v. 2, n. 7, 2022

Journal of
Agricultural
Sciences
Research

VERMICOMPOSTING APPLIED TO VEGETABLE AND ANIMAL RESIDUE

Crisnanda da Silva e Silva
Universidade Federal do Recôncavo da Bahia – Centro de Ciências Exatas e Tecnológicas
Cruz das Almas, Bahia, Brasil

Ludmilla Santana Soares e Barros
Universidade Federal do Recôncavo da Bahia – Centro de Ciências Agrárias, Ambientais e Biológicas
Cruz das Almas, Bahia, Brasil

Marcel Silva Lemos
Universidade Federal do Recôncavo da Bahia – Centro de Ciências Agrárias, Ambientais e Biológicas
Cruz das Almas, Bahia, Brasil

Abstract: Population growth with food consumption consequently generates an increase in waste and environmental problems, requiring sustainable alternatives, reducing pollution from vermicomposting. The objective of this work was to analyze the efficiency of animal residues (AR) and plant residues (VR) as organic fertilizer in different proportions and the time that these residues take to decompose. The AR was obtained at the Experimental Farm and the VR at the University Restaurant. The execution took place at Laboratory N6 (Animal Microbiology) of the CCAAB. Organizer boxes were used, with the following treatments: 100% VR and 0% AR and 50% VR and 50% AR, and the respective times: 0, 30, 60, 90 and 120 days. The following parameters were evaluated: temperature, pH, moisture, Escherichia coli, mesophilic microorganisms and total coliforms. The data were submitted to analysis showing efficiency in the two proportions of plant and animal compost, respectively. Bacterial reduction was verified as a function of time and temperature, which was evaluated every 3 days. The pH observed in the samples was 8.5, ideal value for bacterial growth. For the moisture levels, a significant difference was observed between the treatments 100-0 and 50-50%, as they present different characteristics of the compounds in the proportions, but ideal for vermicomposting. The final compost and the biofertilizer produced proved to be viable in nutrient-deficient plantations.
Keywords: Biodegradation, compost, pollution, sanitation.

INTRODUCTION

The exponential growth of human beings on this planet is responsible for an unprecedented generation of plant and animal organic waste, coming from production systems intended for human maintenance on Earth. However, every protein production system produces negative impacts on the environment, unbalancing the natural systems of decomposition of organic matter, given that the amount of organic waste produced is far beyond what nature can absorb.

A viable and sustainable way of recycling such a large volume of organic waste – the generation went from 66.7 million tons in 2010 to 79.1 million in 2019, a difference of 12.4 million tons (Agência Senado, 2022) – is to process it through composting and use it in urban and rural agriculture as fertilizer. However, it is estimated that only 1.6% of these residues are used in this way in the country (IPEA, 2012).

The composting technique has shown satisfactory results, being considered by several authors an important way to treat organic waste. The process occurs through the stabilization of organic matter under high temperature conditions (above 45ºC), obtaining a stable, sanitized final product, rich in humic compounds and whose use in the soil does not pose risks to the environment (Orrico et al., 2007; Orrico Júnior et al., 2010; Sunada et al., 2015).

The social and economic growth of a nation, perhaps of a planet, needs to be supported by environmental and health dictates, otherwise there will be no evolution, but revolution and backwardness. In this way and considering what has been exposed and the feasible and scientific possibilities existing to control the impacting potential of organic waste, the present study was designed, whose motto is the identification of the efficient retention time for the organic matter to be decomposed, through vermicomposting processes.

MATERIAL AND METHODS

OBTAINING RESIDUES AND DEFINING CONCENTRATIONS

In carrying out the collections, the organic residues that were used were: vegetable residue

(VR), collected at the University Restaurant, and animal residue (AR), avian litter collected at the aviary of the Experimental Farm, both located at the Federal University of Recôncavo da Bahia (UFRB), Cruz das Almas-BA. After being collected, the proportions of plant and animal residues were made, namely: 100% VR + 0% AR (treatment 1) and 50% VR + 50% AR (treatment 2).

Composting with treatment 1 was started and samples were collected at times: 0, 30, 60, 90 and 120 days. The same was done with treatment 2.

The boxes composed of the waste samples were turned every 15 days in order to catalyze and oxygenate the process.

ASSEMBLY OF VERMICOMPOSTING BOXES

Three boxes of the organizer type, brand Giotto, with a capacity of 17 liters were used. In the first battery of experiments, 10 kilograms of waste from treatment 1 were inserted into each box, and in the second experimental battery, 10 kilograms of waste from treatment 2 were used.

These boxes were stacked one on top of the other, where the two upper ones were the digesters and the last one was the collector. The collections were carried out fortnightly, starting on day 0 and ending on day 120, in the three boxes, and the biofertilizer was collected in the last box.

The boxes were drilled with a drill throughout their base, an average of 80 to 100 holes, each 4 millimeters in diameter, illustrated in figure 1.

WEIGHING AND SERIAL DILUTION OF COMPOST AND BIOFERTILIZER

Twenty-five grams of the compound, obtained on the days of collection, were placed aseptically in flasks with 225 mL of 0.1% peptone water solution, obtaining dilution 10^1. Then, successive decimal dilutions, in sterilized test tubes containing 9 mL of the same diluent, up to the decimal fractions from 10^2 to 10^{10} were performed.

In the biofertilizer, we collect the samples with a beaker and with the aid of a micropipette, we transfer them to the test tubes, making the necessary dilutions.

MICROBIOLOGICAL DETECTION OF TOTAL COLIFORMS AND ESCHERICHIA COLI

For the identification of microorganisms, the pour-plate technique was used, using the HiCrome culture medium, which is a specialized for the identification of Escherichia coli (EC) and Total Coliforms (TC). Incubation took place at 35°C for 24 hours and, after that, the reading of the results consisted of counting typical colonies, which for Total Coliforms were pink and for Escherichia Coli, blue. Results were expressed in CFU/g (Colony Forming Units per gram).

DETECTION OF MESOPHILIC MICROORGANISMS

Analyzes of aerobic mesophilic bacteria were performed in both samples, using the technique of in-depth or pour-plate inoculation, in sterile plates, using the PCA culture medium (Plate Count Agar) which is used for bacterial counting in food products, water and other samples of sanitary importance. After manipulation, it was incubated in an oven at 35°C for 48 hours. Results were expressed in CFU/g (Colony Forming Units per gram).

PHYSICOCHEMICAL DETERMINATIONS

For the measurement of the hydrogenic potential (pH) we used the bench pH meter.

The variation of the degree of moisture was carried out through visible and physical aspects of the material.

RESULTS

TEMPERATURE

In order to have a clean production of compounds, we analyze the efficiency of plant and animal compounds, based on microbiological and physical-chemical parameters in different proportions of the respective compounds, also analyzing the behavior of temperatures and physical variation of the compound during the period of analysis if any.

In our current context, we were only able to obtain the partial results of our research, where our compost boxes were made in an aerobic way, that is, the microorganisms existing there needed oxygen for their survival and to accelerate the degradation of the waste produced. The process was characterized by stabilization and maturation factors, which could vary from a few days to several weeks, depending on the environment and the animal and plant compost.

The components of organic matter were used as cellular synthesis, for the formation of tissues, a part of it volatilizes, and the climate of the region interfered in a quantitative way in the results, the compounds transform into a substance of dark or brown color, with a percentage above 50% of organic matter, known as humus, manure or compost.

In order to obtain a quality product, it was necessary for the organic residues to pass through the main variables of temperature and duration of each phase, where the residues went through physical and chemical changes during a period of 120 days, which included bacterial growth, maturation until the degradation of these compounds.

The factors that interfere in these processes were the types of microorganisms present in the animal and vegetable raw material, as well as the size of the particles that were cut (average of 1 to 5 cm), not exceeding this size, so that the degradation time of the final compound was not larger than expected or smaller, so that compression does not occur.

During the entire process, the temperature of the compost and the leachate generated by the waste was observed. Temperature control is used to turn the material or irrigate it when it is high. The temperatures of the boxes were evaluated every 3 days, in order to analyze the behavior of the compounds for the degradation and death of microorganisms during the times of 0, 30, 60, 90 and 120 days and to analyze the optimal temperature to place the worms and start vermicomposting (Figure 2).

The results express that the temperatures presented follow the processes of the lag phases, which is the initial one, during 24 and 48 hours identified by the month of September. In the log phase, where the highest temperature values occur, more than 30 days have passed (October) and the increase in the production of microorganisms increases significantly. In November, it stands out for the stabilization of the temperature, stationary phase and in the month of December the microorganisms are reduced in a logarithmic way, being in the phase of death of the cultures.

The boxes used were 12 cm high, which also interfered in the temperature of the compost, since windrows with a height of 50 cm to 70 cm can reach high temperatures and this type of thermal control serves to kill microorganisms that live at ideal temperatures for humans. The increase in the temperature causes the sterilization of the material that contributed to the death of microorganisms, and some of these organisms can cause diseases to crops.

The study in question showed a low temperature, that is, room temperature in both samples of different initial proportions, ranging from a minimum of 25ºC to a maximum of 33ºC, for the growth of microorganisms. This is

Figure 1. Vermicomposting boxes.

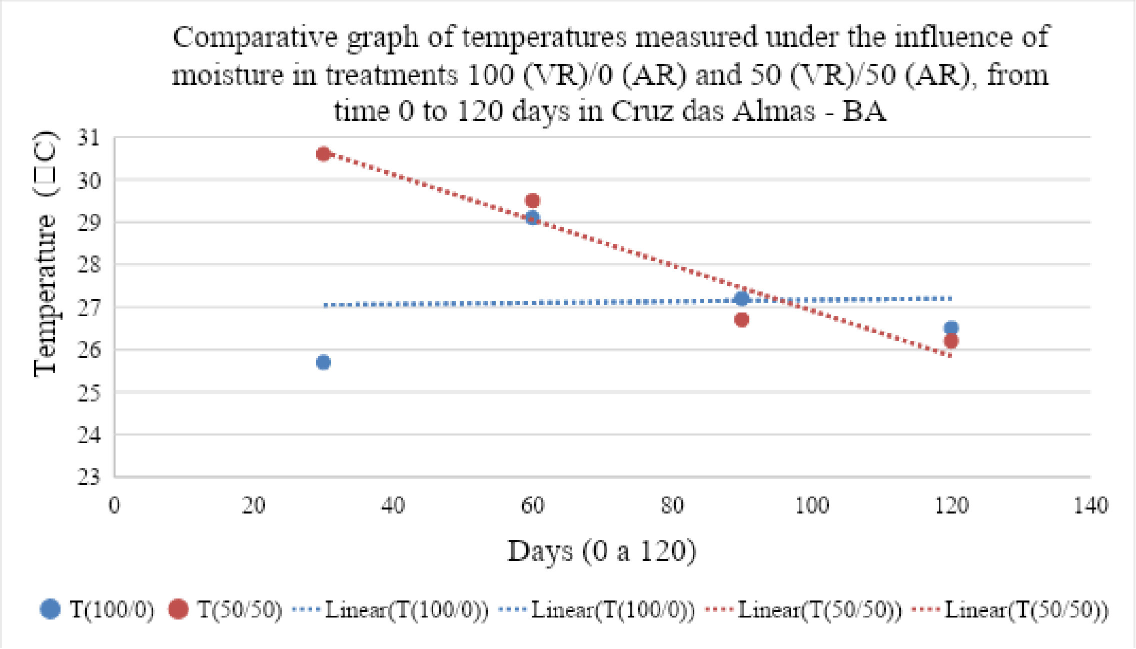

Figure 2. Temperature of the windrows with analysis of 100/0 residues every 3 days from 0 to 120 days in Cruz das Almas – BA. 2021.

related to the high moisture in the 100/0 tabled and in the case of the 50/50, the temperatures were higher, as shown in figure 3, however, as the moisture was low and the particles of the materials were coarser, with good aeration, and its temperature decreases, becoming ambient again. Where the materials were smaller, there was less heat loss as in the first tabled, even with high moisture.

MOISTURE

Our moisture parameter was analyzed only in the residues, every 15 days, during the turning of the boxes. In the first tabled 100/0 vegetable and animal compost respectively, our moisture was 55% to 58%, taking into account that when we analyzed the samples, the liquid of the compost flowed between the fingers, because the vegetable residues that were the husks of fruits and vegetables have a lot of water in their composition and the fibrous materials have an initially high moisture, gradually accelerating their degradation.

In the first days of the weeks of analysis, it was observed that the behavior of the 100/0 compost box, the biological, physical and chemical process generated more quickly the leachate, the slurry generated by the organic residue, because of its moisture.

Unlike the 50/50 compost, vegetable and animal compost, its moisture was between 48% and 54% because the animal compost, the chicken litter, is a type of sawdust with feces, feed and feathers, that is, with little water availability, and in the first days of collection there was no slurry.

COMPARATIVE ANALYSIS BETWEEN SYSTEMS

TEMPERATURE

As the predictor and/or independent variable on the x axis, the days on which the treatments were exposed from day 0 to 120 days and on the y axis, the continuous variables, that is, the response variable, the value of the temperature difference in the analyzed periods, as it resulted from their behavior along the linear regression represented by figure 3.

The trend lines (the trend points identifying the behavior) identify the behavior of temperatures over the established days, and when analyzed show us that in the treatment where 100% RV and 0% RA, identified in the graph as T (100/0) the temperature remained constant throughout the analyzed period, showing only its peak increase due to the death of microorganisms. In the 50% VR and 50% AR treatment, with the identification T (50/50) in the graph, we noticed that its initial temperature was high, and there was a decrease over time. However, at the end of each treatment system, temperatures reached an average value of 26.5ºC in 120 days, with no interference at the end of the processes. We can also identify, as one of the causes of the difference in the initial temperature of the systems, the compounds that were used. The material that had the greatest amount of vegetables was at room temperature, while the compounds of animal feces and wings, being more earthy and more compact, had the highest temperatures, due to their retention of heat.

Based on linear regression and R^2, we can conclude that there was 93.5% of the variation in temperature corresponding to the number of days established for the systems, and in the R-multiple there was 0.030 of correlation between the data.

MOISTURE

On the days that the treatments were exposed from day 0 to day 120, there were no significant differences between them over time. The trend lines identify how the behavior of the moisture took place and, when

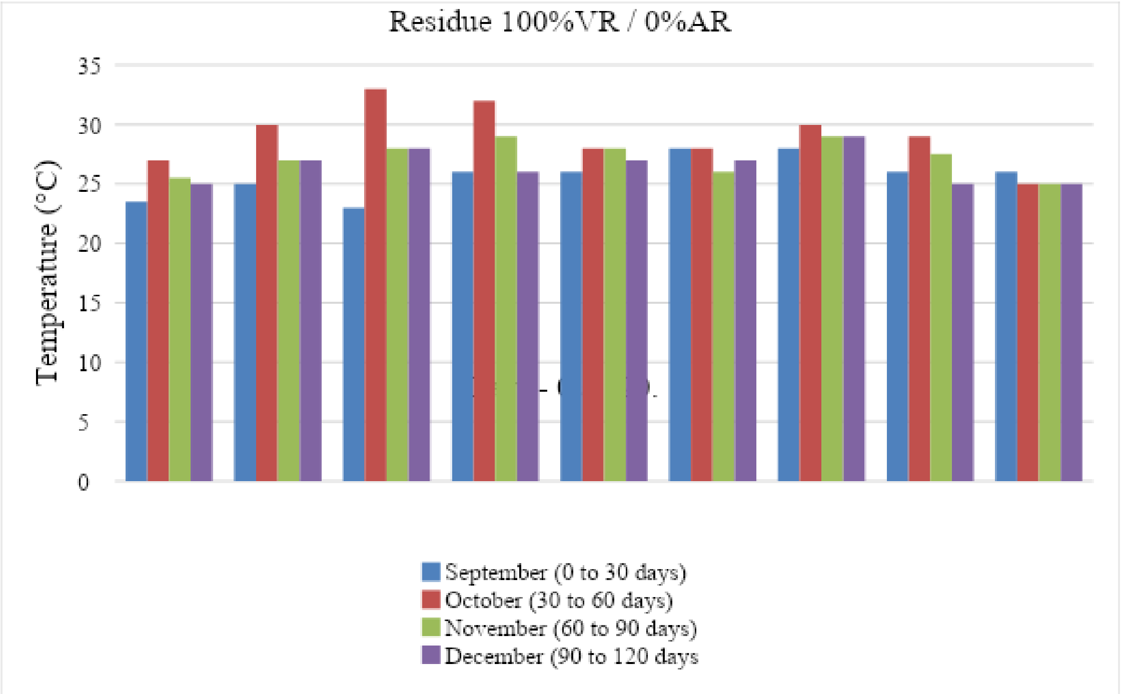

Figure 3: Comparison of temperatures measured with a thermometer in treatments 100(VR)/0(AR) and 50(VR)/50(AR), from 0 to 120 days, under the influence of the moisture of the compounds in the tables in Cruz das Almas – BA. 2021.

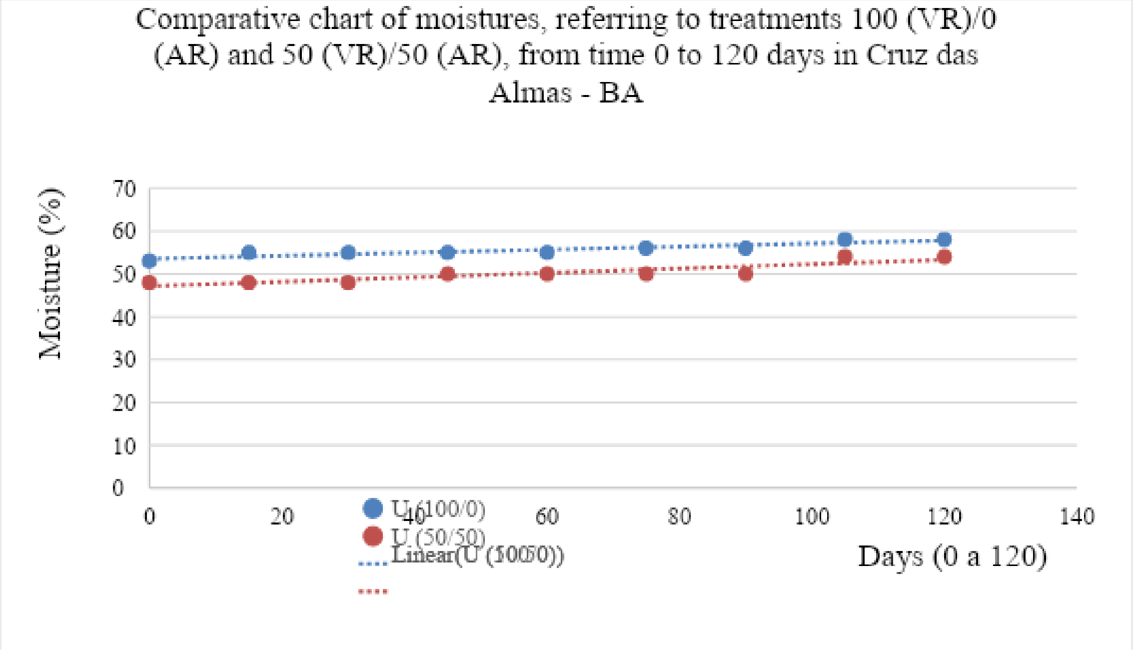

Figure 4: Moisture comparison for treatments 100 (VR)/0 (AR) and 50 (VR)/50 (AR), from 0 to 120 days in Cruz das Almas - BA, taking into account the physical composition of the compounds used.

analyzed, they show us that in the treatment

where 100% VR and 0% AR, identified in the graph as U (100/0), the moisture remained constant throughout the analyzed period, between 53% to 58%. In the 50% VR and 50% AR treatment, with the identification in the graph being U (50/50), we noticed that the moisture was a little lower compared to the first treatment, with constant over time according to figure 4. However, at the end of each treatment system, the moisture indices showed a difference of 5.44% in the average values found during the 120 days.

We can also identify, as one of the causes of this small difference, the external temperature, climate changes in the region, as well as the compounds that were used. The first one with 100% vegetable residue, had a greater amount of liquid in its composition, however, the compounds of the proportion 50% vegetable residue and 50% animal residue, because they are drier, when mixed, their humidity consequently decreased.

Therefore, the R^2 in the graph is an indication that there was approximately 81% of variation in moisture corresponding to the number of days established for the systems, and in the R-multiple there was 0.903 correlation between the data presented in figure 4.

MICROBIOLOGICAL ANALYSIS ON COMPOUNDS AND BIOFERTILIZER

There was a significant reduction of solid compounds, compared to liquids of the proportion 100% VR and 0% AR. Even though both are effective for composting, in the analysis developed for the solid compost there was more efficiency based on the comparative identified in figures 5 and 6 respectively, showing bacterial decline.

Based on the physical and microbiological results, we noticed the temperature efficiency in both compounds. The colonies at the beginning of the treatments showed up in large quantities and over time, these microorganisms died. Even with the temperature remaining ambient for the boxes used, we managed to reach such a temperature that they would die.

Mesophilic bacteria, as they manage to live in favorable environments at this temperature, even after the analyzed period, some plates showed few colonies, however, still existing. Bacteria of the type Escherichia Coli, pathogenic, appeared only in the proportion 100/0, this is due to the fact that the compounds used could already be contaminated from their source of collection, or their way of handling. The Total Coliform bacteria, at first the colonies grew gradually, as shown in figure 3 of bacterial growth, but, there was a decay over the days of analysis.

The results described show us a significant reduction of all types of microorganisms analyzed, as well as, what was more physically efficient was in the solid compost, of the proportion 50% VR and 50% AR. However, there was also a reduction in liquid compounds, reassuring us that the treatment systems were competent for the purpose of the project, doing justice in a sustainable, economic and effective way.

DISCUSSION

Animal production systems and food disposal generate environmental and health impacts that reverberate in unique health. According to Gustavsson et al. (2011), Kummu et al. (2012) and Chiarelotto et al. (2021), approximately a quarter to a third of the total food generated is wasted per year (1.3 billion tons per year).

We live on a globe where the number of animals already exceeds the number of human, and all this set of residues, in addition to food waste, is thrown in landfills or incinerated, without any reuse, which causes massive waste of resources and environmental

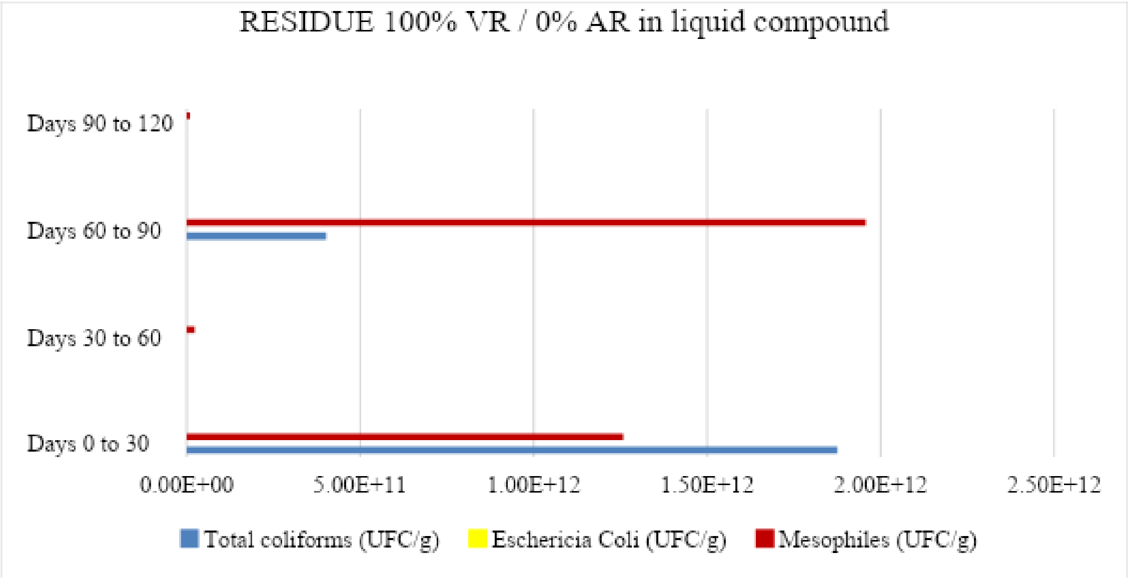

Figure 5: Bacterial degrowth in the liquid compost from days 0 to 120 of residues 100% plant residue and 0% animal residue.

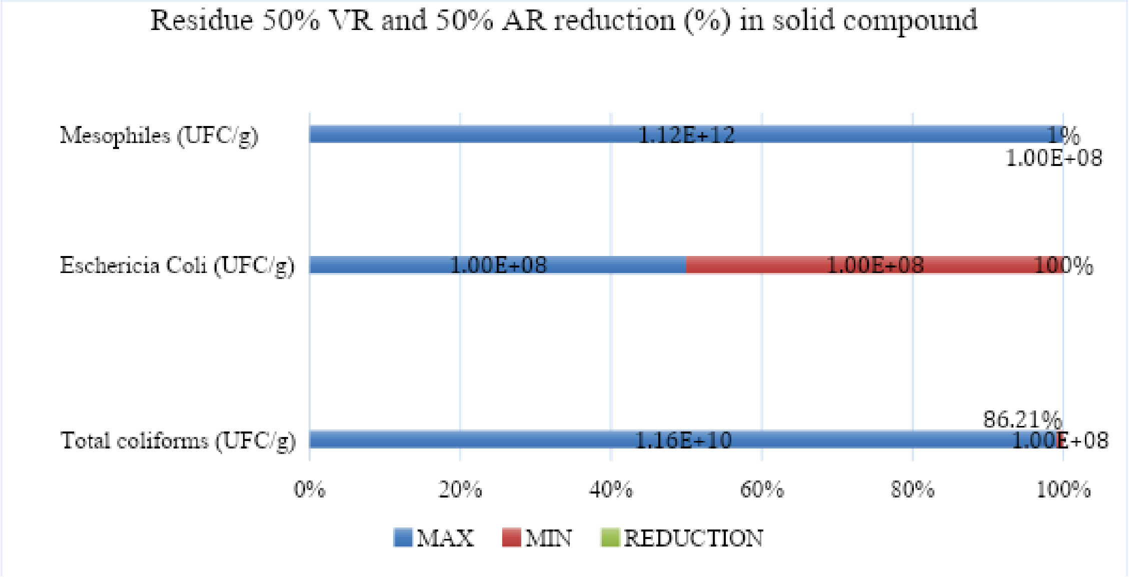

Figure 6: Bacterial degrowth in the liquid compost from days 0 to 120 of residues 50% plant residue and 50% animal residue. Maximum and Minimum of reductions in microbiological parameters in solid compost.

contamination (O'Connor et al., 2022; Zhang et al., 2022).

Microbial contamination in food waste represents a serious risk to human health. The application of contaminated compounds and digests to crops results in numerous foodborne outbreaks (Alegbeleye et al., 2018; Callejón et al., 2015). Pathogens in compounds and digests can contaminate fresh products by internalization, direct interaction, or close runoff (Alegbeleye et al., 2018; Murphy et al., 2016). Contamination by pathogens is particularly present when compounds and digests are improperly processed. E. coli and Salmonella spp. are two of the most commonly used indicators to assess the pathogen content of composts, digests and other soil correction products (Harwood et al., 2005). Therefore, many countries have adopted strict maximum permissible limits for E. coli and Salmonella spp. in soil correction products. Typically, to reduce the risk of microbial contamination of agricultural products, a compound or digest should have <1000 CFU g -1 of E. coli and absence of Salmonella spp. These values are based on the overall safety of soil correction products and do not rule out that other pathogens may be present in the product (Avery et al., 2012).

Pizarro et al. (2019) and Lima and Barros (2021) state that thermotolerant coliforms constitute a subgroup, in the group of total coliforms, which can be distinguished by their ability to grow at high temperatures. They are associated with the fecal material of warm-blooded animals and are represented mainly by Escherichia coli and some strains of Enterobacter and Klebsiella.

In a survey carried out by Pizarro et al. (2019), to test the efficiency of composting on poultry litter, whose compounds would be used as fertilizers in lettuce production, reported that the number of fecal coliforms and mesophilic microorganisms were drastically reduced after composting these animal wastes.

The results of this work demonstrate, on the one hand, that poultry litter is a source of pathogens that can pollute the environment or contaminate products (Orrico et al., 2007; Pizarro et al., 2019), contributing to the increase in incidence of foodborne diseases; however, the use of organic materials, whether animals or vegetables, properly composted, constitutes a beneficial treatment that inactivates these pathogens. Even so, it must be considered that some pathogenic cells could survive the composting process and persist in composted soils.

The results obtained and analyzed in this work corroborate the assertions of Gurtler et al. (2018), Jiang et al., (2020) and Thakali and MacRae (2021), who are unanimous in stating that pathogens can be sufficiently inactivated by optimizing the conditions that occur during composting, vermicomposting and anaerobic digestion.

In corroboration of the assertions of Avery et al. (2012), Gurtler et al., (2018), Jian et al., (2020) and O'Connor et al., (2022) it was possible to attest, through the analysis of the results, that the reduction of pathogens was typically obtained through thermal destruction, natural death, nutrient depletion, and by-product toxicity. This inactivation could be achieved by correctly balancing the processing conditions of pH, C/N relations, particle size, temperature and moisture levels in the raw material. In addition, raw materials that have an increased content of volatile fatty acids and ammonia may have contributed to the inactivation of pathogens. Additionally, the thermophilic temperatures recorded during composting and anaerobic digestion, replacing ambient and mesophilic temperatures, were crucial for the destruction of pathogenic microorganisms.

Another parameter worth mentioning and

which directly influenced the success of the composting process was temperature. Elevated temperature is considered an indirect measure of the success of the composting process, as it indicates an intense process of degradation of organic matter and is extremely important to promote the hygiene of the material and, thus, allow its use in fertilization without risk to the health of animals and people (Orrico et al., 2007; Orrico Junior et al., 2010; Orrico Junior et al., 2012; Qi et al., 2019). With the gradual biodegradation of organic substances (Qi et al., 2019; Chiarelotto et al., 2021), the temperature, recorded in the study in question, increased rapidly at the beginning of composting and then gradually decreased for all treatments. Regardless of the treatment tested, in this study the compounds reached high temperatures (above 55 °C), which was important for the elimination of pathogenic microorganisms.

Low temperature for a short period of time may not be enough to sanitize the final compost. Thus, its use as fertilizer can lead to contamination of the food that will be produced and consequently contribute to the spread of diseases on the property (Gonçalves & Marin, 2007).

At the beginning of the composting process, in this study, a high NMP.g-1 was observed, which suffered a drastic reduction during composting to the point that the presence of total and thermotolerant coliforms was no longer detected at the end of the process. Results similar to these were observed by Curci et al. (2007), Torres et al. (2007) and Orrico et al. (2012), who obtained reductions of pathogenic microorganisms very close to 100%, even in the case of sporulated microorganisms.

In this investigation, regardless of the treatment, the composting process showed an efficiency of 100% in the reduction of coliforms. Soobhany et al. (2017), O'Connor et al. (2022) and Chiarelotto et al. (2021) showed that vermicomposting, compared to aerobic composting, decreased the pathogenic load of different substrates. They concluded that earthworms could further reduce concentrations of E. faecalis, E. coli, Salmonella spp. and total coliforms in organic solid waste through digestive processes and intestinal effect. Currently, the optimization of composting and digestion systems is constantly being implemented to reduce and eliminate the pathogenic risk to animals and humans (Pandey et al., 2016; Palaniveloo et al., 2020; Mishra and Yadav, 2021; O'Connor et al., 2020; Mishra and Yadav, 2021; O'Connor et al. al., 2022).

CONCLUSION

Humans need nutrients for their survival, just like plants. The reuse of natural resources, for the formation of renewable sources, ensure future generations of environmental problems and food precariousness. It is a low-cost social and environmental technology, a viable alternative for reducing the amount of waste, through the formation of plant and animal compounds, free from agents that can cause risks to health, capable of meeting human and environmental needs. Vermicomposting is part of the group of efficient treatments for the proper disposal of

organic matter that is produced daily by people around the world, contributing to the reduction of waste in landfills, returning it to the environment in the form of nutrients. The generation of biofertilizers at the end of the treatments can be used in plantations, due to their composition, maturation processes and bacterial degrowth, proven through temperature. The feasibility of producing compost in different treatments was verified.

REFERENCES

Agência Senado. 2022. https://www12.senado.leg.br/noticias/infomaterias/2021/06/aumento-da-producao-de-lixo-no-brasil-requer-acao-coordenada-entre-governos-e-cooperativas-de-catadores#:~:text=Segundo%20dados%20do%20Panorama%2-0dos,12%2C4%20milh%C3%B5es%20de%20toneladas.

Alegbeleye, O.O., Singleton, I., Sant'Ana, A.S., 2018. Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: a review. Food Microbiology 73, 177–208. https://doi.org/10.1016/j.fm.2018.01.003

Avery, L.M., Booth, P., Campbell, C., Tompkins, D., Hough, R.L., 2012. Prevalence and survival of potential pathogens in source-segregated green waste compost. Science Total Environmantal 431, 128–138. https://doi.org/10.1016/j.scitotenv.2012.05.020

Callej´on, R.M., Rodríguez-Naranjo, M.I., Ubeda, C., Hornedo-Ortega, R., Garcia- Parrilla, M.C., Troncoso, A.M., 2015. Reported foodborne outbreaks due to fresh produce in the United States and European Union: trends and causes. Foodborne Pathogens and Disease 12, 32–38. https://doi.org/10.1089/fpd.2014.1821

Chiarelotto, M., Restrepo, J. C. P. S., Lorin, H. E. F., Damaceno, F. M. 2021. Composting organic waste from the broiler production chain: A perspective for the circular economy. Journal of Cleaner Production. 329: 129717. https://doi.org/10.1016/j.jclepro.2021.129717

Curci, V.C.L.M.; Dutra, I.S.; Dobereiner, J., Lucas Júnior, J. Précompostagem de cadáveres de bovinos acometidos pelo botulismo. Pesquisa Veterinária Brasileira, 2007. 27, 157-161. https://doi.org/10.1590/S0100-736X2007000400005

Dutta, S., He, M., Xiong, X., Tsang, D.C.W., 2021. Sustainable management and recycling of food waste anaerobic digestate: a review. Bioresour. Technol. 341, 125915. https://doi.org/10.1016/j.biortech.2021.125915

IPEA – Instituto de Pesquisa Econômica Aplicada. Diagnóstico dos resíduos sólidos urbanos. Relatório de pesquisa. Brasília, 2012. 82 p. https://www.ipea.gov.br/portal/index.php?option=com_content&view=article&id=17247

V.P. Gonçalves, V. P., Marin, J. M. 2007. Fate of non O157 Shiga toxigenic *Escherichia coli* in composted cattle manure. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 59 (4): 825-831. https://scholar.google.com.br/scholar?q=Gon%C3%A7alves+%26+Marin,+2007&hl=pt-BR&as_sdt=0&as_vis=1&oi=scholart

Graham, J.P., Polizzotto, M.L., 2013. Pit latrines and their impacts on groundwater quality: a systematic review. Environ. Health Perspect. 121, 521–530. https://dx.doi.org/10.1289%2Fehp.1206028

Gurtler, J.B., Doyle, M.P., Erickson, M.C., Jiang, X., Millner, P., Sharma, M., 2018. Composting to inactivate foodborne pathogens for crop soil application: a review. Journal of Food Protection 81, 1821–1837. https://doi.org/10.4315/0362-028X.JFP-18-217

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., Meybeck, A., 2011. Global Food Losses and Food Waste. FAO Rome. http://refhub.elsevier.com/S0269-7491(22)00074-4/sref69

Jiang, Y., Xie, S.H., Dennehy, C., Lawlor, P.G., Hu, Z.H., Wu, G.X., Zhan, X.M., Gardiner, G.E., 2020. Inactivation of pathogens in anaerobic digestion systems for converting biowastes to bioenergy: a review. Renewable and Sustainable Energy Reviews. 120, 109654. https://doi.org/10.1016/j.rser.2019.109654

Khoshnevisan, B., Duan, N., Tsapekos, P., Awasthi, M.K., Liu, Z., Mohammadi, A., Angelidaki, I., Tsang, D.C.W., Zhang, Z., Pan, J., Ma, L., Aghbashlo, M., Tabatabaei, M., Liu, H., 2021. A critical review on livestock manure biorefinery technologies: sustainability, challenges, and future perspectives. Renewable and Sustainable Energy Reviews. 135, 110033. https://doi.org/10.1016/j.rser.2020.110033

Kumar, M., Dutta, S., You, S., Luo, G., Zhang, S., Show, P.L., Sawarkar, A.D., Singh, L., Tsang, D.C.W., 2021. A critical review on biochar for enhancing biogas production from anaerobic digestion of food waste and sludge. Journal of Cleaner Production 305, 127143. https://doi.org/10.1016/j.jclepro.2021.127143

Kummu, M., de Moel, H., Porkka, M., Siebert, S., Varis, O., Ward, P.J., 2012. Lost food, wasted resources: global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. Science Total Environmental 438, 477–489.https://doi.org/10.1016/j.scitotenv.2012.08.092

Lima, D. V., Barros, L. S. S. Alternative water treatment using organic polymers associated with the solar disinfection method. 2021. Journal of Public Health and Epidemiology, 13, 224-232. https://academicjournals.org/journal/JPHE/article-abstract/3AF03D167834

Mishra, A., Kumar, M., Bolan, N.S., Kapley, A., Kumar, R., Singh, L., 2021. Multidimensional approaches of biogas production and up-gradation: opportunities and challenges. Bioresource Technology 338, 125514. https://doi.org/10.1016/j.biortech.2021.125514

Mishra, S.K., Yadav, K.D., 2021. Disposal of garden waste using food waste inoculant in rotary drums and their ranking using analytical hierarchy process. Bioresource Technology Reports 15, 100710. https://doi.org/10.1016/j.biteb.2021.100710

Murphy, S., Gaffney, M.T., Fanning, S., Burgess, C.M., 2016. Potential for transfer of Escherichia coli O157:H7, *Listeria monocytogenes* and *Salmonella* Senftenberg from contaminated food waste derived compost and anaerobic digestate liquid to lettuce plants. Food Microbiology 59, 7–13. https://doi.org/10.1016/j.fm.2016.04.006

O'Connor, J., Mickan, B. S., Siddique, H.M., Rinklebe, J., Kirkham, M. B., Bolan, N. S. Physical, chemical, and microbial contaminants in food waste management for soil application: A review. 2022. Environmental Pollution 300, 118860 . https://doi.org/10.1016/j.envpol.2022.118860

Orrico, A. C. A., Lucas Júnior, J. e Orrico Júnior, M. A. P. Alterações físicas e microbiológicas durante a compostagem dos dejetos de cabras. Engenharia Agrícola. 2007, 27 (3): 764-772. https://doi.org/10.1590/S0100-69162007000400020.

Orrico Júnior, M. A. P., Orrico, A. C. A. e Lucas Júnior, J. Compostagem dos resíduos da produção avícola: cama de frangos e carcaças de aves. Engenharia Agrícola. 2010, 30 (3): 538-545. https://doi.org/10.1590/S0100-69162010000300017.

Orrico Junior, M. A. P., Orrico, A. C. A., Lucas Junior, J., Sampaio, A. A. M., Fernandes, A. R. M., Oliveira, E. A. Compostagem dos dejetos da bovinocultura de corte: influência do período, do genótipo e da dieta. 2012. Revista Brasileira de Zootecnia 41 (5): 1301-1307. https://doi.org/10.1590/S1516-35982012000500030

Palaniveloo, K., Amran, M.A., Norhashim, N.A., Mohamad-Fauzi, N., Peng-Hui, F., Hui-Wen, L., Kai-Lin, Y., Jiale, L., Chian-Yee, M.G., Jing-Yi, L., 2020. Food wastecomposting and microbial community structure profiling. Processes 8, 723. https://doi.org/10.3390/pr8060723

Pandey, P.K., Vaddella, V., Cao, W., Biswas, S., Chiu, C., Hunter, S., 2016. In-vessel composting system for converting food and green wastes into pathogen free soil amendment for sustainable agriculture. Journal of Cleaner Production. 139, 407–415. https://doi.org/10.1016/j.jclepro.2016.08.034

Pizarro M. D., G. C´eccoli, F. F. Mu˜noz, L. S. Frizzo, L. D. Daurelio, C. A. Bouzo. Use of raw and composted poultry litter in lettuce produced under field conditions: microbiological quality and safety assessment. 2019. Poultry Science 98:2608–2614. http://dx.doi.org/10.3382/ps/pez005

Qi, G., Pan, Z., Yamamoto, Y., Andriamanohiarisoamanana, F.J., Yamashiro, T., Iwasaki, M., Ihara, I., Tangtaweewipat, S., Umetsu, K., 2019. The survival of pathogenic bacteria and plant growth promoting bacteria during mesophilic anaerobic digestion in full-scale biogas plants. Animal Science Journal 90, 297–303. https://doi.org/10.1111/asj.13137

Soobhany, N., Mohee, R., Garg, V.K., 2017. Inactivation of bacterial pathogenic load in compost against vermicompost of organic solid waste aiming to achieve sanitation goals: a review. Waste Management 64, 51–62. https://doi.org/10.1016/j

Sunada, N. S. et al. Compostagem de resíduo sólido de abatedouro avícola. Ciência Rural. 2015, 45 (1): 178-183. https://doi.org/10.1590/0103-8478cr20120261.

Thakali, A., MacRae, J.D., 2021. A review of chemical and microbial contamination in food: what are the threats to a circular food system? Environmental Research. 194, 110635. https://doi.org/10.1016/j.envres.2020.110635

Torres, P.; Pérez, A.; Escobar, J.C., Uribe, I. E., Imery, R. Compostaje de biosólidos de plantas de tratamiento de águas residuales. 2007. Engenharia Agrícola, 27: 267-275. https://doi.org/10.1590/S1516-35982012000500030.

Zhang, M., Tashiro Y., Ishida N., Sakai K. Application of autothermal thermophilic aerobic digestion as a sustainable recycling process of organic liquid waste: Recent advances and prospects. 2022. Science of The Total Environment 828, 154187. http://dx.doi.org/10.1016/j.scitotenv.2022.154187

Zuo, R., Chen, X., Li, X., Shan, D., Yang, J., Wang, J., Teng, Y., 2017. Distribution, genesis, and pollution risk of ammonium nitrogen in groundwater in an arid loess plain, northwestern China. Environmental Earth Science 76, 1–16. https://doi.org/10.1007/s12665-017-6963-4.