37,045,926.92	100

Source: (Kincaid, 1999).

Table 6 presents the potential for generating refrigeration for different operating temperatures.

Table 6. Cold generation potential in the ammonia absorption refrigeration system for different service temperatures

Operating temperature (°C)	0	-10	-35
Ratio of thermal energy and refrigeration capacity (decimal)	1.67	1.87	2.82
Cold generation potential (kW)	13,557.10	12,107.11	8,028.48
Cold generation potential (TR)	3,854.94	3,442.65	2,282.89
Ratio of energy consumption for absorption systems and compression systems (%)	7.9	6.9	5.9

Source: Authors, (Cortez, 1998)

The potential for generation of cold using biogas and absorption refrigeration systems meet the demand of the refrigerator at the meat unit. This implies the reduction of energy consumption and resource savings in the meat processing.

Table 7 presents the indicators of the economic analysis for the two scenarios studied.

Table 7. Indicators of Economic Analysis

Indicator	Scenario 1	Scenario 2
NPV - Net Present Value (US$)	9,943,905.21	13,426,459.79
IRR – Internal Rate of Return (% per year)	24.59	29.69
Payback Period (years)	5.3	4.4

Conclusions

The use of biogas from poultry litter proves to be feasible from the energetic standpoint to supply the needs of the meat processing unit. The electricity generated is able to meet the refrigeration demands and all the farm properties involved in the production chain. There is an energy surplus, both thermal and electrical; the electrical energy surplus is about 97,237 MWh annually.

Acknowledgements

The authors would like to thank Fapemig, Research Support Foundation of Minas Gerais and CNPQ, National Council for Scientific and Technological Development, for their financial support.

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