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Poultry litter as biomass energy: A review and future perspectives

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ABSTRACT

Poultry litter is characterized as a heterogeneous compound produced after a poultry production cycle, being the sum of the material used as bedding in association with the animal waste, dead skin, feed scraps, water, feathers and the resulting microbiota. The expansion of poultry production around the world has resulted in elevated generation of this residue. Over the years its use has been restricted to organic fertilizer or simply as a waste to be eliminated and disposed of in the environment. However, this mechanism has caused environmental and social damages due to its indiscriminate use. Because of the energetic and biological properties of poultry litter, its sustainable use as energy can be obtained via thermochemical processes such as anaerobic digestion and through combustion, gasification, pyrolysis or power co-generation systems, in which there is a combination of one or more processes. As a result, there is the potential for generating heat, electricity, fuel gas and biochar with low emission of pollutants. However, it is emphasized that there is no standard with regards to its composition and the source material type, where efforts are more focused on the contents of moisture and inorganic compounds. Therefore, processes that seek to use poultry litter as fuel biomass should be well-controlled and efficient for successful energy generation. In this sense, the objective of this study is to analyze the characteristics of poultry litter as fuel, discuss the main thermochemical processes for its energetic conversion and propose measures to improve its performance as a sustainable biomass.

1. Introduction

The production of broiler chickens has been significantly growing throughout the world, and therefore the high generation of waste becomes a concern for the agricultural sector that increasingly seeks sustainable alternatives for the use of generated wastes. According to Abelha [1], poultry waste may be used for sustainable renewable energy generation, and methods should be explored due to its potential as a fuel and not simply as a waste to be eliminated [2], since its heterogeneous character may cause problems when indiscriminately disposed of in the environment. In this sense, it is necessary to seek measures for proper use of poultry litter for energetic purposes.

The use of poultry litter as a sustainable fuel has been studied for some years for use in thermochemical conversions such as direct burning, or by means of gasification and pyrolysis [3,4]. It has been observed that the gasification and pyrolysis processes of poultry litter present high quality results for the production of fuel gas, reducing emissions and generation of biochar [5–7].

Given the above, the present review sought to analyze the intrinsic characteristics of poultry litter as a fuel, as well as discuss the main thermochemical processes for its energetic conversion and propose measures to improve its performance as a sustainable biomass.

2. Waste generation by broiler poultry

The measured data available in literature in relation to the quantity of poultry litter generated per bird in a 42 day production cycle is quite variable, ranging from 1.5 to 5.7/kg of litter/bird [2,8]. It is common to

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use poultry litter in more than one production cycle for chickens. In Brazil, the average is 6 cycles with the same bedding. And this helps to reduce the volume of generated bed. However, the volume reduction fact not completely minimizes high production chickens generate high amount of waste.

Brazil is the second largest world producer of broiler chickens and it is estimated that the annual volume of litter generated is around 8–10 million tons/year. This calculation is based on the number of chickens slaughtered each year multiplied by the litter volume generated per bird. According to Santos [9], for Brazilian conditions each bird over 42 days produces an average of 1.75 kg of litter, based on natural matter, assuming that the litter has an average moisture content of 20%. Thus, independent of the amount of poultry litter generated, it is noted that the total volume of this residue is high due to elevated productivity, and constitutes a growing concern regarding its disposal. Therefore, it is necessary to analyze this material with regards to its chemical composition as a fuel biomass and its current use as an organic fertilizer.

3. Poultry litter: use as organic fertilizer

After a poultry production cycle, in addition to wastes there is also flaked skin from the birds, waste feed, water, feathers and the microbiota resulting from this heterogeneous mix [10]. Moreover, it also contains antimicrobial and antibiotic residues, which are used as growth promoters and for treatment of infections, endocrine disruptors such as chicken metabolic products, and residues of pesticides and herbicides used in cultivation of the grains used for feed manufacture [11,12].

At present, the main destination of poultry litter is its use as organic fertilizer and/or manufacture of organo-mineral fertilizers, due to its contents of nitrogen, phosphorus and potassium. The litter is presented as a potential organic fertilizer, because in addition to the concentration of nutrients, it permits the inclusion of organic matter to the soil, improving both the physical and chemical attributes [13].

The physico-chemical composition of poultry litter depends on certain parameters such as the type of material from which the litter is produced, for how many consecutive flocks it was used and the management practices employed during production of the birds [10]. In order for a material to be used as litter it must be of medium size, have good absorption capacity without hardening, easily release trapped moisture, have low thermal conductivity with capacity to withstanding high densities, and most importantly be of low cost.

The main materials used as poultry litter are wood shavings, coffee hulls, peanut hulls, rice hulls, dry grass, chopped corn cobs and others [14–16]. According to Toghyani [17], the type of material used as litter does not affect the performance parameters of poultry, considering that they are handled properly in the installations. However, Vieira [18] observed a reduction in the sanitary quality of coffee hull poultry litter in four reuses. As a result, increased incidence of lesions to the carcass was observed due to increased nitrogen concentration in the bed.

Despite the concentration of beneficial nutrients, the massive use of poultry litter as organic fertilizer can result in eutrophication processes in soil and water bodies, the spread of pathogens, production of phytotoxic substances, air pollution and greenhouse gas emissions [3,19]. One of the main concerns regarding the disposal of litter in the environment, when applied as fertilizer, has been the presence of endocrine disruptors, especially 17β-estradiol [11]. Its effect is still unknown, however it is believed to cause sexual reversal in fish when poultry manure is applied in excess in the soil and subsequently leached to water bodies [20,21].

Another barrier to the use of poultry manure as organic fertilizer is the continuous application to soil to improve the production rates of agricultural crops. This can result in high toxicity to animals and plants along with depreciation of the product, however this is only perceived in the medium and long term [22–24]. In the Brazilian state of Paraná, contamination of the water table has been reported due to excessive use of poultry litter as fertilizer [25]. Oviedo-Rondón [26] affirmed that in some regions of the United States, such as Minnesota and North Carolina, saturation of the soil has also occurred due to intense application of litter, and in order to avoid this problem its application for generating electricity should be considered.

It should also be stated that after a production cycle the litter may contain many pathogens that survive up to 11 weeks outside the digestive system of the birds [27]. Additionally, antibiotic residues used as a growth promoters or for the treatment of diseases may be detected, which are not fully absorbed by the birds and up to 75% may be released to the environment [28]. According to Hahn [29], the main microorganisms present in poultry litter are *Escherichia coli*, *Salmonella* and oocysts of Eimeria. Therefore, the use of poultry litter as organic fertilizer, without appropriate treatment, may cause adverse effects to the ecosystem since the antibiotics used in poultry production have been detected in soil, water, plants and sediments [30].

Although poultry litter has advantages with regards to its use as a fertilizer, it is currently verified that its use causes environmental and social damage due to indiscriminant application [7]. In this sense, it is necessary to seek new rational alternatives for the use of poultry litter that result in less impact to the environment with appropriate treatment to eliminate undesirable compounds and pathogens. Among the available alternatives, the use of poultry litter as biomass energy for generation of heat and electricity is gaining prominence [4,7,31,32].

4. Poultry litter: biomass energy

Given the high volume generated by broiler poultry and due to shortage of energy sources and the high price of conventional sources, the use of poultry litter as biomass energy is becoming attractive [3,4,6,7,33] and therefore it may become both technically and economically feasible. Available literature on the use of poultry litter as biomass energy in industrial production units is still incipient. Recent studies indicate the efficiency of heat and energy production from poultry litter in locations near the waste-generating units [4,33]. This is because the cost related to transport is a major factor to be addressed when seeking efficient power generation from any type of biomass.

For utilization of alternative biomasses some factors are important, where the main characteristics are: moisture content, energy density, calorific value, the amount of generated volatile material generated during combustion, the volume of ash at the end of the process, the fixed carbon content, the chemical analysis and the elemental content [34,35].

The moisture content is one of the main indices of non-inherent quality of the evaluated residue, since elevated moisture content may result in more energy consumed for drying the biomass prior to combustion processes. It also influences the initial ignition capability. This decreases the process efficiency and impairs the energy and thermodynamic equilibrium in the final calculation. Furthermore, the high moisture content leads to incomplete combustion and consequent release of carbon monoxide to the environment [36]. In general, for the efficient generation of heat and electricity from poultry litter, it is recommended that the moisture content does not exceed 25% [1].

The calorific value of any biomass can be defined as the amount of energy released in the form of heat during complete combustion of the fuel mass unit, which can be measured in kJ/kg [37]. Energy density is another important parameter, since in terms of transport and storage it becomes crucial, corresponding to the average mass of a solid for a given volume.

The volatiles content is the amount of material that will volatilize at high temperatures and indicates the reactivity of the fuel. In general, for plant biomass the volatile content varies from 65% to 83% [37], whereas in biomass of animal origin the value is more heterogeneous