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EXERGY EVALUATION OF THE USE OF POULTRY LITTER TO SUPPLY THE THERMAL LOAD OF AVIARIES

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Abstract. *Evaluation of energy conversion processes based on exergy analysis takes into account the quantity and quality of transformed energy. This concept can be applied to the production chain of broilers chicken, contributing to a proper diagnosis of the main irreversibilities for improving energy efficiency and reducing environmental impact. Of all the waste generated by broilers chicken intensive production, poultry litter is distinguished by its quantity and pollution potential. Its use complementing or replacing firewood for heating aviaries can be a viable alternative, turning waste from the production process into energy input and raising sustainability levels. The objective of this study was to evaluate the potential of poultry litter as a feedstock for heating aviaries. From data about the calorific value and composition of the poultry litter and firewood varieties, the chemical exergy is calculated and the results are compared. The calculations consider the correlations presented by Kotas (1985) and obtained from solid fuel made up of Carbon, Hydrogen, Oxygen and Nitrogen. Results show strong exergy potential of chicken litter, especially with low moisture content, for replacing the firewood currently used for heating aviaries. Besides, chicken litter can be transformed into fuel, in the form of briquettes or pellets, to help mitigate the environmental impact caused by irregular deforestation and its misuse as fertilizer.*

Keywords: *Exergy, Poultry Litter, Thermal Load, Poultry houses, Aviaries*

1. INTRODUCTION

The intensive rearing of broiler chickens is a livestock activity which demands considerable thermal and electric energy for birds maintenance and ambience. In Brazil, producers use electricity from utilities for cooling, ventilation, water and food supply. Furthermore, they promote heating of aviaries from firewood burning through a distribution heat system. The ambience of poultry houses is the main productivity factor due to the birds characteristics. As warm-blooded beings, about 80% of the energy consumed regards maintenance and only 20% to birds growing (FUNCK; FONSECA, 2008).

On the first days of life, the chicks thermoregulatory system is poorly developed, making them sensitive to cold. Therefore, heating should occur in the first weeks of breeding, when the metabolism of birds is not yet formed (FURLAN, 2006). Nevertheless, as the supply of electricity by utilities still has flaws and Liquefied Petroleum Gas (LPG) prices are high, farmers prefer to ensure their electrical supply using diesel generators and heating the poultry houses by burning firewood obtained in the rural property.

1.1 The firewood and LPG as a fuel

Madalena et al. (2013) researched 98 poultry houses in 44 farms in the western State of Paraná, Brazil, and found that over 68% of them are heated with firewood stoves which consume of 5 m^3 to 20 m^3 per production cycle. The values agree with Funck and Fonseca (2008) with 20 m^3 per cycle, Nascimento (2011) with 12 m^3 per cycle and Miele et al. (2010) with an average of 15.7 m^3 for conventional aviaries and 31 m^3 for air-conditioned aviaries. 1m^3/day is usually spent in the first two weeks of accommodation.

Sardinha, Macedo and Macedo (2002), investigated direct and indirect combustion of firewood. They estimated the High Heating Value (HHV) of 20,930 kJ/kg in nature and, for coal, a HHV value of 33,488 kJ/kg. This increase in the Heating Value was justified by the increase in the percentage of carbon, which changed from 50.3% to 85%. In this regard, Gabardo et al. (2011) evaluated the possibility of using forest residues for carbonization or for producing briquettes and pellets. The HHV of Araucaria was found to be 19,600 kJ/kg, and that of Pinus was 18,220 kJ/kg. These measurements were performed again after the carbonization process and of 27,990 kJ/kg and 32,050 kJ/kg respectively, were verified. This increase in the calorific value of charred materials with respect to the materials in nature was explained by the removal of oxygen and hydrogen, concentrating carbon energy.

Sturion and Tomaselli (1990) studied the Bracatinga wood and, during the drying period, they determined the moisture loss and the calorific value of the wood. Results showed that a large amount of water was removed and substantial gains in term of calorific power can be obtained for using drying for 4 months.

Leite et al. (2014) evaluated the quality of Coffea Arabica wood as a source of bioenergy in three cropping systems, indicating approximate values of 19,499.8 kJ/kg to HHV and 18,004 kJ/kg to LHV. In another study by Silva (2013), the biomass produced in a Portuguese *Eucalyptus Globulus* forest, showed HHV of 18,000 kJ/kg and the LHV of 16,790 kJ/kg.

Funck and Fonseca (2008) analyzed firewood and LPG heating systems, used in poultry houses of the same capacity of the west of Paraná, Brazil. For the firewood system, they found a consumption of 20 m^3 per breeding cycle and the material presented LHV of 19,200 kJ/kg, with a specific mass of 450 kg/m^3. The poultry heated with LPG consumed 429 kg, with a LHV of 47,234 kJ/kg. The authors indicated the use of firewood as a heat source which provides good thermal conditions and lower costs for heating in the poultry houses studied.

Another study conducted by Santos and Lucas Jr. (2004) into energy balance of poultry houses, shows an average of 548.3 kg per breeding cycle in a conventional aviary, considering a LHV of 46,464.6 kJ/kg.

1.2 Poultry litter as a fuel

In recent years, alternative energy sources have been highlighted as energy supply. The main sources currently studied include solar energy, wind energy and biomass. The latter presents substantial prospects in rural areas due to its availability from livestock production. It accounts for 14% of the world energy supply, reaching 34% in developing countries (SORDI; SOUZA; OLIVEIRA, 2005).

Despite the high energy consumption, the intensive rearing of broiler chickens generates an excessive amount of poultry litter. It consists of a mix of bedding material, excreta, feed wastes and feathers (LYNCH et al., 2013). This waste has been used as fertilizers on farming due to its richness in nutrients such as nitrogen, phosphorus, potassium, calcium and sulphur.

Brazilian poultry farms do not usually have sufficient land to use this waste as fertilizer on cropland and the excessive use may cause environmental problems such as soil and water contamination. However, the quantity excreted (amount of 0.93 kg/bird/cycle) presents considerable potential when processed to provide its energy for the energy balance of the aviary (SANTOS, 2001). In this form, although occur losses of the nutrients during the burning due the volatilization, the ashes from burning are sources of phosphorus and potassium and it is free of contaminants. (SORDI; SOUZA; OLIVEIRA, 2005).

Poultry litter is said to be reused up to six cycles of production. It is a viable alternative to reduce the environmental impact besides favoring regions with shortage of feedstocks and problems for selling wastes. The analyses of Moisture Content (MC), Ash Content (AC) and Heating Value (HV) improve the efficiency of the material, making it competitive with the other energy sources (BRAND, 2007).

Dagnall, Hill and Pegg (2000) conducted a study about sources of collectable farmyard manure in order to determine the potential for Anaerobic Digestion (AD) plants. They indicated AD and direct combustion of poultry litter as interesting alternatives for the European industry.

Miles, Miles and Bock (2004) demonstrated that staged combustion in a conventional fluidized bed poultry can be used to recover fractions of phosphorus and potassium in forms that can be used in the existing feed and fertilizer industries. Furthermore, pilot studies with poultry litter in fluidized bed combustors can recover useable ash. This study compared the turkey litter and swine solids with poultry litter. The HHV of 15,300 kJ/kg and a LHV 9,300 kJ/kg were found in poultry litter.

Lynch et al. (2013) studied poultry litter as a resource in fuel quality terms and indicate the application of fluidized bed technology to solve both energy and waste problems. The authors recognize the low value fuel due to its high moisture, which ranged from 18.7% to 51.8% with an average closer to 40%. Nevertheless, with low moisture it becomes a good fuel, as It was found having HHV of 18,020 kJ/kg (experiment) and 19,500 kJ/kg (calculated). The ash remaining after combustion represents a reduction in the original material of over 90% by weight. They concluded that poultry litter is a useful biomass source when produced locally.

Quiroga et al, (2010) characterized the poultry manure from all the laying hen farms in Asturias with a view to its possible use as an energy source. They highlight that the replacement of fossil fuels by biomass to produce energy will result in a net reduction in greenhouse gas emission. The element analyzed presents high moisture content, with average values of 74.5% and it indicates co-combustion with other types of waste such as forest and wood waste should be considered as a feasible alternative energy source.

Santos and Lucas Jr. (2004) showed the energy balance in poultry houses. They found the average poultry litter energy coefficient corresponds to 15,239 kJ/kg for a fraction of 76.12% solid mass, a figure that converges with that found by Sordi, Souza and Oliveira (2005), whereupon HHV showed a variation of 11,600 kJ/kg to 16,100 kJ/kg due to a different moisture percentage.

Proposals for using this waste have been made by various researchers, such as using the bed poultry for generating biogas by using the boatload type digester (AIRES, 2009). Besides the use of bird litter as a substrate in farming, part of the researchers accepts the use of broiler litter in the form of briquettes or pellets to supply boilers to generate electric or thermal energy (KUNZ et al., 2011).

Sordi et al. (2005) conducted a study in western Paraná on the energy potential of poultry waste regarding its raw, technical and economic potential. They concluded that the chicken litter biomass in the region could represent 3.3% of the installed energy potential of biomass in Brazil. Likewise, they consider AD and direct combustion as alternative forms of waste reduction and energy cogeneration.

This paper assesses the potential of poultry litter as feedstock for heating aviaries by using the exergy analysis. The calculations consider the correlations presented by Kotas (1985) and obtained for solid fuel consisting of Carbon, Hydrogen, Oxygen and Nitrogen. The study takes into account the amount and quality of the transformed energy and it can contribute to a proper diagnosis of the main irreversibilities for improving energy efficiency and for reducing environmental impacts.

2. MATERIAL AND METHODS

At the end of a production cycle, the quantity of poultry litter is determined by mass of absorbent material (m_{abs}), the initial number of chicks produced (n_c) and the mass of dry waste generated per bird in the cycle (m_{exc}), as shown in equation (1), where d indicates the breeding time. Furthermore, the mass of absorbent material depends on its specific mass ρ_{abs} and its volume ($\forall_{abs}$). The number of broilers (n_b) that generate waste depends on the death rate (i_{mort}) and time that the birds remain alive (x), as shown in equation (2).

$$m_{bed} = m_{abs} + n_{cycles} * \sum_{x=1}^{d} n_c * \frac{m_{exc}}{d} \tag{1}$$

$$m_{bed} = \forall_{abs} * \rho_{abs} + n_{cycles} * \sum_{x=1}^{d} n_b * \left(1 - \frac{i_{mort}}{d} * x\right) * \frac{m_{exc}}{d} \tag{2}$$

The amount of firewood to be consumed in one breeding cycle, as shown in equation (3), depends on the number of days in which the system must be heated (din), generally at the initial phase, the daily firewood volume spent ($\forall_{fwd}$) and the average wood density adopted (ρ_{fw}).

$$m_{fw} = din * \forall_{fwd} * \rho_{fw} \tag{3}$$

The energy capacity of solid fossil fuel was reported by Moran et al. (2011) and Cengel (2008). According to the authors, during a burnout, residual gases which leave the reaction should be at room temperature and, because fuels containing Hydrogen, the burn results in water formation in the vapor or condensed phase. The Low Heating Value (LHV) indicates the amount of heat transferred in the burnout of 1 kg of the element, when combustion gases are cooled to the boiling point of water, without condensation. Likewise, the High Heating Value (HHV), indicates the amount of heat transferred in the burnout of 1 kg of element, when combustion gases are cooled to the boiling point of water, with condensation (CENGEL, 2008; MORAN et al., 2011). If the fuel is not composed of Hydrogen, the HHV and LHV are parallel, as there is not water formation or energy lost in water vaporization.

The HHV can be found experimentally with a bomb calorimeter. Furthermore, from literature data about elemental composition of the dry biomass, it is possible to calculate the HHV of fuel with the equation (4) developed by Channiwala and Parikh, which holds true for most solid, liquid and gaseous fuels.

$$HHV = 349.1C + 1178.3H + 100.5S - 103.4O - 15.1N - 21.1A \tag{4}$$

The symbols C, H, S, O, N and A, are the mass percentage of Carbon, Hydrogen, Sulphur, Oxygen, Nitrogen and Ash, respectively (CHANNIWALA; PARIKH, 2002).

Another relation cited by the authors allows calculating directly from the proximate analysis. In the equation (5), (FC) indicates the percentage of Fixed Carbon, (VM) the percentage of Volatile Matter and (A) the percentage of Ash (PARIKH; CHANNIWALA; GHOSAL, 2005).

$$HHV = 353.6FC + 155.9VM + 7.8A \tag{5}$$

From HHV, it is possible to calculate the LHV by correlations indicated by Quiroga et al (2010), shown in equation (6). All the calculated values in the equations (4-6) are measured in kJ/kg.

$$LHV = HHV - \left(\frac{2441.8 * 9 * H}{100}\right) \tag{6}$$

The energy contained in poultry litter and the firewood used can be obtained from the equation (7), where m_i is the mass of firewood or the poultry litter.

$$E_i = m_i * LHV_i \tag{7}$$

Solid and liquid industrial fuels are solutions of numerous chemical compounds of normally unknown nature, which makes it difficult to determine the entropy of reaction with a high degree of accuracy. Szargut and Styrylska (1964) assumed correlation (8) for dry organic substances contained in solid fossil fuels, where B is the fuel chemical exergy and β represents the ratio of chemical exergy of the LHV. The applicability of the expressions obtained can be extended to cover industrial fossil fuels from equation (9), which is indicated for a wide range of industrial solid fuels, but not for wood and (10), which includes wood with proximate accuracy of 1%. Values calculated by Kotas (1985) indicate a range of 1.15 to 1.30 for the wood coefficient.

$$\beta = \frac{B}{LHV} \tag{8}$$

$$\beta = 1.0437 + 0.1882 * \frac{H}{C} + 0.0610 * \frac{O}{C} + 0.0404 * \frac{N}{C}, \qquad \frac{O}{C} < 0.667 \tag{9}$$

$$\beta = \frac{1.0438 + 0.1882 * \frac{H}{C} - 0.2509 * \left(1 + 0.7256 * \frac{H}{C}\right) + 0.0383 * \frac{N}{C}}{1 - 0.3035 * \frac{O}{C}}, \qquad 0.667 < \frac{O}{C} < 2.67 \tag{10}$$

To calculate the chemical exergy of LPG on a molar basis, the composition of 70% butane (C_4H_{10}), and 30% propane (C_3H_8) is considered. The value is found from the equation (11), in which x_i indicates the mole fraction of each component, $\bar{R}$ is the Universal Gas Constant and T_0 at standard room temperature. For this work, the γ_i activity coefficient is considered unitary considering the perfect mixture of gases.

$$b_{q,mist} = \sum_i x_i b_{q,i} + \bar{R}T_0 \sum_i x_i \ln(\gamma_i x_i) \tag{11}$$

The authors that present greater detail in the elemental composition of wood and poultry litter are highlighted. With these data, the values of HHV, LHV, β and B_q are found, using the equations (4-9). The comparison of the data calculated and the data found in articles provides an average value for this study.

The comparative calculation of the inputs takes into account a 42 day production cycle in a conventional aviary 1,200 m^2, the bed of wood shavings of Pinho with 8 cm and 85 kg/m^3 density. A mortality rate of 3% is considered and the excreted amount to be 0.93 kg/bird/cycle. Demand for firewood for the cycle occurs at the initial breeding stage (21 days), consuming 1 m^3/day, which features wood density of 450 kg/m^3. HHV averages are adopted from the syntheses carried out in several papers.

The exergetic evaluation of the use of LPG consider the LHV cited by authors and the B_q calculated by equation (11). The energy supply for heating the aviaries at the initial breeding stage is analyzed considering the firewood, LPG and the litter poultry as inputs. After the quantification of energy and the exergy accompanying the three inputs the feasibility of replacing or complementation that was proposal is analyzed.

3. RESULTS AND DISCUSSION

Table (1) presents a synthesis of the elemental composition of wood and HHV found. The values marked with (*) were obtained by authors of analytically or experimentally. The values marked with (**) were calculated in this work from equations (4-6) and (8-10), the latter, as reported by Kotas (1985), were obtained from data applicable to dry substances.

Value (***) was obtained from the average of wood shaving samples studied by Moulin et al (2011). The value marked with (****) were extracted from Kotas (1985) for wood. The value for LHV** by Menezes (2013) was calculated considering 6% of the Hydrogen.

At the end of the table, the HHV values for the substances, after charred, studied by Gabardo (2011) were added, whose objective was to compare the values and check the increase of HHV. This occurs due to the increased of percentual of fixed carbon in the sample. As reported by Gabardo et al (2010), a greater concentration of carbon in the residue results in a higher calorific value of the materials, indicating that the appropriate treatment of biomass can substantially increase its energy potential.

The average value of 18,731.77 kJ/kg found for LHV** was greater than cited by Hepbasli (2008) which indicated 15,320 kJ/kg and Silva (2013) with 16.790 kJ/kg, however, it remained close to Leite et al. (2014) with values in 18.004 kJ/kg and Funck and Fonseca with 19200 kJ/kg.

The average value of 20,091.78 kJ/kg found for HHV** was within the range of values experimentally estimated by Quirino et al (2005) with a range of 14,023 kJ/kg to 22,018.4 kJ/kg, which obtained these values from 240 woody species with an average of 19,808 kJ/kg.

These energy potentials can be achieved only when considering the low humidity of the wood combustion. According to Cunha et al. (1989), the greater the moisture content of the firewood, the lower its combustion energy due to the water evaporation process, which absorbs energy on combustion. Sturion and Tomaselli indicate the drying of the wood within four months, maximizing its energy potential of the HHV calculated values. This time also was reported by Brand et al (2012).

Table 1: Chemical Exergy of Firewood from Elemental Composition

Author	Material Studied	C* (%)	H* (%)	O* (%)	S* (%)	N* (%)	Ash* (%)	HHV* (kJ/kg)	LHV* (kJ/kg)	HHV** (kJ/kg)	LHV** (kJ/kg)	β**	Bq** (kJ/kg)
Sardinha and Macedo (2002)	Dry Firewood	50.30	6.00	43.00			0.40	20,900.00		20,174.89	18,856.32	1.07	20,208.04
Marri et al (1982)	Dry Firewood	51.80	6.30	41.30			0.50			21,225.70	19,841.20	1.05	20,773.75
Silva (2013)	Firewood	47.00	5.60	40.00	0.01		0.10	mínimum value		18,869.08	17,638.41	1.07	18,873.36
		54.00	7.00	44.00	0.05		0.50	maximum value		22,544.38	21,006.04	1.05	22,150.05
Leite et al (2014)	Wood of coffe tree	49.68	6.61	41.76	0.04	0.44	1.46	19,471.80	17,978.20	20,780.44	19,327.81	1.07	20,603.72
Moulin et al (2011)	Wood shaving	47.62	6.01	45.50	0.01	0.16	0.97	19629,0 (***)		18,979.15	17,658.38	1.12	19,742.35
Telmo et al (2010)	Wood of eucaliptus	46.20	5.80	47.20	0.02	0.20	0.58	18,000.00	16,700.00	18,068.83	16,794.21	1.15	19,323.50
Author	**Material Studied**	**VM (%)**		**FC (%)**		**Ash (%)**							
Menezes (2013)	Pinus and Araucaria	4.42		91.15		4.42		17,230.00	16,910.00	32,954.19	31,635.62	1.15	36,380.97
		2.24		95.58		2.24		17,320.00	17,000.00	34,163.78	32,845.20	(****)	37,771.98
Gabardo (2011) wastes	Pinus and Araucaria							18,220.00					
								19,600.00					
Gabardo (2011) after charred	Pinus and Araucaria	16.31		82.64		1.05		32,050.00		31,772.42			
		18.60		72.30		9.10		27,990.00		28,536.00			
Average								**18,677.40**	**17,147.05**	**20,091.78**	**18,731.77**	**1.09**	**20,239.25**
*Cited values from literature		**Calculated values with 4-9 equations						***Average of samples			(****) Kotas (1985) for wood		

The values of chemical exergy found in this paper was slightly higher than the reported by Hepbasli (2008a) after studying several of woody biomass types in Turkey with results between 17,900 kJ/kg until 19,630 kJ/kg. However, the value was significantly higher than reported by Hepbasli (2008b) that studied energy prices and exergy from various energy renewable sources and indicated 17,641 kJ/kg. Notwithstanding the exergetic coefficients obtained are slightly lower values than that cited by Kotas (1985) for wood, but strong convergence can be seen with de cited values by Hepbasli (2008a).

According to Gabardo (2011) waste of forest origin are a viable alternative to coal production and this is shown in the comparison between the material in nature and the charred material. However, they lack economic and technical feasibility studies for the proper treatment of these wastes.

Table (2) illustrates a synthesis of the chemical composition of chicken litter and the calorific value presented by the authors. Values marked with (*) have been reported in the literature and obtained analytically/experimentally by the authors. Values marked with (**) were calculated herein from equations (4, 6, 8-10). The marked values of LHV* were calculated using equation (6) from the percentage of Hydrogen and values of HHV*.

The sharp difference found between LHV* and LHV** to Miles and Bock (2004) and Quiroga et al (2010) is justified by the percentual of moisture used by the authors, respectively 35% and 75%. The oxygen O* grifed is calculated by the difference 100% - (C + M + N + S + Ash + Cl) indicated in Lynch et al (2013).

The average value of 16,775.88 kJ/kg was found for HHV** above that reported by Sordi et al (2005) which was 16,100 kJ/kg, values reported by Santos and Lucas Jr (2004) with 15,239.1 kJ/kg, Dagnall et al (2000) with 13,500 kJ/kg and Fried et al (2005) with 10,200 kJ/kg.

Despite the difficulty in the surveying data, as the values date back to local diversity of climate, feed composition, lineage of birds and adequacy of sheds, an average estimate of the chemical exergy of wood and chicken litter was obtained from the calculations and showed in Table 2. These values could not be compared, since other studies with the exergetic evaluation of the inputs proposed here, were not found.

Table 2: Chemical Exergy of Litter Poultry from Elemental Composition

Author	Material Studied	C* (%)	H* (%)	O* (%)	S* (%)	N* (%)	Ash* (%)	Cl* (%)	HHV* (kJ/kg)	LHV* (kJ/kg)	HHV** (kJ/kg)	LHV** (kJ/kg)	β**	Bq** (kJ/kg)
Linch et al (2013)	Poultry Litter	45.17	5.85	27.25	0.45	5.16	15.49	0.35	18,020.00	16,734.39	19,484.72	18,199.11	1.11	20,191.72
Steinfeld et al (2006)	Poultry Litter	37.38	4.19	15.64	0.74	3.76	37.79	0.50	14,900.00	13,979.20	15,589.48	14,668.68	1.09	16,053.14
Miles and Bock (2004)	Poultry Litter	39.50	4.30	27.30	0.80	3.90	22.90	1.28	15,300.00	9,300.00	15,571.64	14,626.66	1.01	14,758.29
Quiroga et al (2010)	Poultry Manure	36.20	4.60	18.91	0.10	5.90	33.65	0.64	13,084.00	2,664.00	15,313.25	14,302.35	1.11	15,819.32
Fried et al (2005)	Poultry Litter	42.60	5.70	32.20	0.40	3.40	15.50	0.10	10,200.00	8,947.36	17,920.30	16,667.66	1.03	17,234.04
Average									**14,300.80**	**10,324.99**	**16,775.88**	**15,692.89**	**1.07**	**16,811.30**
	*Cited values from literature					**Calculated values with 4-9 equations								

Table (3) shows the results of the estimated masses, the energies and the exergies available as feedstock. There are two estimates for aviary heating from the LPG due to local differences and different amounts demanded for heating. The exergy of LPG was calculated by equation (11) and it considered a mixture of ideal gases from butane (70%) and propane (30%).

The mass of firewood takes into account 20 days of consumption, spending 1 m^3/day with an average density of 450 kg/m^3, which is calculated by the equation (3). The exergy value is an average of the values obtained from Table (1).

The chicken litter mass in the last line, was calculated from the equation (2) with six reuse cycles considered for the wood shavings introduced into the system. Others values are cited for comparing the results.

Santos and Lucas Jr. (2004) reported the major value in wastes generated due to the fact that their study considers only one production cycle. According to Santos (1997) and Santos (2001) the reuse of the poultry litter, results in a reduction of the wastes between 16% to 35% for cycle. This explains the lower values obtained by Baldin (2013) and Bratti (2013), whose values have been obtained from the quotient of the mass of poultry litter removed by the number of cycles.

The percentual of moisture highlighted was estimated and the LHV highlighted was obtained from the average of the Table (2), as well as the average of exergy for the poultry litter.

Table 3: Comparison of the Chemical Exergy for different feedstocks in heating of aviaries.

Feedstock	Mass (kg)	Cycles	LHV (kJ/kg)	Moisture	Energy (GJ)	Exergy (kJ/kg)*	Exergy (GJ)*
LPG(a)	429.0		47,234.0		20.3	48,608.8	20.9
LPG(b)	548.3		46,464.6		25.5	48,608.8	26.7
Firewood(a)	9,000.0		19,200.0	Dry	172.8	20,239.3	182.2
Litter Poultry(b)	27,702.5	1.0	15,217.3	0.2388	320.9	16,811.3	465.7
Litter Poultry(c)	20,580.0	6.0	11,600.0	0.2800	171.9	16,811.3	346.0
Litter Poultry(d)	13,562.0	8.1	15,692.9	0.2800	153.2	16,811.3	228.0
Litter Poultry	18,183.0	6.0	15,692.9	0.2800	205.4	16,811.3	305.7

(a) Funck and Fonseca (2008); (b) Santos and Lucas Jr (2004); (c) Baldin (2013); (d) Bratti (2013)

Energy demand and its exergy from LPG is less than the wood heating system, justified by Funck and Fonseca (2008) due to the lower calorific value of the wood. Moreover as gas heating is more localized, it reduces losses considerably. Nevertheless, the high cost of acquiring LPG directs the preference of producers to using wood that comes from direct extraction or of planted forests on the property itself.

Considering the bed of birds with the estimated moisture, it is possible to see that the energy it provides is greater than the energy currently demanded by the use of firewood, and all exergy lost by non-use, could meet the demand of the exergy system with a surplus by at last 25%. This replacement would represent a significant environmental gain, since the use of woody biomass would be reduced besides solving the problem of soil and water contamination by chicken litter misuse.

Using these materials after treatment processes would further increase the calorific value and the consequent energy potential. With this, incentives should be given to the development of technologies in poultry production, making the combustion of these residues in furnaces in the densified form possible.

The densification technique commonly used is the production of briquettes and pellets. Its goal is to raise specific biomass mass up to 10 times. The reduction in volume and moisture makes its feasible use in developed countries, replacing the wood in charcoal production and equipment with automatic feed.

4. CONCLUSION

This study evaluated the replacement or supplement to conventional fonts, such as firewood and LPG by residual chicken litter from production process. Considering a conventional breeding shed, when using heating hoods to LPG, it consumes approximately 500 kg, accounting for an available energy of 22 GJ and an exergy calculated to be 23.4 GJ. For the same environment, the heating supplied by wood consumes an amount of 9,000 kg, with an available energy of 172.8 GJ and exergy of 182.2 GJ.

Comparing these data with the residual biomass of the process, the heating by burning 18,183 kg of poultry litter generated at every production cycle, could provide 205.4 GJ of energy and 305.7 GJ of exergy to the system. These values show the energetic potential of waste could supply the exergetic demand to the system with surplus by at last 25%.

The indication of authors for firewood heating system was based on costs, without any environmental concern. But, appropriate treatments and low humidity rates may allow the replacement of woody biomass by the bed of birds, reducing the emission of greenhouse gases and mitigating environmental impacts of soil and water contamination.

The values surveyed here represent local consumption realities, which depends on several factors such as microclimate, bird lineage, structures of aviaries, management and performance of the technologies involved. However, as the first study in the area in the light of exergy, may represent important parameters of comparison for future technologies investigating sustainability standards in small farms.

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