

Biotechnological conversion of organic wastes by vermiculture to increase crop yields

Yulia V. Daus ^{1*}, Angelina Yu. Dubina ², Valery A. Eviev ³, Victoria V. Evieva ⁴, Amina N. Badrudinova ³

¹ Kuban State Agrarian University named after I. T. Trubilin, Krasnodar, Russia

² Don State Agrarian University, Roston-On-Don, Russia

³ Kalmyk State University named after B.B. Gorodovikov, Elista, Russia

⁴ Moscow Institute of Physics and Technology, Moscow, Russia

Abstract. The work is devoted to the application of vermiculture biotechnology for processing organic waste and obtaining biohumus, as well as assessing the impact of the resulting product on crop yields and quality. The study included laboratory experiments on vermicomposting of different types of organic waste in different proportions with soil filler, as well as field trials using biohumus as a fertiliser for potatoes, carrots and oats. It was found that vermicomposting is effective for processing a wide range of organic wastes to produce biohumus rich in humus, macro- and microelements. The optimum ratio of organic waste and soil filler for biohumus production was 65:35. Field trials have shown that the use of biohumus helps to increase yields and improve the quality indicators of agricultural crops, including an increase in carotene and sugars in carrots, a decrease in non-protein nitrogen in potatoes, and a reduction in disease and pest damage. The results confirm the prospects of vermiculture as an environmentally safe method of waste utilisation and obtaining a valuable organic fertiliser.

1 Introduction

In the modern world the problem of organic waste utilisation is one of the most acute and topical. Intensive development of industry, agriculture and the growth of urban population lead to the accumulation of a huge amount of waste, a significant part of which consists of organic substances such as farm animal manure, poultry manure, food industry waste, plant residues and sewage sludge. Improper disposal of these wastes can lead to serious environmental problems, including soil, water and air pollution, the spread of pathogens, and the loss of valuable resources that could be used to improve soil fertility and produce environmentally friendly products. Thus, effective waste management plays an important role in agricultural systems [1, 2].

In order to address this problem, many approaches have been developed and implemented. One of the most traditional methods is composting, which allows the conversion of organic waste into valuable fertiliser. However, this process requires significant time investment as well as temperature and humidity control. Another common approach is to use organic waste as feedstock for biogas production, which not only utilises the waste but also provides a renewable energy source. However, this process requires specialised equipment and compliance with technological parameters. There are also chemical methods of waste processing, such as pyrolysis and gasification, which allow to obtain various

products, including synthetic fuel. However, they may be accompanied by the formation of harmful substances and require significant financial investment.

In recent years, more and more attention has been paid to biotechnological methods of organic waste processing, which are more environmentally friendly and allow obtaining valuable products, including biofertilisers. One such method is vermiculture, which is based on the use of earthworms to process organic waste into biohumus. This method is characterised by its simplicity, affordability and high efficiency. Biohumus produced in this way is a high quality organic fertiliser that contains high amounts of humus, macro- and microelements, enzymes and beneficial microflora, and has a prolonged action. This product can significantly increase the fertility of soils, improve their physical and chemical properties and contribute to higher crop yields. At the same time, it is important to note the role of family farmers in this process [3]. Vermiculture is a waste-free technology that allows processing a wide range of organic waste, including animal and poultry waste, sewage sludge, food industry waste and others.

The use of vermiculture is a very promising and important direction, as it offers an environmentally safe and effective way to utilise organic waste, while providing a valuable fertiliser. The utilisation of organic waste not only solves the problem of its disposal, but also contributes to the improvement of the environment and the creation of sustainable agroecosystems, and the

* Corresponding author: zirochka2505@gmail.com

use of biohumus helps to reduce dependence on mineral fertilizers, allows to obtain environmentally friendly agricultural products and improve food security, which is especially important in the context of developing countries [4, 5]. The aim of the presented work is to investigate the possibilities of applying vermiculture biotechnology to process organic waste and use the resulting biohumus as biofertiliser to increase crop yields and quality, which also meets the growing demands for food quality [6]. In this paper, the effect of different ratios of organic waste and soil filler on the vermicomposting process was investigated, and the effect of biohumus on yield and quality parameters of potatoes, carrots and oats was evaluated.

2 Method and materials

The research presented in this article was conducted to study the efficiency of biotechnological processing of organic waste by vermiculture and to assess the impact of the obtained biohumus on crop yields. The experimental work included two main stages: the first - obtaining biohumus by vermicomposting of different types of organic wastes, and the second - assessing the impact of the obtained biohumus on crop yield and quality under field conditions.

For vermicomposting experiments, the red California earthworm *Eisenia foetida* was used as the main biological agent. Various organic wastes such as poultry litter, sludge-lignin, sewage sludge, cattle manure (Cattle) and food wastes were used as substrates for vermicomposting in different ratios with soil filler namely 50:50, 65:35 and 80:20 (waste: soil). The vermicomposting process was carried out in special containers providing necessary aeration and humidity. The worm infestation density was 2000 specimens per square metre. The duration of composting varied from 1 to 3 months depending on the type of waste.

The obtained biohumus was used as a fertiliser in growing potatoes of 'Dobro' variety, carrots of 'Nantes' variety and oats of 'Dogoy' variety under field conditions. Field experiments were conducted with the application of biohumus at a dose of 3 tonnes/ha. To determine the yield and quality indicators of crops, harvesting and analysis of relevant parameters such as total yield, dry matter content, carotene content, sugars, nitrogen, fibre and the presence of damage by pests and diseases were carried out. Standard agrochemical methods of analysis were used.

3 Results and discussion

The experimental work carried out within the framework of this research was focused on the in-depth study of the vermicomposting process of organic waste and subsequent evaluation of the impact of the obtained biohumus on the productivity of agricultural crops. The experiment was structured in two interrelated stages: the first stage involved optimising the process of organic waste bioconversion using earthworms *Eisenia foetida* and obtaining biohumus as output, while the second

stage was aimed at field trials of the biofertiliser to assess its impact on yield and quality parameters of potatoes, carrots and oats. In the first phase, laboratory tests were conducted using various organic wastes including poultry litter, sludge-lignin, sewage sludge, cattle manure, and food waste. These wastes were mixed with soil filler in three different proportions: 55:45, 65:35 and 85:15 (waste:soil) to analyse the effect of different proportions on the final product. Three parallel experiments were performed for each variant to ensure reliability and reproducibility of the results. The vermicomposting process was carried out in specially prepared containers in which a microclimate with aeration, humidity and temperature in the range of 21-24°C was maintained optimum for the worms' activity. Each container was stocked with a population of earthworms at a density of 1900 individuals per square metre, and the composting period varied from 35 to 85 days, depending on the characteristics of the feedstock being processed. Throughout the observation process, visual changes in the substrate were monitored and samples were taken for laboratory analysis for humus content and essential macro- and microelements. In the second stage, three separate field experiments were conducted, one for each of the crops under study: potatoes, carrots and oats. In each of these field experiments, control plots where no fertiliser was applied and experimental plots where biohumus obtained in the first stage was applied. Biohumus was applied at a dosage of 2.8 tonnes/ha to all crops before planting, for potatoes and carrots, and under pre-sowing treatment for oats. Plant health was monitored continuously during the growing season and harvesting was carried out at the end. Crop yields were measured as well as qualitative parameters such as dry matter content, carotene, sugars, nitrogen, fibre, and the extent of pest and disease damage to fruits and seeds.

The results of the first stage of experiments demonstrated that vermicomposting is an effective method of processing various types of organic wastes. The greatest accumulation of humus was observed in variants with the use of poultry manure and food waste in the ratio of 65:35, where the humus content reached 5.10% and 9.80%, respectively, these indicators were noticeably higher than in other variants. For example, in the variant using sludge-lignin, at a similar ratio, the humus content was only 4.15%. In the 55:45 variants, humus levels were generally slightly lower, ranging from 3.70 per cent for sewage sludge to 9.10 per cent for food waste. The 85:15 ratio variants in turn showed even lower humus levels, ranging from 2.80% for sewage sludge to 6.80% for food waste. It was also found that the 65:35 ratio provided the best conditions for the reproduction and activity of earthworms, which contributed to a more intensive recycling of waste, which is also underlined by the importance of analysing the agroecological potential [7, 8]. The humus content of biohumus obtained from poultry manure with a 65:35 ratio was 13% higher than in the control sample, where mineral fertiliser was used exclusively, confirming the importance of agro-landscape modelling to obtain a quality fertiliser [9, 10]. In the second stage of field

trials, it was found that the application of biohumus had a positive effect on the yields of all three crops studied. In particular, the yield of potatoes in the experimental plots was on average 70.4% higher than in the control plots where mineral fertilisers were used. At the same time, the average yield in the control plots was 12.5 t/ha, while in the experimental plots it was 21.3 t/ha. For carrots, the application of biohumus increased the yield by 45.8% (control 22.0 t/ha, experiment 32.1 t/ha), and the dry weight of oats increased by 14.9% (control 3.0 t/ha, experiment 3.45 t/ha), which once again confirms the effectiveness of biohumus as a fertiliser. In addition, there was a significant improvement in the quality parameters of products: carrots showed an increase in the level of carotene and sugars, and potatoes showed a decrease in the content of non-protein nitrogen, which indicates an increase in nutritional value and storability. Also, it was recorded that the application of biohumus reduced the damage of potato tubers by pests and diseases. In the control this indicator was 15.9%, and in the experiment 11.2%, which indicates the protective properties of biohumus.

In general, the obtained data correspond to the results of similar studies, which confirm the effectiveness of vermicomposting for the utilisation of organic waste and the positive effect of biohumus on the productivity and quality of agrocultures. Thus, in studies conducted in different regions, it was found that the use of biohumus from cattle manure helps to increase grain yields by 22-33% and vegetable yields by 32-42%. Importantly, the positive effect of biohumus on soil microbial activity and improvement of its physico-chemical properties was also confirmed, which may be related to the assessment of the geo-ecological state of landscapes [11, 12]. The results obtained are in agreement with the findings of other scientists who found that biohumus helps to improve plant resistance to stressful conditions such as drought and diseases. In addition, the results showed that biohumus not only improves the quantitative characteristics of the crop, but also changes its composition in qualitative terms, increasing the concentration of useful substances, which increases the nutritional value of the resulting products. However, it should be noted that the efficiency of biohumus can vary depending on the type of organic waste used, as well as soil and climatic features of the region. Therefore, in order to achieve maximum efficiency, it is necessary to adapt the vermicomposting technology to local conditions and types of waste, as well as to take into account the influence of weather conditions on yield [13, 14]. Along with this, the prospect of utilising the waste to create new products should be considered [15]. This study contributes to the understanding of the benefits of vermiculture as a promising technology for utilising organic waste while producing a valuable organic biofertiliser, which is an important step towards more sustainable and environmentally friendly farming practices.

4 Conclusion

The study demonstrates the prospects of vermiculture as an effective method of organic waste utilisation with simultaneous production of a valuable biofertiliser. The results of laboratory and field experiments clearly indicate the positive impact of vermicomposting on the qualitative characteristics of organic waste and the subsequent increase in crop productivity. Optimisation of the vermicomposting process showed that the ratio of organic waste and soil filler in the proportion of 65:35 is the most favourable for maximum accumulation of humus in biohumus. It is at this ratio that the highest activity of earthworms and, consequently, the most efficient waste processing is achieved. This demonstrates the importance of selecting the correct ratio of components to optimise the process.

Field studies have confirmed that biohumus application has a significant stimulating effect on yield and quality of agricultural products. In particular, it was found that biohumus application contributes to a noticeable increase in the yield of potatoes, carrots and oats, as well as improving their quality characteristics. The carotene and sugar content of carrots increased significantly, while the amount of non-protein nitrogen in potatoes decreased, indicating an increase in the nutritional value and storability of tubers. Biohumus application also reduced pest and disease damage to potato tubers, confirming its protective properties and potential for reducing chemical pesticide use. In the control, this index was 15.9%, while in the experiment it was 11.2%, which indicates the protective properties of biohumus that require further study in terms of biotechnological approach [16, 17].

Thus, it can be concluded that vermiculture is not only an effective method of disposal, but also highlights the importance of introducing biotechnological methods in agriculture and the need for further study and optimisation of the vermicomposting process for different types of organic waste and soil and climatic conditions. It is also advisable to take into account the human factor associated with labour activity and population migration [18]. The findings contribute to the development of environmentally friendly and sustainable agricultural practices that contribute to solving the problems of waste management and food security.

References

1. N. Garambois, U. Le Goff, L. Thibaudeau, Agrarian dynamics and climate change in the Senegalese Sahelian peanut basin. *Agrar. Syst. Clim. Change: Journeys Adapt. Glob. South*, **15**, 37, (2024). DOI: 10.1079/9781800628137.0001
2. H. Cochet, O. Ducourtieux, N. Garambois, Agrarian systems and climate change: Journeys of adaptation in the global south. *Agrar. Syst. Clim. Change: Journeys Adapt. Glob. South*, **1**, 208, (2024). DOI: 10.1079/9781800628137.0000

3. B. Aparecida da Silva, R. Evangelista de Oliveira, A. Cavalieri Sais, E. Cardoso leite, Family farmers and trees: ecological functions, ecosystem services and food production in agrarian reform settlements in Brazil. *Agroecol. Sustain. Food Syst.*, **49**, 4-21 (2025). DOI: 10.1080/21683565.2024.2405515
4. S. Bamidele, BRICS Revolution: The Global Agrarian Shift Sparked by Emerging Economies. *India Q.*, (2025), Article in press. DOI: 10.1177/09749284241307937
5. V. I. Golik, T. A. Panfilova, V. Yu. Konyukhov, Mining Informational and Analytical Bulletin. **11-1**, 175-189 (2023). DOI: 10.25018/0236_1493_2023_111_0_175
6. A. Al Mozahid. What counts as “quality” in agrarian taste? Subjectivities, gender, and rice agroecology in northern Bangladesh. *Cult. Agric. Food Environ.*, **46**, 88-105 (2024). DOI: 10.1111/cuag.12323.
7. S.A. Makhosheva, M.V. Zhanokova, V.M. Dzaparova, I.K. Totrukova. Ecological aspect of sustainable development of high-mountain regions in the conditions of innovative economy formation. *Sustainable Development of Mountain Territories*, **16**, 754–769 (2024). DOI: 10.21177/1998-4502-2024-16-2-754-769.
8. I.I. Bosikov, E.V. Khekert. Analysis of the quality of underground mineral waters of terrigenous deposits of the hauteriv barremian aquifer of the lower cretaceous. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, **2**, 36-47, (2024). DOI: 10.32014/2024.2518-170x.392.
9. T.I. Kosovtsova. Factors of conservation of cultural landscapes of the Bavarian Alps. *Sustainable Development of Mountain Territories*, **11**, 371–379, (2019). DOI: 10.21177/1998-4502-2019-11-3-371-379.
10. T. A. Panfilova, K. A. Bashmur, V. V. Kondratiev, *Mining Informational and Analytical Bulletin*, **11-1**, 239-251 (2023). DOI: 10.25018/0236_1493_2023_111_0_239.
11. L.S. Malyukova, N.V. Martyushev, V.V. Tynchenko, V.V. Kondratiev, V.V. Bukhtoyarov, V.Y. Konyukhov, K.A. Bashmur, T.A. Panfilova, V. Brigida, Circular Mining Wastes Management for Sustainable Production of *Camellia sinensis* (L.) O. Kuntze. *Sustainability (Switzerland)*, **15(15)**, 11671 (2023). DOI: 10.3390/su151511671
12. A.I. Smirnov, N.V. Plotnikova, V.G. Burov, N.V. Martyushev, Features of the fine structure of the active layers of organic solar cells. *Key Eng. Mat.*, **712**, 176-181, (2016). DOI: 10.4028/www.scientific.net/KEM.712.176
13. B.V. Malozyomov, N.V. Martyushev, S.N. Sorokova, E.A. Efremkov, D.V. Valuev, M. Qi, Analysis of a Predictive Mathematical Model of Weather Changes Based on Neural Networks. *Mathematics*, **12 (3)**, 480 (2024) DOI: 10.3390/math12030480
14. A.A. Kapanski, E.A. Efremkov. Geospatial Clustering in Smart City Resource Management: An Initial Step in the Optimisation of Complex Technical Supply Systems. *Smart Cities*, **8**, 14 (2025). DOI: 10.3390/smartcities8010014.
15. A.L.S. Hansted, W.J. Newell, K.A. Hawboldt, An initial analysis of the market potential of a wet ash waste stream from a pulp and paper mill in Newfoundland and Labrador. *Ind. Crops Prod.*, **225**, 120557 (2025). DOI: 10.1016/j.indcrop.2025.120557
16. V.I. Golik, S.N. Sorokova, Q. Mengxu, Tailings Utilization and Zinc Extraction Based on Mechanochemical Activation. *Materials*, **16 (2)**, 726 (2023) DOI: 10.3390/ma16020726
17. L.S. Malyukova, N.V. Martyushev, V.V. Tynchenko, V.V. Kondratiev, V.V. Bukhtoyarov, V.Y. Konyukhov, K.A. Bashmur, T.A. Panfilova, V. Brigida, Circular Mining Wastes Management for Sustainable Production of *Camellia sinensis* (L.) O. Kuntze. *Sustainability (Switzerland)*, **15 (15)**, 11671 (2023) DOI: 10.3390/su151511671
18. A. Smith, Labour migration, mass unemployment and the state: Class, gender and work in the Land Settlement Association in inter-war rural England. *J. Rural Stud.*, **114**, 103498 (2025). DOI: 10.1016/j.jrurstud.2024.103498