



EFFECTIVENESS OF THE EARTHWORM (*EISENIA FETIDA*) ON THE PHYSICAL AND CHEMICAL PROPERTIES OF VERMICOMPOST DERIVED FROM BARBERRY AND PISTACHIO WASTES AND ANIMAL MANURE

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ABSTRACT

The management of agricultural wastes such as barberry and pistachio is of particular importance due to the high production volume and environmental challenges. The earthworm *Eisenia fetida* plays an important and key role in improving the physical, chemical and biological properties of soil and vermicompost. The present study aimed to investigate the effect of the earthworm *E. fetida* on the physical and chemical properties of vermicompost derived from barberry and pistachio wastes and animal manure. This study was conducted in a randomized complete block design with five replications during 2022 in the city of Mood, located in South Khorasan Province. The treatments included barberry leaves, barberry leaves and branches in equal proportions, barberry branches, pistachio waste, sheep manure, sheep and cow manure in equal proportions and cow manure. After ensuring that the treatments were ready based on the appearance of the vermicompost, after 50 days, the worms were manually separated from the materials in the bed and the vermicompost product was examined for the desired traits. In this study, the nutrients including Iron, Nitrogen, Boron, Zinc, Sulfur and Manganese as well as the physicochemical traits of the treatments such as saturated moisture content (sp), pH, electrical conductivity (Ec), sodium (Na), potassium (K), calcium (Ca), chlorine (Cl), phosphorus (P), organic carbon (O.C), mineral matter (O.M), apparent specific gravity and true specific gravity were evaluated. According to the results, there was no significant difference between the percentage of saturated moisture, pH, organic carbon, mineral matter, chlorine, apparent specific gravity and true specific gravity among the treatments used ($P < 0.05$). Treated cow manure showed higher concentrations of Iron (234.10 mg/kg), Zinc (2.64 mg/kg), Manganese (9.57 mg/kg) and Phosphorus (4795.35 mg/kg) compared with others. On the other hands, barberry leaves showed the highest levels of nitrogen (2.61 mg/kg), boron (18.27 mg/kg), sulfur (4700 mg/kg), sodium (5916.66 mg/kg), potassium (28250 mg/kg), and calcium (17586.33 mg/kg). In summary, the present study

showed that the use of *E. fetida* in treatments containing cow manure and barberry leaves can release significant amounts of chemical elements required for plant growth and development. Therefore, the combination of vermicompost derived from cow manure and barberry leaves can be effective as an optimal product for use in the production of agricultural, horticultural and other plants.

Keywords: *Eisenia fetida*, Vermicompost, Cow manure, Barberry waste, Chemical and physical properties.

INTRODUCTION

Vermicompost, produced through the biological activity of earthworms, is a valuable organic fertilizer that plays a significant role in enhancing plant health and productivity. It improves both clay and sandy soil structures due to its humus content and can retain water up to eight times its own weight. Natural growth hormones such as auxins and gibberellins present in vermicompost stimulate seed germination and plant development. Unlike chemical fertilizers, which may cause soil salinity or root burn, vermicompost is entirely stable and free of side effects, making it suitable for use in everything from large-scale farms to household potted plants (Machado & Serralheiro, 2017). As an alternative to chemical fertilizers, vermicompost is widely utilized in organic agriculture for the cultivation of vegetables, fruits, and cereals. Its benefits also extend to urban gardening, small-scale plots, and even hydroponic systems (Khan et al., 2024). Vermicomposting, as an efficient biotechnological process, utilizes the synergistic interaction between earthworms and microorganisms to offer a sustainable solution for recycling agricultural and livestock waste. At the core of this process lies *Eisenia fetida* (commonly known as the red Californian worm), a species recognized as an "ecosystem engineer" due to its exceptional tolerance to salinity and electrical conductivity (up to 10 dS/m), adaptability to a broad pH range (5–9), and remarkable ability to decompose complex compounds such as lignin and tannins (Maharjan et al., 2023). Numerous national and international studies have explored the impact of agricultural and livestock waste on vermicompost production. Internationally, researchers such as Gupta et al. (2015) and Katiyar et al. (2013) investigated solid waste management in India, concluding that cow manure is commonly used either as an organic fertilizer or as a plant-growing medium after stabilization. Yuvaraj et al. (2021) studied the environmental impacts and vermicomposting potential of cow manure. Other researchers, including Soobhany et al. (2015), demonstrated that the use of earthworms such as *Eudrilus eugeniae* enhances the recovery of nutrients from cow manure through composting and vermicomposting processes.

Kharrazi et al. (2014), Rasouli-Sadaghiani (2015), and Rahimi and Goldareh (2022) examined the potential of organic waste materials for vermicompost production. Kharrazi et al. (2014) reported that the combination of corn waste, cow manure, cardboard, and compost significantly improved vermicompost quality. Similarly, Rasouli-Sadaghiani (2015) concluded that using various organic materials in the presence of earthworms produced more favorable results than in their absence, highlighting the importance of earthworm activity in improving compost quality. Furthermore, Rahimi and Goldareh (2022), in a study on the bioavailability of lead in contaminated soils in the presence of organic matter, demonstrated that *Eisenia fetida* possesses the capacity to absorb and accumulate lead, thereby contributing to soil remediation.

According to the Food and Agriculture Organization (FAO, 2023), over two billion tons of agricultural and livestock waste are generated globally each year. Iran, with its economy strongly tied to agriculture and livestock, contributes a significant share. Improper management of these wastes leads to serious environmental issues, including groundwater contamination from toxic leachates, emission of greenhouse gases (especially methane and nitrogen oxides), and soil structure degradation (Gupta et al., 2015). Additionally, this mismanagement

represents a substantial loss of valuable resources that could otherwise be repurposed within a circular economy framework. Among these wastes, barberry (*Berberis vulgaris*) and pistachio (*Pistacia vera*) residues, along with livestock manure, hold particular significance in Iran. As the world's leading producer of barberry (over 90%) and pistachio (over 50%), Iran faces a unique set of challenges in managing these specific waste streams (Fatehi et al., 2005; Hokmabadi, 2018; Nakhaei, 2023).

Despite several studies on the vermicomposting of agricultural and livestock waste in Iran, limited attention has been paid to the vermicomposting potential of barberry and pistachio residues combined with animal manure—materials that are often underutilized or discarded. In light of this gap, the present study was designed to investigate the effect of *Eisenia fetida* on the physical and chemical properties of vermicompost derived from barberry waste, pistachio waste, and animal manure. The novelty of this research lies in its unique combination of raw materials, simultaneous evaluation of multiple parameters, and the development of context-specific solutions for managing specialized agricultural and livestock waste in Iran. The findings of this study may serve as a foundation for designing industrial-scale vermicomposting systems that not only address environmental challenges but also contribute to the production of high-value organic fertilizers.

MATERIALS AND METHODS

This study was conducted in 2022 in the city of Mood, located in South Khorasan Province, Iran, using a randomized complete block design (RCBD) with five replications. Seven different treatments were evaluated: (1) barberry leaves, (2) an equal mixture of barberry leaves and branches, (3) barberry branches, (4) pistachio waste, (5) sheep manure, (6) a 1:1 mixture of sheep and cow manure, and (7) cow manure. During the composting period, the ambient temperature and relative humidity were maintained at approximately 23°C and 40%, respectively. For treatment implementation, polyethylene containers were used, each with a total volume of 5 liters, based on the volume of initial substrate material. Each container was filled with 0.5 kilograms of substrate material.

To ensure proper aeration, 2 mm-diameter holes were drilled into the bottoms and sides of the containers. Additionally, to facilitate drainage of leachate or compost tea, all containers were placed on a 10 cm-high rack. The containers were stored in a controlled environment to maintain a relatively stable temperature.

Earthworms of the species *Eisenia fetida*, cultivated at the Vermicompost Production Center in Ferdows County, were used in this study. After adjusting the substrate moisture to an optimal range of 60–70%, the materials were thoroughly mixed, and 20 grams of earthworms were added to each treatment container. Once the vermicompost was deemed mature based on its visual and physical characteristics (after approximately 50 days), the worms were manually separated from the bedding, and the resulting vermicompost was subjected to physical and chemical analysis. To determine pH and electrical conductivity (EC), a 1:10 solution was prepared by mixing 1g of compost with 10mL of distilled water. After several hours of equilibration, measurements were taken using a calibrated pH and EC meter.

For organic matter (OM) and organic carbon (OC) analysis, 2g of compost sample were mixed with 10 mL of potassium dichromate and 20 mL of concentrated sulfuric acid. After 30 minutes, 25 mL of the solution was treated with sodium fluoride powder and five drops of diphenylamine indicator, which turned the mixture brown. This solution was then titrated with Mohr's salt (ammonium ferrous sulfate) until a green endpoint was reached. Nutrient elements were quantified after acid digestion using the following instruments and techniques: sodium (Na) and potassium (K) via flame photometry; phosphorus (P) via spectrophotometry; nitrogen

(N) via the Kjeldahl method; and other elements (such as Fe, Zn, Mn, B, S, Ca, and Cl) via atomic absorption spectrophotometry (AAS). All nutrient concentrations were expressed in mg/kg.

The study's design and trait evaluations followed a randomized complete block design. Data collection was performed using Microsoft Excel (version 2016), and statistical analysis was carried out using JMP software (version 13, SAS Institute). Analysis of variance (ANOVA) was used to assess treatment effects, and mean comparisons were conducted using the Least Significant Difference (LSD) test at the 1% and 5% significance levels.

RESULTS

1. Nutrient Elements

The analysis of variance for nutrient elements revealed statistically significant differences among treatments for nitrogen (N), sulfur (S), potassium (K), calcium (Ca), and phosphorus (P) ($P < 0.01$). The mean comparisons for these chemical traits are also presented in Table 1. Nitrogen (N) levels varied significantly across treatments. The barberry leaf treatment had the highest nitrogen content (26100 mg/kg), whereas the barberry wood treatment showed the lowest (11800 mg/kg). However, no statistically significant difference was found between the pistachio waste and barberry leaf treatments in terms of nitrogen content. Furthermore, no significant differences in nitrogen levels were observed among the pistachio waste, sheep manure, mixed sheep and cow manure, and cow manure treatments ($P > 0.05$). Regarding sulfur (S), significant differences were observed among treatments. The barberry leaf treatment had the highest sulfur content (4700 mg/kg), while the barberry wood treatment recorded the lowest (700 mg/kg) (Table 1). No significant differences were found among the sheep manure, barberry leaf, cow manure, and mixed manure treatments ($P > 0.05$). Similarly, the barberry wood and pistachio waste treatments did not differ significantly in sulfur content ($P > 0.05$). The treatments containing barberry leaves (28,250 mg/kg) and barberry wood (11,758.33 mg/kg) exhibited the highest and lowest potassium concentrations, respectively (Table 1). However, no significant differences were observed among the treatments involving sheep manure, cow manure, pistachio waste, and the combined application of sheep and cow manure ($P > 0.05$). Regarding calcium content, the treatments with barberry leaves (17,583.33 mg/kg) and barberry wood (7,458.33 mg/kg) showed the highest and lowest concentrations of this element, respectively (Table 1). No statistically significant differences in calcium levels were found among the treatments with cow manure, sheep manure, barberry leaves, and the combined cow and sheep manure. Additionally, no significant differences in calcium content were found between the treatments of barberry wood and leaves, as well as between pistachio waste and barberry wood ($P > 0.05$).

With respect to phosphorus content, the treatments containing cow manure (4,795.35 mg/kg) and barberry wood (1,431.83 mg/kg) exhibited the highest and lowest concentrations of this element, respectively (Table 1). Among the evaluated treatments, no statistically significant differences were observed in phosphorus levels between the treatments containing barberry leaves, a mixture of barberry wood and leaves, pistachio waste, and barberry wood ($P > 0.05$). Furthermore, the results showed no significant difference between the treatments with sheep manure and the combined cow and sheep manure. Similarly, no significant difference was observed between the cow manure treatment and the combined cow + sheep manure treatment ($P > 0.05$).

2. Micronutrient Elements

The analysis of variance for micronutrient elements revealed statistically significant differences among treatments for iron (Fe), boron (B), zinc (Zn), manganese (Mn), sodium

(Na), and chlorine (Cl) ($P < 0.01$). The mean comparisons for these traits are also presented in Table 2. The iron (Fe) content differed significantly among treatments, with the highest concentration observed in the cow manure treatment (234.10 mg/kg) and the lowest in the barberry wood treatment (13.53 mg/kg).

With respect to boron (B), significant differences were noted among treatments. The highest boron concentration was found in the barberry leaf treatment (18.27 mg/kg), while the lowest was in the cow manure treatment (1.76 mg/kg). No significant differences in boron content were observed among the barberry wood, pistachio waste, sheep manure, and mixed sheep and cow manure treatments ($P > 0.05$). Similarly, the cow manure, barberry wood, sheep manure, and mixed manure treatments did not differ significantly in boron content ($P > 0.05$). Mean comparisons for zinc (Zn) revealed significant differences among treatments. The highest concentration of zinc was recorded in the cow manure treatment (2.64 mg/kg), while the lowest was observed in the pistachio waste treatment (0.59 mg/kg). No significant differences in zinc levels were found among the barberry wood, pistachio waste, and the combined barberry leaf and wood treatments ($P > 0.05$). For manganese (Mn), the highest concentration was observed in the cow manure treatment (9.57 mg/kg), while the sheep manure treatment had the lowest (5.77 mg/kg). No significant differences in manganese levels were observed among the barberry leaf, combined barberry leaf and wood, barberry wood, sheep manure, pistachio waste, and mixed manure treatments ($P > 0.05$).

In terms of sodium (Na), the barberry leaf treatment had the highest concentration (5,916.66 mg/kg), while the barberry wood treatment had the lowest (1,833.33 mg/kg). Nonetheless, no statistically significant differences in sodium levels were found among the cow manure, barberry leaf, and mixed manure treatments ($P > 0.05$).

Table 1 - Nutrient contents (N, P, K, Ca, S) of different materials as vermicompost

Treatments	N	P	K	Ca	S
mg/Kg					
Barberry leaves	26100a	1590.33c	28250.00a	17583.33a	4700a
barberry leaves and branches	18100c	1475.35c	17291.66bc	10416.66bd	1600b
barberry branches	11800d	1431.83c	11758.33c	7458.33d	700c
Pistachio waste	23800ab	1868.14c	20166.66b	9125.00cd	1300bc
Sheep manure	21000b	3054.99b	14187.50bc	14583.33ac	4300a
Cow and sheep manure	21000b	4004.89ab	15708.33bc	16750.00ab	4000a
Cow manure	22800b	4895.35a	14920.83bc	15416.66ac	4000a

Table 2 - Nutrient contents (Fe, Zn, Mn, Na, B and Cl) of different materials as vermicompost

Treatments	Fe	Zn	Mn	Na	B	Cl
mg/Kg						
Barberry leaves	29.13de	1.78C	7.42b	5916.66a	18.27a	14875.00a
barberry leaves and branches	23.16de	0.82e	7.27b	3666.66bc	8.92b	15333.33a
barberry branches	13.53e	0.74e	6.34b	1833.33d	1.93cd	12458.33a
Pistachio waste	40.21d	0.59e	6.74b	2250.00cd	2.72c	13916.66a
Sheep manure	142.10c	1.45d	5.77b	2841.66bd	2.41cd	15416.66a
Cow and sheep manure	169.54b	2.16b	6.38b	4458.33ab	2.47cd	12666.66a
Cow manure	234.10a	2.64a	9.57a	5750.00a	1.76d	13333.33a

Table 3 - Comparison of the average chemical & physical properties in the studied treatments, including organic carbon, EC, and pH of various materials as vermicompost.

S.O. V	Sp	Ec	pH	O.C (%)	O.M(%)	Bulk Density	Particle Density
Barberry leaves	118.33a	8.65bc	8.75a	6.53a	8.45a	0.45a	1.51a
barberry leaves and branches	122.50a	5.81cd	8.70a	4.90a	5.43a	0.45a	1.51a
barberry branches	101.16a	4.56d	8.03a	4.37a	4.85a	0.45a	1.52a
Pistachio waste	98.16a	7.70cd	7.91a	6.07a	10.50a	0.44a	1.51a
Sheep manure	103.33a	8.23bc	8.45a	5.89a	5.30a	0.47a	1.54a
Cow and sheep manure	95.50a	11.30ab	8.45a	5.87a	7.71a	0.47a	1.55a
Cow manure	91.66a	12.78a	8.23a	8.35a	13.11a	0.48a	1.52a

3. Physicochemical Properties

The analysis of variance for physicochemical properties showed significant differences among treatments for electrical conductivity (EC) ($P < 0.01$). However, no statistically significant differences were found for saturation moisture content (SP), pH, organic carbon (OC), organic matter (OM), bulk density, or particle density ($P > 0.05$).

Among the studied physical traits, the highest and lowest values of electrical conductivity (EC) were observed in the cow manure (12.78 dS/m) and barberry wood (4.56 dS/m) treatments, respectively. There was no significant difference in EC between the cow manure and mixed cow and sheep manure treatments ($P > 0.05$).

DISCUSSION

The present study was conducted to evaluate the effect of the earthworm *Eisenia fetida* on the physical and chemical properties of vermicompost derived from barberry and pistachio wastes, as well as livestock manures. In this study, the impact of seven different treatments—including barberry leaves, a mixture of barberry wood and leaves, barberry wood, pistachio waste, sheep manure, cow manure, and a combination of cow and sheep manure—on the physical and chemical characteristics of the resulting vermicompost was investigated. Key findings revealed significant differences among the treatments in terms of nutrient concentrations, including iron, nitrogen, boron, zinc, sulfur, manganese, sodium, potassium, calcium, phosphorus, and electrical conductivity (EC). In contrast, parameters such as saturation moisture content, pH, organic carbon percentage, organic matter percentage, chlorine content, bulk density, and true density showed no statistically significant variation across treatments.

The observed consistency in these parameters across all treatments suggests that the studied organic resources do not have a substantial short-term impact on the carbon stability of the resulting vermicompost. These results are in agreement with the findings of Banaś and Kożuch (2019), who emphasized the pivotal role of time in the decomposition of organic matter. Time is a critical factor influencing both the rate and extent of organic matter breakdown. The decomposition process typically begins with the rapid degradation of easily digestible compounds such as sugars and starches, followed by the slower breakdown of more resistant substances like lignin and cellulose. The duration of this process can range from weeks for labile compounds to hundreds or even thousands of years for more recalcitrant materials (Ferreira et al., 2020).

1. Nutrient Elements:

The results of this study indicated that, in the treatment derived from cow manure, the earthworm *Eisenia fetida* exerted the greatest influence on the concentrations of iron, zinc, and manganese. Although *E. fetida* is a widely used and effective species for vermicomposting cow manure, its impact on iron content is not solely determined by the worm species itself. Other factors, such as the initial iron content of the cow manure, the duration of the vermicomposting process, and the presence of additional materials or amendments, can also affect the final iron concentration in the vermicompost. This finding is consistent with previous studies, including those of Mashur et al. (2021), who reported that *E. fetida* is highly suitable for decomposing organic materials in livestock manure, and that its activity can enhance the bioavailability of nutrients such as iron in the final vermicompost.

According to the findings of the present study, the effect of *E. fetida* on increasing zinc levels in the cow manure treatment has also been reported by Kováčik et al. (2022), which aligns with the current results. The presence of *E. fetida* in cow manure treatments can influence zinc concentrations and potentially increase the amount of plant-available zinc. Through their biological activity, earthworms accelerate the breakdown of organic matter and improve soil structure, thereby enhancing the availability of nutrients, including zinc. Previous studies have shown that cow manure compost processed by *E. fetida* can result in increased levels of plant-available zinc in the soil (Garau et al., 2021). The use of *E. fetida* in cow manure vermicomposting may thus improve the availability of zinc, along with other nutrients, in the final product. This effect is primarily attributed to the digestive processes of earthworms and the microbial activity stimulated by their castings. As observed in the current study, the increase in manganese content in the cow manure treatment was also influenced by the biological activities of *E. fetida*, a result that is consistent with previous studies such as Shafique et al. (2023). During cow manure vermicomposting with *E. fetida*, the concentration of manganese—particularly its bioavailable forms—can increase throughout the process. This increase does not necessarily indicate a negative impact, as the overall process often reduces the bioavailability of other heavy metals.

The results further demonstrated that, in the barberry leaf treatment, *E. fetida* had the greatest effect on nitrogen, boron, and sulfur concentrations. The impact of *E. fetida* on nitrogen enrichment in barberry leaves can be explained by its critical role in nutrient cycling, particularly nitrogen. Earthworms accelerate the decomposition of organic matter and release nitrogen compounds, which are subsequently transformed into plant-available forms such as ammonium and nitrate (Cui et al., 2023). Through enhancing nitrogen mineralization in the surrounding soil, *E. fetida* can indirectly increase the nitrogen content of barberry leaves. Earthworms like *E. fetida*, by speeding up organic matter decomposition and nitrogen release, play a crucial role in nutrient cycling. This increase in available soil nitrogen can be absorbed by plants, including barberry, and potentially lead to elevated nitrogen levels in their tissues, including woody tissues (Xu et al., 2013).

In addition to nitrogen, the presence of boron and sulfur in barberry leaves has been confirmed, and their release is associated with the activity of specific microorganisms, including *E. fetida* (Nakhaei, 2023; Vera-Maldonado et al., 2024). Specifically, foliar application of boron and sulfur (in the form of sulfate), combined with nitrogen (as urea), to barberry trees can explain the increased concentration of these elements in plant leaves (Nakhaei, 2023).

2. Chemical and Physical Properties:

In the realm of soil chemistry, earthworms act as living recycling factories. Each day, they ingest organic materials—such as leaves and plant residues—equivalent to their own body weight, and transform them within their digestive system, with the aid of enzymes and symbiotic microbes, into a nutrient-rich substance known as "castings". These castings, commonly referred to as vermicompost, are among the richest natural fertilizers in the world (Ahmed and Al-Mutairi, 2022). Vermicomposts contain 5 to 11 times more nitrogen, 7 times more phosphorus, and 3 times more potassium than regular soil. They are also rich in humus, humic acids, plant growth hormones (such as auxins and gibberellins), and beneficial microbial communities (Hrčka et al., 2025).

The present study demonstrated that in the cow manure treatment, *Eisenia fetida* had the most pronounced impact on physical parameters, particularly electrical conductivity (EC). These results are consistent with those reported by Ramos et al. (2022), whose findings indicated that when cow manure was used as a substrate for vermicomposting with *E. fetida*, the highest influence was observed on EC. This suggests that earthworms, in the presence of cow manure, significantly altered the electrical properties of the material—likely due to changes in ion concentrations and nutrient content (Ramos et al., 2022). Moreover, in the cow manure treatment, the amount of phosphorus released by *E. fetida* was substantially higher than in other treatments. This effect is likely due to favorable conditions created by cow manure, such as a higher carbon-to-phosphorus (C/P) ratio and the presence of phosphate-solubilizing bacteria. Enhanced phosphorus release is beneficial for plant growth, as phosphorus is a vital macronutrient for plant development.

In this study, the release of potassium by *E. fetida* was significantly higher in the barberry leaf treatment compared to other treatments. Similar findings were reported by Kováčik et al. (2022), who found that the presence of barberry leaves significantly increased potassium release by *E. fetida* relative to other substrates. This suggests that barberry leaves may enhance the ability of earthworms to solubilize potassium, making it more readily available for plant uptake (Sánchez- Suárez et al., 2025).

According to the findings of this research, the release of calcium by *E. fetida* was also notably higher in the barberry leaf treatment compared to other treatments. This indicates that barberry leaves may significantly influence the biological activity of *E. fetida*, particularly in relation to calcium metabolism (Rahimi-Madiseh et al., 2017). It is also noteworthy that the greatest potassium release occurred in the barberry leaf treatment, a result consistent with the findings

of Fatehi et al. (2005), who reported that barberry is a rich source of potassium, with a concentration of approximately 526.4 mg per 100 grams. This makes it a valuable dietary source of this essential mineral for human nutrition.

CONCLUSION

The present study was conducted to investigate the effects of the earthworm *Eisenia fetida* on the physical and chemical properties of vermicompost produced from barberry and pistachio wastes, as well as livestock manures. Seven treatments were evaluated, including barberry leaves, a combination of barberry wood and leaves, barberry wood alone, pistachio waste, sheep manure, cow manure, and a mixture of cow and sheep manure. According to the obtained results, cow manure significantly increased the concentrations of iron (234.10 mg/kg), zinc (2.64 mg/kg), and manganese (9.57 mg/kg) compared to other treatments. Among the physical parameters, electrical conductivity (EC) was highest in the cow manure treatment (12.78 dS/m) and lowest in the barberry wood treatment (4.56 dS/m), indicating an accumulation of soluble salts—likely due to the high mineral salt content inherent in livestock manure. Furthermore, the barberry leaf treatment provided the highest levels of nitrogen (26100 mg/kg), boron (18.27 mg/kg), sulfur (4700 mg/kg), sodium (5,916.66 mg/kg), potassium (28,250 mg/kg), and calcium (17,586.33 mg/kg), making it a valuable source of essential nutrients for plants.

Overall, this study demonstrates that the combination of vermicompost derived from cow manure and barberry leaves, due to its richness in essential elements, holds considerable potential for use in agricultural production and can effectively support the growth and development of a variety of crops.

REFERENCES

1. Ahmed N, Al-Mutairi KA. 2022. Earthworms Effect on Microbial Population and Soil Fertility as Well as Their Interaction with Agriculture Practices. Sustainability, 14(13):7803. <https://doi.org/10.3390/su14137803>
2. Banaś J, Kożuch A. 2019. The Application of Time Series Decomposition for the Identification and Analysis of Fluctuations in Timber Supply and Price: A Case Study from Poland. Forests, 10(11):990. <https://doi.org/10.3390/f10110990>
3. Blake GR. 1965. Bulk Density in Methods of Soil Analysis. Agronomy, No. 9, Part 1, C. A. Black, pp. 374-390.
4. Cui J, Jiang J, Chang E et al. 2023. Underlying reasons and factors associated with changes in earthworm activities in response to biochar amendment: a review. Biochar, 5:79. <https://doi.org/10.1007/s42773-023-00287-x>
5. FAO. 2023. Food and Agriculture Organization of the United Nations. <https://www.fao.org>. Accessed on 04 August 2025.
6. Fatehi M, Saleh TM, Fatehi-Hassanabad Z, Farrokhfal K, Jafarzadeh M, Davodi S. 2005. A pharmacological study on Berberis vulgaris fruit extract. J Ethnopharmacol., 102(1):46-52. <https://doi.org/10.1016/j.jep.2005.05.019>
7. Ferreira V, Elozegi A, Tiegs SD, von Schiller D, Young R. 2020. Organic Matter Decomposition and Ecosystem Metabolism as Tools to Assess the Functional Integrity of Streams and Rivers—A Systematic Review. Water, 12(12):3523. <https://doi.org/10.3390/w12123523>
8. Garau M, Sizmur T, Coole S, Castaldi P, Garau G. 2022. Impact of *Eisenia fetida* earthworms and biochar on potentially toxic element mobility and health of a contaminated soil. Sci Total Environ., 806(Pt 3):151255. <https://doi.org/10.1016/j.scitotenv.2021.151255>

9. Gupta N, Yadav KK, Kumar V. 2015. A review on current status of municipal solid waste management in India. J Environ Sci., 37:206–217. <https://doi.org/10.1016/j.jes.2015.01.034>
10. Hokmabadi H. 2018. Pistachio wastes in Iran and the potential to recapture them in value chain. Pistachio Health J., 1(4):1-12.
11. Hrčka M, Kraus K, Hřebečková T, Tunklová B, Kubeš J, Hanč A. 2025. Effects of Sewage Sludge Compost and Vermicompost on Wheat Yield and Vitality. Agriculture, 15(5):551. <https://doi.org/10.3390/agriculture15050551>
12. Katiyar RB, Sundaramurthy S, Sharma AK, Arisutha S, Pratap-Singh A, Mishra S, Ayub R, Jeon BH, Khan MA. 2023. Vermicompost: An Eco-Friendly and Cost-Effective Alternative for Sustainable Agriculture. Sustainability, 15(20):14701. <https://doi.org/10.3390/su152014701>
13. Katiyar RB, Suresh S, Sharma AK. 2013. Solid waste management in Bhopal (India): Present and future challenges. Ultra Chem., 9:197–214.
14. Khan MT, Aleinikovienė J, Butkevičienė LM. 2024. Innovative Organic Fertilizers and Cover Crops: Perspectives for Sustainable Agriculture in the Era of Climate Change and Organic Agriculture. Agronomy, 14(12):2871. <https://doi.org/10.3390/agronomy14122871>
15. Kharrazi M, Unesi H, Abedini J. 2014. Effect of corn waste blended with cow dung and paper on vermicompost qualities using *Eisenia fetida*. Appl Field Crops Res., 27(103):179-191. <https://doi.org/10.22092/aj.2014.101219>
16. Klute A. 1986. Methods of soil analysis. Part 1: Physical and mineralogical methods. 2nd Edition, American Society of Agronomy and Soil Science Society of America, Madison, USA.
17. Kováčik P, Šimanský V, Smoleň S, Neupauer J, Olšovská K. 2022. The Effect of Vermicompost and Earthworms (*Eisenia fetida*) Application on Phytomass and Macroelement Concentration and Tetanic Ratio in Carrot. Agronomy, 12(11):2770. <https://doi.org/10.3390/agronomy12112770>
18. Lorenzo JM, Munekata PE, Dominguez R, Pateiro M, Saraiva JA, Franco D. 2018. Main Groups of Microorganisms of Relevance for Food Safety and Stability: General Aspects and Overall Description. Innov Technol Food Preserv., 53–107. <https://doi.org/10.1016/B978-0-12-811031-7.00003-0>
19. Machado RMA, Serralheiro RP. 2017. Soil Salinity: Effect on Vegetable Crop Growth. Horticulturae, 3(2):30. <https://doi.org/10.3390/horticulturae3020030>
20. Maharjan KK, Noppradit P, Techato K. 2023. Potential of *Eisenia fetida* (Redworm) for the conversion of three varieties of organic waste. Int J Recycl Org Waste Agric., 12:341-350. <https://doi.org/10.30486/ijrowa.2022.1958871.1466>
21. Mashur M, Bilad MR, Hunaepi H, Huda N, Roslan J. 2021. Formulation of Organic Wastes as Growth Media for Cultivation of Earthworm Nutrient-Rich *Eisenia foetida*. Sustainability, 13(18):10322. <https://doi.org/10.3390/su131810322>
22. Nakhaei F. 2023. Foliar Nutrient Applications to Barberry (*Berberis vulgaris*). II: Effects on Leaf Nutrient Content and Physico-Chemical Characteristics of Fruit and Yield. J Med Plant By-product., 12(4):357-363. <https://doi.org/10.22092/jmpb.2022.354742.1364>
23. Oyege I, Balaji Bhaskar MS. 2023. Effects of Vermicompost on Soil and Plant Health and Promoting Sustainable Agriculture. Soil Syst., 7(4):101. <https://doi.org/10.3390/soilsystems7040101>
24. Rahimi G, Goldareh F. 2022. The effect of *Eisenia fetida* earthworm on bioavailability of lead- contaminated soils in the presence of organic matter. Water Soil Sci., 32(3):61-75. <https://doi.org/10.22034/ws.2021.41267.2369>
25. Rahimi-Madiseh M, Lorigoini Z, Zamani-Gharaghoshi H, Rafieian-Kopaei M. 2017. *Berberis vulgaris*: specifications and traditional uses. Iran J Basic Med Sci., 20(5):569-587. <https://doi.org/10.22038/IJBMS.2017.8690>
26. Ramos FR, Santana NA, Andrade N, Romagna IS, Tirloni B, Silveira AO, Domínguez J, Jacques RJS. 2022. Vermicomposting of cow manure: Effect of time on earthworm

- biomass and chemical, physical, and biological properties of vermicompost. *Bioresour Technol.*, 345:126572. <https://doi.org/10.1016/j.biortech.2021.126572>
27. Rasouli-Sadaghiani M, Ejlali S, Saeidlou SA. 2015. The Effects of *Eisenia foetida* Activity and Different Organic Residues on Some Soil Chemical Properties and Corn Growth Indicators. *JWSS*, 19(73):113-123.
28. Rehman ZU, Ijaz N, Ye W, Ijaz Z. 2023. Design optimization and statistical modeling of recycled waste-based additive for a variety of construction scenarios on heaving ground. *Environ Sci Pollut Res.*, 30:39783–39802. <https://doi.org/10.1007/s11356-022-25014-0>
29. Sánchez-Suárez F, Palenzuela MV, Campos-Vazquez C, Santos-Dueñas IM, Ramos-Muñoz VM, Rosal A, Peinado RA. 2025. Effects of the Application of Different Types of Vermicompost Produced from Wine Industry Waste on the Vegetative and Productive Development of Grapevine in Two Irrigation Conditions. *Agriculture*, 15(15):1604. <https://doi.org/10.3390/agriculture15151604>
30. Satterthwaite D, McGranahan G, Tacoli C. 2010. Urbanization and its implications for food and farming. *Philos Trans R Soc Lond B Biol Sci.*, 365(1554):2809-20. <https://doi.org/10.1098/rstb.2010.0136>
31. Shafique I, Andleeb S, Naeem F, Ali S, Tabassam T, Sultan T, Abbasi MA. 2023. Cow dung putrefaction via vermicomposting using *Eisenia fetida* and its influence on seed sprouting and vegetative growth of *Viola wittrockiana* (pansy). *PLoS One*, 18(2): e0279828. <https://doi.org/10.1371/journal.pone.0279828>
32. Soobhany N, Mohee R, Garg VK. 2015. Recovery of nutrient from municipal solid waste by composting and vermicomposting using earthworm *Eudrilus eugeniae*. *J Environ Chem Eng.*, 3:2931–2942. <https://doi.org/10.1016/j.jece.2015.10.026>
33. Vera-Maldonado P, Aquea F, Reyes-Díaz M, Cárcamo-Fincheira P, Soto-Cerda B, Nunes-Nesi A, Inostroza-Blancheteau C. 2024. Role of boron and its interaction with other elements in plants. *Front Plant Sci.*, 15:1332459. <https://doi.org/10.3389/fpls.2024.1332459>
34. Xu D, Li Y, Howard A. 2013. Influence of earthworm *Eisenia fetida* on removal efficiency of N and P in vertical flow constructed wetland. *Environ Sci Pollut Res.*, 20(9):5922-9. <https://doi.org/10.1007/s11356-013-1860-1>
35. Yuvaraj A, Thangaraj R, Ravindran B, Chang SW, Karmegam N. 2021. Centrality of cattle solid wastes in vermicomposting technology—A cleaner resource recovery and biowaste recycling option for agricultural and environmental sustainability. *Environ Pollut.*, 268:115688. <https://doi.org/10.1016/j.envpol.2020.115688>