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STUDY OF PROPERTIES OF VERMICOMPOST BASED ON COW DUNG

Abstract

Unprocessed waste from agriculture sector, especially animal husbandry, causes of environmental problems. Therefore, efficient use of animal husbandry waste is relevant. In the scientific work, the main substrate is cow manure and its qualitative properties were analyzed. Experiments were carried out to study vermicompost (biohumus). The experiment used cow dung and organic waste (food waste and leaf litter). Cow dung is very rich in macro and micro elements. Accordingly, after the process of vermicomposting in biohumus, a balanced content of elements was determined (N, P, K, Mg, Ni, Cd, Zn, Cu, Cr and etc.). Earthworms absorb unnecessary toxic substances and pathogenic microflora and produce coprolites with useful elements. In the article, for the determination of analyzes, the ultraviolet spectrometric method and optical emission spectrometry with inductively coupled plasma were used. The aim of the work is - to investigate the theoretical and applied aspects of the rational use of the bioresource of technological Californian red earthworms and the potential of the microbial community of organic waste for the development of scientific foundations of vermicomposting and reproduction of soil the fertility.

Keywords: *Earthworms, vermicomposting, organic waste, soil, biohumus, cow dung, elements, microorganisms.*

Introduction

Vermicomposting is the processing of organic waste. Unlike traditional composting, where the conversion of organic matter into fertilizer occurs mainly under the influence of soil microorganisms, earthworms also participate in vermicomposting. Vermitechnology is aimed at fulfilling two main tasks: the prevention and elimination of environmental pollution and the efficient direct use of waste or products.

The efficiency of earthworms in the vermicomposting makes it more rapid and fundamental process in amendements of physicochemical parameters, increments of the nutrients content and reduction in heavy metals [1-2]. People in rural areas face problems relating to the infestation of weeds mainly because their livelihood is largely dependent on agriculture (Singh, 2021) [3]. Earthworms have been successfully used in the vermicomposting of urban, industrial and agricultural wastes in order to produce organic fertilizers and obtain protein for animal feed. Vermicompost contains highly enriched nutrients (nitrogen, potassium, phosphorus) and this process gradually makes them easily available to plants [4-5].

Vermicomposts also contain a large amount of humic substances. The ability of vermicomposts to increase plant growth is attributed to variety of physico-chemical factors, since vermicomposts have high porosity and water-holding capacity, have large surface area, providing strong absorption capacity and nutrient retention.

Mechanisms by which earthworms increase the availability of plant nutrients is still debated, but some researchers suggest that they depend on the activity of microorganisms in the intestines of earthworms. The hypothesis that microbial metabolites, especially plant growth regulators, could be responsible for the stimulatory effect of earthworm coprolites was first put forward by foreign authors [6-7] based on the experiments of etc. [8], who found that the addition of live and dead earthworms to the soil was associated with an increase in the growth of the tested plants. Then [9] hypothesized the participation microorganisms in stimulating plant growth, and subsequent microbiological, physical and chemical changes in maturing coprolites confirmed that earthworms and their coprolites stimulate soil fertility by increasing the stability of aggregates through polysaccharides of bacteria and by increasing the rate of decomposition of organic material by microflora.

The effectiveness of vermicomposting depends on the type of earthworm used in the process. In the process of vermicomposting, the use of epigean earthworms, which feed on any organic waste, quickly adapt to the substrate and have high reproductive capacity, is recommended .

Earthworms are one of the most famous and well-studied groups of soil invertebrates and belong to the Annelida phylum - annelids. The phylum Annelida includes the subphylum Clitellata girdle rings. This subtype, in turn, includes the class of oligochaete worms, Oligochaeta. The order haplotaxida, which includes the suborder earthworms (Lumbricina) belongs to the oligochaetes . The suborder Lumbricina includes 8 genera - Eiseniella, Eisenia, Bimastus, Eophila, Octolasium, Allobophora, Lumbricus. Earthworms are an extremely important taxonomic group in aquatic and terrestrial ecosystems [10-11].

Eisenia fetida is a common earthworm used in vermicomposting worldwiden. According to the ecological classification, earthworms Eisenia fetida belong to the epigeic category.

During the vermicomposting process, earthworms and microorganisms secrete various enzymes that break down molecules. Molecules of organic wastes are covalently or non-covalently linked to form polymeric structures during biosynthesis. The effect of biological catalysts contributes to the separation or binding of components of macromolecules [12].

Leaf litter contains some mineral elements in a hard-to-reach (poorly soluble) form. Composting greatly facilitates the extraction of these substances and uptake by plants. This makes it possible to use recycled litter as fertilizer. One of the most problematic elements of mineral nutrition, in terms of extraction from the litter and return to the root horizons, is calcium.

In addition, cow manure, plant residues increase the survival of earthworms. Many literature sources reported that the concentration of heavy metals decreased in wastes treated with earthworms.

One of the most important agrotechnical advantages of vermicompost over traditional bedding manure is the absence of helminth eggs, pathogenic microflora and high fertilizer and technological properties.

Coprolites, being a humus-like product, have characteristics similar to humus: stimulate plant nutrient uptake and metabolism, have a positive effect on protein synthesis with hormone-like activity, and influence soil properties through soil colloids and buffering properties. Earthworms stimulate microbial activity and metabolism, and also influence microbial abundance, thereby releasing more available nutrients and microbial metabolites into the soil.

Vermitechnology or vermicomposting carries out biodegradation of complex organic substances based on the synergistic effect caused by the action of earthworms and microorganisms.

Materials and Methods

Raw material

Substrates for vermicomposting were created in several versions. For vermicomposting, substrates were prepared in the production workshop of the Institute of «Ecology» at the International Kazakh-Turkish University named after Kh.A. Yasawi. The bulk of the substrate is semi-rotted cow manure. The basic physico-chemical parameters of the raw materials are shown in Table 1.

Table 1 - Basic physico-chemical parameters of the raw materials

Parameters	Substrate (cow manure)
pH/H_2O	8.2±0.1
pH/$CaCl_2$	8.5±0.3
Ec (μS/cm)	1252±201.1
C,%	17.15±0.02
N, %	0.87±0.01

C/N ratio	19.71±0.5
C/H ratio	6.69±0.2
H, %	2.564±0.02
S, %	0.716±0.04
Total nutrients (mg kg^{-1} DW)	
P	7905±104.5
Mg	15700±1201
K	8560±122.0
Available nutrients (mg kg^{-1} DW)	
P	1569±201
Mg	1400±120
K	1510±147
Total micronutrients (mg kg^{-1} DW)	
As	6.721±0.4
Cd	0.512±0.02
Cr	30.125±1.4
Ni	17.422±0.9
Pb	23.023±1.2
Zn	220.147±12.1
Cu	20.478±2.4
Available micronutrients (mg kg^{-1} DW)	
As	1.201±0.14
Cd	0.243±0.01
Cr	<0.005
Ni	0.357±0.02
Pb	6.470±0.9
Zn	68.405±7.4
Cu	1.02±0.08

Manure in any condition (fresh, semi-rotted, humus) is a source of macro- and microelements such as nitrogen, phosphorus, potassium, calcium, silicon, sulfur, chlorine, magnesium, boron, manganese, cobalt, copper, zinc, molybdenum.

Experimental Design

For activation of composting with worms and vermiculture process the calcium peroxide is inserted into the support medium composition. Calcium peroxide, having dissolved slowly in water-containing system, disengages oxygen and contributes to aeration of whole support medium areas. In this case anaerobic zones are eliminated, which are environmental pollution sources with harmful substances, working capacity of producer-worms becomes better. Final products, generating during decaying of calcium peroxide, are harmless for biological resources (O_2, H_2O, $CaCO_3$).

Worms were introduced only on neutral substrates. There should be an average of 1500 worms per 1 m^3 of substrate. In our work, for vermicomposting we used bins with dimensions of 47x38, each of which was filled with 1000 pieces of Californian red worms. The climatic conditions were favorable and temperature and moisture were maintained by sprinkling water regularly.

The odor intensity of the substrates before processing by worms was 4-5 points, and after the addition of calcium peroxide it was reduced to 2 points on a scale of organoleptic indicators.

Red California worms (E.foetida) acted as producers in this process. The cow manure were used as the main substrate. In order to enrich the cow manure with nutrients, special attention was paid to the composition of the substrates.

The biological decomposition process takes place in an oxygen (aerobic) and oxygen-free (anaerobic) environment with the participation of microorganisms. Aerobic biological decomposition (composting or vermicomposting) with the participation of microorganisms is a complex process that takes from 1 month to 1.5-2 years at a temperature of 30-60ºC and a humidity of 30-70%. And the biohumus presented in the research work was made with an accelerated version of vermitechnology. In order to obtain biohumus or vermicompost, the process is carried out in an aerobic environment. Substrates should be fully aerated to avoid anaerobic conditions. In an airless environment, the productivity and performance of earthworms decreases sharply. In this regard, calcium peroxide was used to aerate the entire volume of the substrate, that is, to eliminate anaerobic zones [13].

Vermicomposting

The steps for defining analysis are shown in Figure 1. Semi-rotted cow dung washed with water and placed in boxes with organic substrates for vermicomposting, then after vermicomposting the obtained biohumus is determined for chemical analysis.

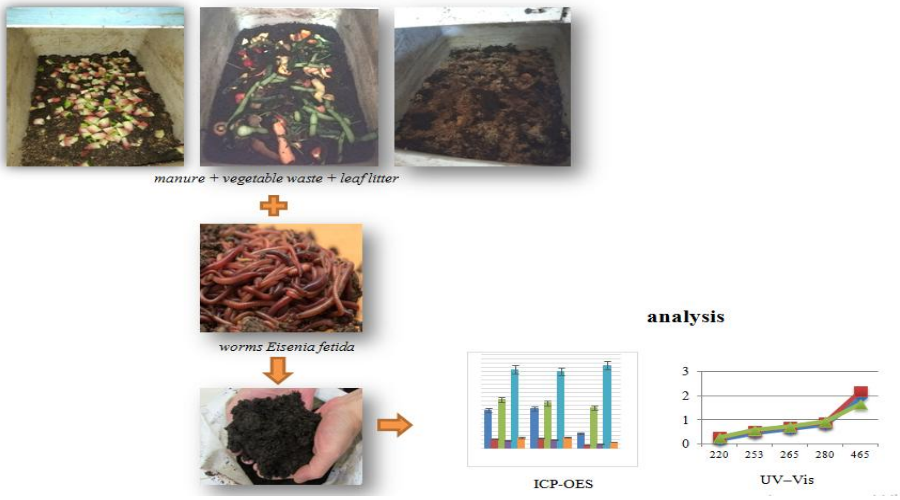

Figure 1 - The steps for defining analysis

Manure was brought from farms. Before fermentation began, they were first dried and washed with running water.

Three composting variants were prepared.

- 50 % cow manure + 45% vegetable waste + 5 % CaO_2 (VC I)
- 70 % cow manure + 30 % vegetable waste (VC II)
- 60 % cow manure + 40 % leaf litter (VC III)

In our work, for the compositions of the substrate we used cow manure, leaf litter, vegetable waste, which are organic feed for earthworms. Calcium peroxide (CaO_2) is a tetragenous white crystal, odorless, has the following physico-chemical parameters: it decomposes at a temperature of 275 °C, the density is 600 kg/m3. Calciumperoxide (CaO_2), a kind of traditional solid inorganic peroxide,can generate hydrogen peroxide (H_2O_2) when dissolves in aqueous solution, thereby initiating advanced oxidation process. Owing to stable oxidation capability, CaO_2 has been commonly used in the field of agriculture,medicine and wastewater treatment as preservative, bactericide and oxidant. Application of calcium peroxide (CaO_2), additives to processed support medium reduces the content of generated toxins smelling strong while rotting the plants, pH of environment is regulated, additional oxygen and calcium entry to worms' organism is ensured, which maintain their vigorous activity. Applied calcium peroxide helps to Californian worms to conduct the microorganisms' selection process more active, the eggs of insects and helminthes collapse [14-15].

Agrochemical analysis

The pH value and EC were determined from the aqueous solution. The 8 g sample was weighed and subsequently filled with 40 ml of demineralized water. The suspension was shaken using a mechanical shaker. The pH was then measured using a WTW pH 340i pH meter. Subsequently, the suspension was filtered to determine the EC according to EN 15933. The EC was measured using a WTW Cond 730 inoLab® conductometer. The total carbon and nitrogen content were determined using a CHNS Vario MACRO cube analyzer (Elementar Analyser Systeme GmbH, Germany). The total contents of macroelements and microelements were determined by wet decomposition using a closed microwave heating system Ethos 1, MLS GmbH, Germany. Furthermore, the available contents of macroelements for plants (K, Mg, P) were determined. The contents were measured in extracting reagent (NH_4NO_3 and 0.002 mol/L EDTA ethylenediaminetetraacetic acid). Measurements of total and available element contents were made using inductively coupled plasma optical emission spectrometry (ICP - OES Agilent Technologies 700).

Statistical Analysis

Values are arithmetic means of three to six values (according to repeatability of analysis) ± standard deviations. Based on the results of normality and homogeneity tests, the non-parametric Wilcoxon test ($P \leq 0.05$) was chosen for statistical analyses.

Results and discussion

Selected physico-chemical properties

Table 2 shows the agrochemical properties measured in the three variants after the vermicomposting process.

Table 2 - Values of basic agrochemical properties of vermicomposts

	Variant (VC) I	**Variant (VC) II**	**Variant (VC) III**
pH/H_2O	8.62±0.3	8.27±0.1	7.60±0.2
pH/$CaCl_2$	8.0±0.2	7.59±0.1	7.33±0.2
Ec (µS/cm)	1417±1.2	1331±2.5	2016±2.4
C,%	14.61	13.98	12,13
N, %	0.92	0.95	0.97
C/N ratio	15.8309	14.7542	12.4881
C/H ratio	7.8645	8.0406	7.9523
H, %	1.858	1.739	1.526
S, %	0.358	0.279	0.268

The pH values were almost identical in variants I and II, and in variant III the pH values were neutral. Electrical conductivity (EC) expresses the content of soluble salts including potassium ions, ammonium, nitrate ion and others. Table 2 shows that the highest electrical conductivity of extracts is characteristic of vermicompost based on manure and leaf litter (option III). The electrical conductivity of extracts from different types of vermicompost is determined by different ion pools: easily mobile forms of inorganic nitrogen predominate in manure, calcium and magnesium ions predominate in litter, and phosphates and sulfates may be present among inorganic anions.

EC, pH values indicate a suitable material for fertilization. The content of nutrients, especially macro and microelements necessary for plant nutrition, is a key parameter of the agronomic value of vermicompost. Figure 2 shows the total and available content of phosphorus, potassium and magnesium in the variants of vermicompost.

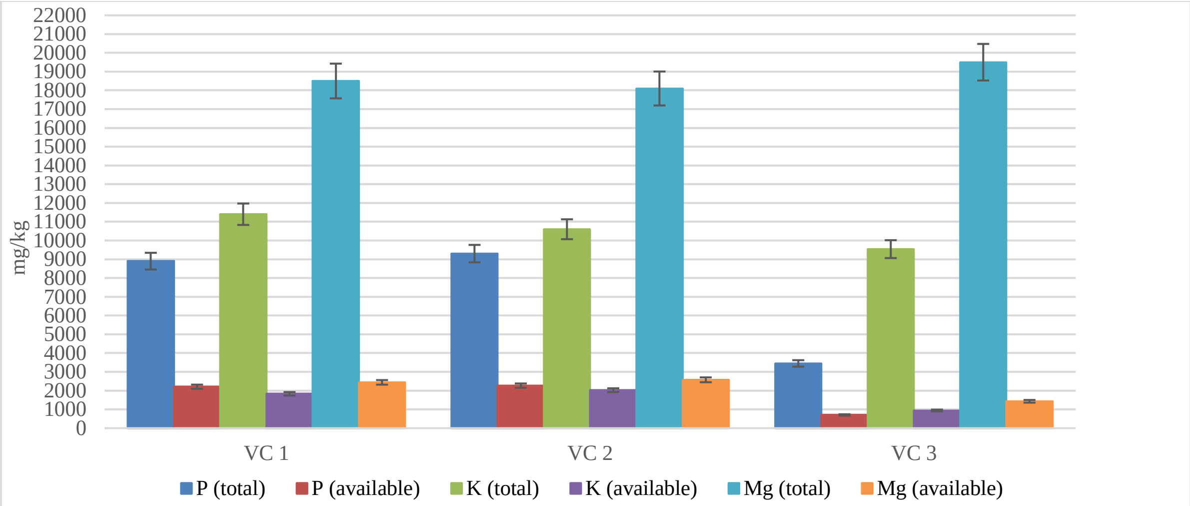

Figure 2 - Total and available content of phosphorus, potassium and magnesium elements in vermicomposts

Phosphorus anions attract negatively charged cations. Phosphorus increases the absorption of heavy metals. In addition, the availability of phosphorus depends on the pH. The high amount of magnesium element depends on the composition of the substrates.

The total phosphorus content varied from 3450-9300 mg/kg, the available phosphorus content ranged from 705 to 2209 mg/kg. The highest total phosphorus content in variant II reached an average of 9300 mg/kg, and the available content was 2267 mg/kg. The lowest potassium content (total) 9540 mg/kg, the (available) potassium content of 941 mg/kg was in option III. The highest total magnesium content of 19500 mg/kg is shown in option III, the available magnesium content of 2577 mg/kg was shown in option II.

UV-vis spectroscopical analysis

Formation of humic acids (HC) humic and fulvic acids (FC) fulvate complexes determines the presence of mobile types of heavy metals. Binding and retention of many heavy metals depends on the category of organic acids. In this regard, a detailed analysis of the nature of humic acids and their properties in compost, biohumus and other organomineral fertilizers-ameliorants is of significant economic importance. According to the literature, molecules of humic acids in the soil consist of aromatic nuclei, naphthenic rings, aliphatic chains, as well as functional groups with various oxygen content. Electronic absorption spectra in the visible region are widely used to estimate the ratio of carbons in the aromatic groups and aliphatic groups of humic acids.

Electronic absorption spectra in the visible region characterize the condensation of aromatic structures and have an important role in evaluating the ratio of carbons in the aromatic groups and aliphatic groups of humic acids.

UV/Vis spectrometer by recording the absorption spectra between 220 and 665 nm. Samples were measured in a 10 ml cylinder vials and with a standard phosphate buffer blank (NaOH).

The absorbance ratio of A465/A665 has been used to understand the qualitative enrichment of humic acids among the VC I, VC II, VC III vermicompost samples (table 3).

The UV/Vis absorbance spectra of Has isolated from all studied samples were typically featureless and characterized by the absence of identifiable maxima and/or minima with decreasing absorbance at increasing acquisition wavelength.

Table 3 - UV/Vis calculated ratios

	UV/Vis ratios
Variant	E4/E6 Ratio
VC I	9,675
VC II	9,918
VC III	7,417

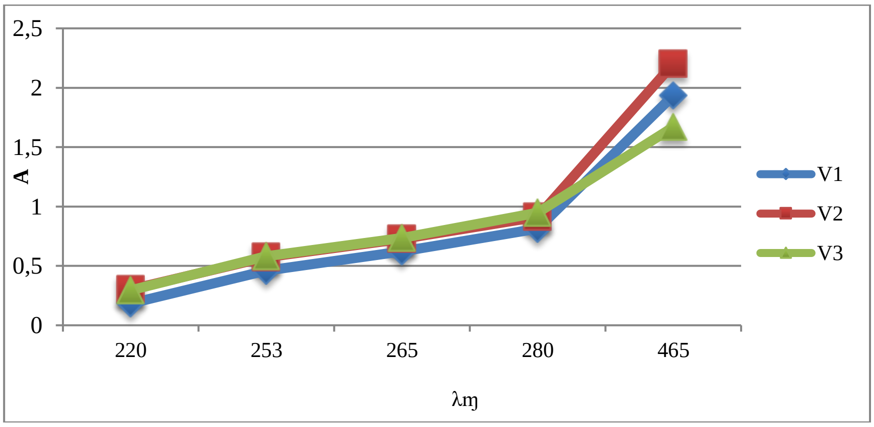

Figure 3 - Electronic absorption spectra of humic acids obtained from substrates of different composition

As can be seen from the data obtained (Figure 3), the values of optical densities of HA solutions in all cases depend on the wavelength D = f (λ) and gradually increase as they move to the long-wave part of the spectrum. The highest value of optical density HA belongs to vermicompost variant II (Figure 3).

The ratio of the E4:e6 and E2:E4 excitation coefficients was used to characterize the spectra of electron absorption HA. The values of these coefficients for humic acids obtained from vermicompost are 7.4 and 9.9, respectively. The values of HA obtained when adding CaO_2 to the substrate and excluding CaO_2 when taking biohumus were 9.6 and 9.9, respectively. The ratio under consideration does not depend on the concentration of the solution and the thickness of the absorbing layer that absorbs light, it characterizes the relative degree of condensation of humus substances. As it turned out, the higher the E4: E6 ratio, the more developed the peripheral part of the molecule, and the smaller the proportion of the aromatic nucleus is the particle. The decrease in optical densities of humus acids also depends on the substrate used to obtain biohumus.

Table 4 - Content of risk elements in vermicomposters at the process end (available)

mg/kg of dry matter							
Elements	As	Cd	Cr	Ni	Pb	Zn	Cu
VC I	0.954	0.0382	<0.005	0.198	3.68873	56.3636	3.2
VC II	0.766	0.068	<0.005	0.141	3.90931	65.4545	3.2
VC III	0.772	0.116	<0.005	0.148	5.6375	27.5	1.9

Table 5 - Content of risk elements in vermicomposters at the process end (total)

mg/kg of dry matter							
Elements	As	Cd	Cr	Ni	Pb	Zn	Cu
VC I	5.215	0.324	23.731	12.148	14.981	198.015	30.668
VC II	4.595	0.423	22.882	12.413	19.331	215.754	33.686
VC III	5.545	0.373	28.875	15.964	18.193	113.507	24.175

The content of risk elements was measured in options I, II and III (table 4 and 5). None of the contents exceed the limit values. The highest total content of Pb, Zn and Cu elements was shown in variant II. The highest total content of elements Cr, As and Ni was shown in variant III. The available content of Zn and Cu according to the variant was as follows: VC III < VC I < VC II. The available content of cadmium was according to the variant VC I < VC II < VC III.

In addition, earthworms can alter soil pollutants and reduce heavy metal levels. Chlorocyte cells of earthworms are able to detoxify harmful chemicals and heavy metals, are presented in the literatures.

Some toxic substances (including heavy metals) have the ability to accumulate in the body (cumulation effect or bioaccumulation). The body of red Californian worms consists of chloragogenic epithelium (tissue). Chlorogenic tissue is the main center in which glycogen and fat are synthesized and stored. Chlorogenic tissue (inside glycogen and fat) slowly metabolizes toxic substances, which explains the possibility of the bioaccumulation potential of the biomass of Californian red worms. Therefore, the content of heavy metals in vermicompost is reduced compared to the initial options.

Conclusion

In the substrates obtained by vermicomposting, the highest index in the E4/E6 (465/665 nm) region in versions I and II indicates that the functional groups of humic components are high and the peripheral part of the molecule is more developed. After vermicomposting, all heavy metals were slightly reduced compared to the original substrate. these studies were conducted in order to determine the qualitative characteristics of biohumus, and according to the study it was found that cow manure is a good substrate. The values for pH, EC, and macro- and micro- elements indicate suitable material for fertilization, and therefore the phytotoxicity test using seed germination was not carried out. The research work will continue.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ИЗУЧЕНИЕ СВОЙСТВ БИОГУМУСА НА ОСНОВЕ КОРОВЬЕГО НАВОЗА

Аннотация

Непереработанные отходы сельского хозяйства, особенно в сфере животноводства, представляют собой значительную экологическую угрозу, приводя к загрязнению окружающей среды и потере биологических ресурсов. Поэтому эффективное использование отходов животноводства становится актуальной задачей. В данной научной работе основным субстратом является коровий навоз, и проведен анализ его качественных свойств. Были выполнены эксперименты по изучению вермикомпоста (биогумус), в которых использовались коровий навоз и органические отходы, такие как пищевые остатки и опавшие листья. Коровий навоз является источником различных макро- и микроэлементов, таких как азот (N), фосфор (P), калий (K), магний (Mg), а также микроэлементов, включая никель (Ni), кадмий (Cd), цинк (Zn), медь (Cu) и хром (Cr). Эти элементы играют важную роль в питании растений и восстановлении плодородия почв. Калифорнийские дождевые черви активно поглощают токсичные вещества, патогенную микрофлору и органические остатки, превращая их в копролиты, которые обогащены полезными элементами. Для анализа состава использовались ультрафиолетовый спектрометрический метод и оптико-эмиссионная спектрометрия с индуктивно связанной плазмой. Целью работы - является исследование теоретических и прикладных аспектов рационального использования биоресурсов технологических красных калифорнийских дождевых червей, а также потенциала микробного сообщества органических отходов для разработки научных основ биогумусового компостирования и восстановления плодородия почв.

Ключевые слова: Дождевые черви, вермикомпостирование, органические отходы, почва, биогумус, коровий навоз, элементы, микроорганизмы.

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СИЫР КӨҢІ НЕГІЗІНДЕ АЛЫНҒАН ВЕРМИКОМПОСТТЫҢ ҚАСИЕТТЕРІН ЗЕРТТЕУ

Аңдатпа

Ауыл шаруашылығының, әсіресе мал шаруашылығының саласында пайда болатын өңделмеген көң қалдықтары қазіргі таңда экологиялық тұрғыдан маңызды мәселелердің бірі болып табылады. Сондықтан да мал шаруашылығы қалдықтарын тиімді пайдалану өзекті міндеттердің бірі болып саналады. Бұл мақалада сиыр көңі негізіндегі көң негізгі субстрат болып табылады және оның сапалық қасиеттеріне зертханалық талдау жұмыстары жасалған. Сиыр көңі және органикалық қалдықтар (тағам қалдықтары, жапырақ түсімдері) пайдаланылатын вермикомпостты (биогумус) зерттеу бойынша тәжірибелер жүргізілді.

Сиыр көңінің құрамында макро - және микроэлементтердің мол мөлшері бар екендігі анықталды. Вермикомпосттау үдерісі нәтижесінде вермикомпостта N-азот, P-фосфор, K-калий, Mg-магний, Ni-никель, Cd-кадмий, Zn-цинк, Cu-медь, Cr-хром сияқты элементтердің теңгерімді мөлшері анықталды. Бұл элементтер өсімдіктер үшін маңызды элементтер саналады. Вермикомпосттау үдерісінде калифорниялық қызыл жауын құрттары маңызды рөл атқарады. Олар токсиндер мен патогендік микроорганизмдерді өз денелеріне сіңіріп, олардың әсерін жояды және органикалық қалдықтардан коректік заттармен байытылған копролиттер шығарады. Алынған вермикомпостты (биогумус) талдау үшін ультракүлгін спектрометриялық әдіс және индуктивті байланысқан плазмалық оптикалық-эмиссиялық спектрометрия әдісі қолданылды.

Жұмыстың мақсаты технологиялық калифорниялық қызыл жауын құрттарының биоресурстарын ұтымды пайдаланудың теориялық және қолданбалы аспектілерін зерттеу, сондай-ақ органикалық қалдықтардың микробтық қауымдастығының вермикомпосттаудың ғылыми негіздерін әзірлеу және топырақ құнарлылығын қалпына келтіру әлеуетін бағалау болып табылады.

Кілт сөздер: жауын құрттары, вермикомпосттау, органикалық қалдықтар, топырақ, биогумус, сиыр көңі, элементтер, микроағзалар.

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АЛМАТЫ ОБЛЫСЫ ЖАҒДАЙЫНДАҒЫ АСБҰРШАҚТЫҢ САҢЫРАУҚҰЛАҚ АУРУЛАРЫНА ТӨЗІМДІЛІГІН ЗЕРТТЕУ

Аңдатпа

Зерттеу 2021-2023 жылдары Алматы облысындағы Саймасай агропаркі мен "ҚазЕӨҒЗИ" ЖШС тәжірибелік учаскелерінде өткізілді.

267 сұрыптық үлгідегі бастапқы селекциялық материалды зерттеу және анықтау үшін дәнді-бұршақты дақылдар жинағы құрылды, оның ішінде: 79 асбұршақ үлгісі.

Өсімдік ауруларымен күресудің тиімді стратегиясы патогендерді, соның ішінде олардың биологиясын, экологиясын және өзгергіштігін мұқият білуді талап етеді. Бұршақ дақылдарының аурулары өнімділікті, демек, фермерлердің кірістерін айтарлықтай төмендетеді. Саңырауқұлақ өсімдіктерінің қоздырғыштары бүкіл әлемде бұршақ дақылдарында айтарлықтай шығындар тудыратыны хабарланды. Бұршақ дақылдарының ең көп таралған саңырауқұлақ қоздырғыштары: қарапайым тамыр шірігі *(Aphanomyces euteiches),*