Journal of Animal Production, 32 (3), https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3611

Husbandry and Nutrition

Review

Effects of Hen Manure on the Environment, and Possibilities of Reutilization

Sahirys Casas Rodríguez *, Luis Domingo Guerra Casas *

*Ignacio Agramonte Loynaz University of Camaguey. Carretera de Circunvalación Norte km 5 ½, Camagüey, Cuba 74650.

Corresponding author: sahirys.casas@reduc.edu.cu

Received: July 2020; Accepted: October 2020; Published: November 2020.

ABSTRACT

Background: Excessive amounts of stools accumulated in intensive poultry production systems can create enormous pollution problems due to the large amounts of toxic substances they generate. The opportunities to reuse these wastes may interest researchers, breeders, and farmers.

Aim. To offer specialists and others who might be interested, abridged and updated information about chicken manure, its negative effect on the environment, and some efficient uses.

Development: Intensive poultry production systems generate large amounts of stools on the soil, creating huge pollution problems, due to the substances they produce, which pollute the soil and water. Moreover, the development of potentially pathogenic microorganisms poses a threat to human and animal health. The existence of promising technology that can turn stools from free-range birds into goods with added value and energy not only benefits human and animal health, but also the economy.

Conclusions: Hen manure is one of the most pressing environmental pollution issues, but it offers multiple opportunities to be used for the benefit of man. Hence, the minimization of wastes, prevention of pollution, and recycling, should be present in the daily practice of intensive poultry production systems, to guarantee the health of workers, consumers, and the environment.

Key words: composting, hen manure, environment, pollution (Source: *AIMS*)

How to cite (APA)

Casas Rodríguez, S., & Guerra Casas, L. (2020). Effect of Hen Manure on the Environment, and Possibilities of Reutilization *Journal of Animal Production, 32*(3). https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3611

INTRODUCTION

In Cuba and other developing nations, poultry rearing has grown quickly. These intensive poultry production systems can create enormous pollution problems, due to large amounts of polluting substances that also originate massive amounts of stools on the soil. Undoubtedly, one of the main problems is the undesirable smell of the farming residues (Mullo, 2012; Gohil, Budholiya, Mohan, Prakash, 2020).

Fresh hen manure contain hydrogen sulfur (H_2S), and other organic compounds that harm the inhabitants near poultry farms (Rodríguez, 2017; Prasai, Walsh, Midmore, Jones, Bhattarai, 2018). The sensation of filth that comes along with residue dumping, as well as the emergence of apparent symptoms of environmental degradation, may even be the source of disease transmission.

The transformation of hen manure through different treatments generates an alternative to provide added value to an abundant residue in poultry productions, and reduce the negative environmental impact from the lack of processing (Bragachini, Huerga, Mathier, and Sosa, 2015). Additionally, it increases the efficiency of poultry farms, by reducing the proportion of wastes upon transformation into a farm sub-product with commercial value (Agbabiaka *et al.*, 2020).

Furthermore, processed hen manure may also increase crop production, and consequently, supplies to the population, by improving productivity and the nutritional quality of crops. It provides food safety, and increases crop nutrient contents, and it limits the need to increase cropland area, preserving the soil by preventing degradation, and improving the quality of human life (Quiñones, 2017).

Minimizing wastes, preventing pollution, and recycling, are part of the daily practice. In other words, this is a more serious reasoning into producing without leaving wastes (Arévalo, Puglla, and Danilo, 2018; Fahimi *et al.*, 2020).

Besides, proper implementation of bird stool recycling as a dietary supplement for ruminants, and some monogastric animals, like pigs, or as fertilizer for several crops, is a practice that cuts down costs of production, by providing protein, phosphorus, calcium, and other minerals, along with organic elements (Arévalo *et al*., 2018).

Knowing the effect caused by this residue on the environment favors the adoption of measures aimed to increase the sustainability of productivity in aviculture, and ensure the health of farmers, consumers, and the environment. This issue has been repeatedly discussed at the United Nations Food and Agriculture Organization, whose goal for human survival, is summarized in the expression “One Health” (FAO, 2016).

Therefore, the aim of this review is to offer specialists, and others who might be interested, abridged and updated information about hen manure, its negative effects on the environment, and some of the most efficient uses.

DEVELOPMENT

ORGANIC RESIDUES ON POULTRY FARMS

Hen manure

Hen manure is the mix of feces and urine from hens or caged chickens, along with the indigestible portion of food, cells from the mucosa of the digestive apparatus, products from gland secretion, microorganisms from the intestinal biota, several mineral salts, feathers, and a minimum percentage of foreign material (Arévalo *et al*., 2018).

As a result of intensive production, the poultry industry has the potential of producing not only eggs and meat, but also quality organic waste material like hen manure (Cajamarca, Almeida, Díaz, Berrones, 2018). This material has a potential to increase crop production, some of the most important include nutrient contribution, such as N, P, and K, and an increase in the organic matter of the soil.

The terms hen manure and chicken manure are not synonyms, so it is important to define them:

- Hen manure: The excreta from layer hens that accumulate during the production of eggs, or during development periods for this type of birds, mixed with food wastes and feathers. The bedding material may or may not be considered.

- Chicken manure: The excreta from broilers, from the beginning until they exit farms, which is mixed with feed wastes, feathers, and bedding material.

Knowing the amount and composition of hen manure and bedding produced with different poultry production practices is essential for efficient and environmental management. To quite a few farmers that rely on outdated principles, manure is the best fertilizer of all (Rodríguez, 2017). Although manure has a significant relevance, with many qualities and advantages, the inconveniences of this fresh fertilizer should be mentioned as well. Therefore, hen manure should be transformed using different treatments (Ali, Bashir, Ali, Bashir, 2016; Tullo, Finzi, Guarino, 2019).

Hen manure is traditionally used as a fertilizer; its composition depends primarily on the diet and bird lodging system (Nieto and González, 2018). Hen manure from floored houses contains a mix of stools and absorbing material that could be wood shave, dry grass, peel, and others, which are used for bedding. This mix remains in the shed throughout the entire productive cycle.

Effect of bird stools on the environment

The application of fresh hen manure can cause a considerable increase of biological activity in the soil, whereas the stools of approximately a week old has a very high revitalizing effect on the soil (Kantarli, Kabadayi, Ucar, Yanik, 2016).

In Poland, one of the main poultry production leaders in Europe, according to Dróżdż *et al.* (2020), the number of poultry farms has progressively increased for a decade, and in turn, has produced even greater amounts of stools from free-range birds, which must be properly handled, either on the site using available technology, or using a more centralized approach. A similar situation takes place in leading poultry production countries, such as The United States, Canada, and Brazil.

Once on the soil, phosphorus, for instance, is released through the action of phytases produced by the microorganisms of this system. Then it moves through rivers and lakes, and causes eutrophication of water currents and water reservoirs (Owamah, Alfa, Onokwai, 2020).

Under these circumstances, a speedy growth is observed in alga, along with a depletion of water oxygen contents, which causes lethality of aquatic species. The sensation of filth that comes along with the dumping, and the appearance of evident signs of environmental degradation are other factors that affect life quality of humans (Rodríguez, 2017).

When handling animal feed, according to Arévalo *et al*. (2018), production operations are not properly implemented; the discharge of nutrients, organic matter, pathogens, and the emission of gases from wastes, may lead to significant pollution of essential resources to life (water, soil, air). Mullo (2012), classified the effects that poultry wastes cause to the environment, and it was generalized as this: the ones affecting the atmosphere, soil, and water.

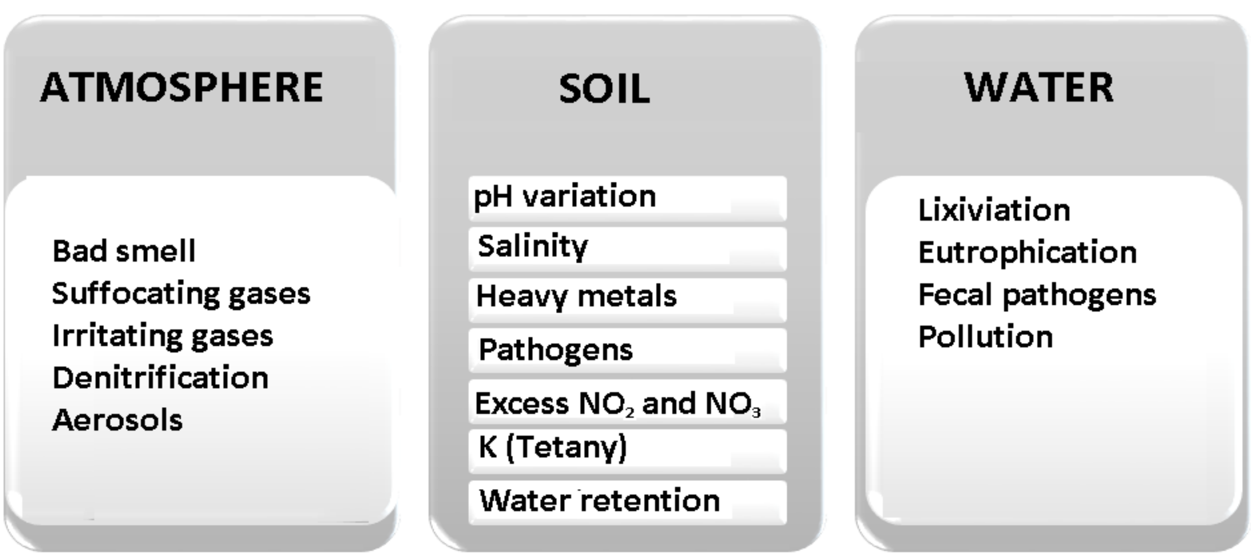

Figure 1. Poultry wastes in the **environment** (Source: Mullo, 2012).

In birds, more than 50% of N in the feed is excreted as uric acid, so one advantage could be the inhibition of conversion to ammonia, besides multiple combinations of nutritional management, lodging system, treatment choices, and residual disposal, so it can reduce environmental pollution, which leads to sustainable growth in the long run (Daniyan, Daniyan, Abiona, and Mpofu, 2019).

Throughout poultry production, a number of needs go beyond productive requirements. Therefore, the implementation of recycling strategies that enable environmental sanitation, and allows for nutrient recirculation that contributes to better balance between man and nature leads to greater economic benefits, increasing efficiency and productivity during production (Riaz, Wang, Yang, Li, and Yuan, 2020).

Figure 2. Accumulation of excreta (Source: The authors).

The environmental impact of considerable volume of waste is highly significant, and endangers the future of humans. Therefore, implementation of strategies in recycling management is required. These strategies will contribute to the disposal of such wastes, and their use, either by direct use as animal feed, or through recovery and production of energy and fertilizers (Choudhury, Felton, Moyle, and Lansing, 2020).

If these residues are inappropriately handled, they may have a negative impact on the environment (Barreto, 2019). Some of the problems derived from inappropriate residue use are described below:

Soil

When hen manure is applied to the soil inappropriately, the first effect is a mechanical action consisting in compression by capping the pores of the soil, thus decreasing the draining capacity of the land (Rodríguez, 2017).

Then, a chemical action takes place, with structural degradation of the soil, caused by the high contents of salts and nutrients, due to progressive accumulation of residues. It triggers a biological action consistent in the development of potentially pathogenic microorganisms to man and animals (Owamah, Alfa, and Onokwai, 2020). Finally, organic matter and nutrient excess may lead to a decline in oxygen levels (up to anaerobiosis) in the environment, hindering nitrogen mineralization. Moreover, plants absorb nitrogen in greater amounts than what can be assimilated, causing the accumulation of nitrates, that generate poisoning (Barreto, 2019; Choudhury *et al.*, 2020).

Waters

Because of the high presence of microorganisms (MO) and hen manure nutrients, if the latter is disposed of (or otherwise, is drained by the waters from cleaning) in rivers, springs, and the water table, they cause eutrophication issues, consisting in a dramatic decrease of oxygen, since it is used for oxidation of organic matter and nutrients. Galarza, Ortíz, and Morales (2016), agreed with Ramírez (2015), in that with the depletion of oxygen, aquatic life disappears. Likewise, ammonium and nitrite contents produce toxicity that affects aquatic organisms.

Human and animal health

The life quality of populations near poultry farms depends on responsible residue management (Irigoyen, 2018). Therefore, it is a matter of social, business, and professional responsibility, an ethical issue that may compromise the future.

Improper excreta disposal also favors the development of potentially pathogenic microorganisms, which, in turn, can transmit diseases like rotavirus, colibacillosis, gastrointestinal parasites, salmonellosis, and others (Cajamarca *et al.*, 2018).

Furthermore, and equally important, the inclusion of fresh wastes, like hen manure in the diet of animals is a spread practice among national poultry farmers; however, it promotes cross propagation of different diseases among species, due to pathogens that can be carried in the stools (Choudhury *et al.*, 2020; Owamah *et al.*, 2020).

Economic impact

Poultry farms may face social and legal issues, as a result of smelly air and the proliferation of flies. Accordingly, the most convenient action is to find a way to address them. Hen manure composting is an adequate procedure that brings economic benefits.

There are “direct” costs associated to the implementation of measures to address problems caused by pollution from residues. Regarding water for consumption, the cleaning costs are notoriously increased (it requires 10 g of chlorine per nitrogen gram) (Galarza *et al.*, 2016).

The legislation of industrial countries facing serious pollution problems compels farmers who sell certain residues to characterize it biologically and physicochemically, to know its production volumes, and to implement stabilization that ensures the final product is biochemically and environmentally safe, as the purchaser, will be compelled to use this product properly through fertilizing plans. Hence, an important program like environmental protection, depends both on collective and personal responsibility and solidarity.

Furthermore, its use as feed generates high economic revenues. It was demonstrated by Marshall (2000) in Cuba, in stabled fattening lambs on a basic diet of low quality hay, protein supplement containing hen manure, and soymeal, which produced gains of 130 g/animal/day, at a cost of $ 2.12/kg live weight, and a cost-benefit ratio of $ CUP 1.42, with 75% supplementation. It improved efficiency in 18% compared to the system implemented in the fattening facility.

Hence, the study of promising technologies that can turn stools from free range birds into goods with added value and energy not only ensures human and animal health, but also the economic factor.

Hen manure quality

The quality of hen manure is mainly determined by the type of feed, bird age (young birds produce less stools due to lower consumption of feed in early stages), the amount of wasted feeds, the amount of feathers, air temperature, and ventilation of the facility (Mullo, 2012). The permanence time of birds in the house is also important, in relation to the emission of ammoniacal odors, and the treatment given to the hen manure during drying (Miah *et al*., 2016).

The highest quality hen manure comes from caged layers, and then from floor layers, or facilities for breeding or developing (Rodríguez, 2017; Choudhury *et al.*, 2020; Owamah *et al.*, 2020). However, it also depends on factors like the bedding type used, storage time, and the percent of moisture, etc. (Bragachini *et al*., 2015), apart from different periods in which hen manure is accumulated, in which humidity contents, organic matter, nitrogen, and crude energy decrease due to accumulation time increase (Arévalo *et al*., 2018).

Figure 3. Stools from caged layers (Source: The authors).

Production hen manure

A posture bird has demonstrated to excrete 35.8-40.8 g of feces on average, containing 75% water, which is a factor to add to the work burden, without reporting income to the farm (Galarza *et al.*, 2016). Therefore, hen manure is suggested to undergo dehydration and recycling before use as a source of feed for ruminants.

UTILIZATION OF HEN MANURE

Curing

Birds excrete their stools with urine, which provide these droppings with greater contents of nitrogen than other species that perform the two functions separately. When hen stools are used as feed for ruminants, or as a crop fertilizer, special attention must be paid to what is known as excreta “curing”. This practice is recommended by several specialists who coincide in that drying must be in the shade, thus preventing contamination with flies (Bragachini *et al.*, 2015). Accordingly, nets are placed on top of it to prevent the presence of the insects, though allowing air circulation to complete fermentation by hen manure maturation and “curing”.

Main uses

As animal feed

By partially replacing soymeal by hen manure as diet supplement in stabled fattening sheep, Marshall (2000) achieved remarkable results, with up to 130 g/animal/day gains.

Several factors are involved in the chemical composition of hen manure, such as diet composition, age, and physiological status of the birds, since it is especially rich in protein and minerals. However, the high contents of fibers from the bed, and non-protein nitrogen (NPN) found in the feces of birds, make it more appropriate for consumption (Bragachini *et al.*, 2015).

Sanitized hen manure makes a product ready for the consumption of other species, namely cattle. Trials conducted by Arango (2017) showed that the protein average was 22%, within the expected range (18-23%) for this product. The ash contents do not cause laxative effects on cattle, since the percentage is lower than the maximum allowed. Moreover, the above-mentioned author says that with the application of this product in the diet of bovines, a residue is being reused, making it economical and sustainable. Mixed with molasses (another residue), it improves palatability in a 80:20 ratio, which is a positive choice, due to high consumption, and as a source of energy.

Used as organic fertilizer

Although the possible uses of compost are wide and diverse in farming, its value can be summarized in three variants: fertilizer, organic or humic amendment, and peat for cropping. The main use is determined by the final goal of application: to supply nutrients to crops (fertilizer), increase humus levels in the soil (organic amendment), or use it as a substrate (partial or total) for crops (FONCODES, 2017).

An organic fertilizer often creates the basis for successful use of mineral fertilizers. The combination of organic fertilizer/organic matter, and mineral fertilizers, offers ideal environmental conditions for that crop (Arango, 2017). The utilization of hen manure as an organic fertilizer after drying (cured) makes a solid product with a considerable value as a fertilizer (Quiñones, 2017).

Composting (Mullo, 2012; Nieto, and González, 2018), is the ideal alternative, since it stabilizes organic matter, ensures proper use of the fertilizing property of hen manure, which is expressed in its contribution to normal crop development, and in the recovery of highly degraded soils.

Production of biogas

Biogas is a flammable and renewable gas, which is produced by the transformation of organic matter by methanogenic bacteria, under anaerobic conditions, which can replace fossil fuels or biomass (burning wood), so it can be used to produce electricity and heat (Suárez, Sosa, Martínez, and Curbelo, 2017).

The production of biogas from hen manure aims to reduce its negative impact on the environment. Hence, the effects of greenhouse gas emissions are reduced, energy can be generated, and fertilizers can be produced (Burguet, 2016; Rodríguez, 2017; Choudhury *et al.*, 2020; Owamah *et al.*, 2020).

A biogas system consists in tightly-closed bioreactors filled with biodegradable solid organic residues (hen manure), which have high contents of organic matter treated for decomposition through an anaerobic process that generates biogas (Belduma, 2015; Miah *et al*., 2016; Choudhury *et al.*, 2020).

A comprehensive review of hen manure utilization shows coincidence with the reports made by Irigoyen (2018) and Choudhury *et al.* (2020), who assured that it is one of the most thoroughgoing fertilizers with the best nutrients for the soil. It can be noted considering the nitrogen, calcium, and phosphorus is provides.

According to Miah *et al*. (2016), Irigoyen (2018) and Owamah *et al.* (2020) it is one of the main productive problems to tackle by the aviculture sector to achieve sustainability of intensive breeding. Still pending is an objective analysis of every farm, and the strong determination to address the mitigation tasks demanded; the technologies, management recommendations, and tools are already available. The issue to address by poultry rearing professionals is the ethical conflict that emerges due to economic grounds, and the solutions recommended.

CONCLUSIONS

Hen manure disposal is one of the most pressing environmental pollution issues. Hence, minimizing wastes, preventing pollution, and recycling, should be present in daily intensive poultry practices in production systems to guarantee the health of workers, consumers, and the environment.

The existence of promising technology reduces the negative effects of stools from free-range birds on the environment, turning the excreta into products with added value and energy.

REFERENCES

Agbabiaka, O. G., Oladele, I. O., Akinwekomi, A. D., Adediran, A. A., Balogun, A. O., Olasunkanm, O. G., & Olayanju, T. M. A. (2020). Effect of calcination temperature on hydroxyapatite developed from waste poultry eggshell. *Scientific African*, *8*, e00452. https://doi.org/10.1016/j.sciaf.2020.e00452

Ali, G., Bashir, M. K., Ali, H., & Bashir, M. H. (2016). Utilization of rice husk and poultry wastes for renewable energy potential in Pakistan: An economic perspective. *Renewable and Sustainable Energy Reviews*, *61*, 25-29. http://dx.doi.org/10.1016/j.rser.2016.03.014

Arango Orozco, M. J. (2017). *Abonos orgánicos como alternativa para la conservación y mejoramiento de los suelos* (Doctoral dissertation, Corporación Universitaria Lasallista). http://hdl.handle.net/10567/2036

Arévalo, H. G., Puglla, C, Danilo, J. (2018). *Valoración nutricional de la gallinaza para alimentación animal y procesos industriales* (Master's thesis, Universidad de las Fuerzas Armadas ESPE. Maestría en Nutrición y Producción Animal). http://repositorio.espe.edu.ec/handle/21000/14805

Barreto, Torrella, S. I. (2019). El enfoque de producciones más limpias en la práctica laboral del Ingeniero Químico. *Transformación*, *15*(2), 124-138. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2077-29552019000200124

Belduma, Z A. (2015). *Evaluación de la producción de biogás a partir de la degradación de gallinaza sometida a diferentes relaciones C/N.* Machala-El oro-Ecuador. http://repositorio.utmachala.edu.ec/handle/48000/2850

Bragachini, A. M. A., Huerga, A. I., Mathier, A. D. F., Sosa, A. N. (2015). *Residuos pecuarios: una problemática que puede transformarse en oportunidad. Ed. electrónico.* *http://www.produccionanimal.com.ar/Biodigestores/66INTAResiduospecuarios2014.pdf*

Burguet, Fernández, G. (2016). Valoración energética del residuo avícola, impacto económico-ambiental y análisis experimental en Europa de la reducción de amoniaco en explotaciones avícolas mediante compuesto enzimático. http://hdl.handle.net/10651/38420

Cajamarca, D. I., Almeida, L. E. H., Díaz, N. I. G. Berrones, M. B. P. (2018). *Evaluación del plan de administración ambiental para la granja avícola dos hermanos. INNOVA Research Journal*, *3(*10.1), 42-54. https://doi.org/10.33890/innova.v3.n10.1.2018.776

Choudhury, A., Felton, G., Moyle, J., & Lansing, S. (2020). Fluidized bed combustion of poultry litter at farm-scale: Environmental impacts using a life cycle approach. *Journal of Cleaner Production*, *276*, 124231. https://doi.org/10.1016/j.jclepro.2020.124231

Daniyan, I. A., Daniyan, O. L., Abiona, O. H., Mpofu, K. (2019). Development and Optimization of a Smart System for the Production of Biogas using Poultry and Pig Dung. *Procedia Manufacturing*, *35*, 1190-1195. https://doi.org/10.1016/j.promfg.2019.06.076

Dróżdż, D, Wystalska, K, Malińska, K, Grosser, A., Grobelak, A, Kacprzak, M. (2020). Management of poultry manure in Poland–Current state and future perspectives. *Journal of Environmental Management*, *264*, 110327. https://doi.org/10.1016/j.jenvman.2020.110327

Fahimi, A., Bilo, F., Assi, A., Dalipi, R., Federici, S., Guedes, A., ... & Fiameni, L. (2020). Poultry litter ash characterisation and recovery. *Waste Management*, *111*, 10-21. https://doi.org/10.1016/j.wasman.2020.05.010

FAO. (2016). *Alerta sobre riesgo global por abuso de los antimicrobianos*. Retrieved on January 18, 2018, from http://www.fao.org/news/story/es/item/382676/icode/

FONCODES. (2017). Producción y uso de abonos orgánicos: biol, compost y humus. Producción Y Uso de Abonos Orgánicos: Biol, Compost Y Humus, 9-20. https://docplayer.es/16125811-Produccion-y-uso-de-abonos-organicos-biol-compost-y-humus.html

Galarza, J. C. G., Ortíz, H. D., & Morales, C. C. T. (2016). Manejo de desechos orgánicos y cumplimiento de la normativa legal ambiental en las avícolas de la provincia de Tungurahua. *Ojeando la Agenda*, (44), 3. https://dialnet.unirioja.es/servlet/articulo?codigo=5803856.

Gohil, A., Budholiya, S., Mohan, C. G., & Prakash, R. (2020). Utilization of poultry waste as a source of biogas production. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2020.02.807

Irigoyen, J. (2018). Manejo de residuos en granja y plantas avícolas. http://bibliotecavirtual.corpmontana.com/handle/123456789/4069

Kantarli, I. C., Kabadayi, A., Ucar, S., & Yanik, J. (2016). Conversion of poultry wastes into energy feedstocks. *Waste Management*, *56*, 530-539. http://creativecommons.org

Marshall, W.A. (2000). Contribución al estudio de la ceba ovina estabulada sobre la base de hemo y suplemento proteico con harina de soya y gallinaza. Tesis presentada en opción al Grado Científico de Doctor en Ciencias Veterinarias.

Mullo, I. (2012). Manejo y Procesamiento de la Gallinaza. *línea]. Riobamba: Escuela Superior Politécnica de Chimborazo*. http://dspace.espoch.edu.ec/bitstream/123456789/2114/1/17T1106

Nieto, A. S. F., & González, A. R. B. (2018). Destino sostenible de los residuos generados en las plantas de beneficio avícola. *AiBi revista de investigación, administración e ingeniería*, 11-22. https://doi.org/10.15649/2346030X.473

Owamah, H. I., Alfa, M. I., & Onokwai, A. O. (2020). Preliminary evaluation of the effect of chicken feather with no major pre-treatment on biogas production from horse dung. *Environmental Nanotechnology, Monitoring & Management*, *14*, 100347. https://doi.org/10.1016/j.enmm.2020.100347

Prasai, T. P., Walsh, K. B., Midmore, D. J., Jones, B. E., & Bhattarai, S. P. (2018). Manure from biochar, bentonite and zeolite feed supplemented poultry: moisture retention and granulation properties. *Journal of environmental management*, *216*, 82-88. https://doi.org/10.1016/j.jenvman.2017.08.040

Quiñones, A. T. A. (2017). Producción de biogás para el desarrollo sustentable: experiencias en municipios cubanos. In *Congreso Universidad*, *6*(6). http://revista.congresouniversidad.cu/index.php/rcu/article

Ramírez B, H. A. (2015). *Desarrollo de alternativas de producción rentables a partir de desechos de empresas avícolas en la provincia de El Oro* (Master's thesis, Machala: Universidad Técnica de Machala). http://repositorio.utmachala.edu.ec/handle/48000/4180

Ramírez, A. I. J., Chávez, R. F., Pérez, J. G. A., Villalba, J. A. M., Angulo, A. U., Celani, P., ... & Zubiaga, J. T. (2018). *Sustentabilidad y tecnología: herramientas para la gestión segura y eficiente del hábitat, 2*. ITESO.http://hdl.handle.net/11117/5468

Riaz, L., Wang, Q., Yang, Q., Li, X., & Yuan, W. (2020). Potential of industrial composting and anaerobic digestion for the removal of antibiotics, antibiotic resistance genes and heavy metals from chicken manure. *Science of The Total Environment*, *718*, 137414. https://doi.org/10.1016/j.scitotenv.2020.137414

Rodríguez-Fernández, P. A. (2017). Impacto de los residuos orgánicos sobre algunos indicadores del crecimiento y productividad de la malanga (*Xanthosoma sagitifolium, schott*). *Ciencia en su PC*, (2). https://www.redalyc.org/pdf/1813/181351615004

Suárez-Hernández, J., Sosa-Cáceres, R., Martínez-Labrada, Y., Curbelo-Alonso, A., Figueredo-Rodríguez, T., Cepero-Casas, L. (2017). Evaluación del potencial de producción del biogás en Cuba evaluation of the biogas production potential in Cuba. *Estación experimental de Pastos Y Forrajes Indio Hatuey* 85. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942018000200001

Tullo, E., Finzi, A., & Guarino, M. (2019). Environmental impact of livestock farming and Precision Livestock Farming as a mitigation strategy. *Science of the total environment*, *650*, 2751-2760. https://doi.org/10.1016/j.scitotenv.2018.10.018

AUTHOR CONTRIBUTION

Information gathering and redaction of the manuscript: SCR and LDGC (50 % each)

CONFLICT OF INTERESTS

The authors declare no conflict of interests.