Influence of the ratio of ingredients in the processed substrata on adaptation of the Eisenia Foetida (Sav.) worms to them

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Abstract. Recently in Russia and in the near and far abroad the vermicomposting of organic wastes has been widely adopted. In a vermiculturing the species of worms specializing in eating of vegetable oddments and excrement of mammals are used, it is Eisenia foetida (Savigni, 1826) and its subspecies E.f. foetida, E. Fandrei, and also an ordinary earthworm which is Lumbricus terrestris, the small red worm L. rubellus and types of Dendrobaena subrubicunda and D. Veneta. Many researchers consider that the vermicomposting promotes a solution of the problem of utilization of large numbers of household garbage, rainfall of sewage, wastes of the food industry, the cellulose-paper and woodworking, tanning, hydrolyzing industries, and branches of agriculture. The technology of a vermiiruproducing supposes the preparation of substrata. Such receptions as humidification of wastes; their aeration, neutralization; crushing and homogenization, use of various excipients in substrata (straw, rotten hay, opit, peat, some quantity of the mineral soil) reduce terms of preparation of substrata for a vermiculture. Our researches were devoted to definition of an optimum ratio of ingredients in the substrata prepared for a vermiculturing on the basis of a bird's dung for successful adaptation of Eisenia foetida (Sav.) to them.

1. Introduction
Now the industrial poultry farms – the producers of food eggs and fowl - face a serious problem – utilization of a bird's dung which exit makes 227 kg from each one thousand eggs and 4600 kg from one ton of fowl. The continuity of a production cycle on poultry farms excludes the complete involvement of it in the processes of circulation of chemical elements in agrobiogeocenoses. As the result of it the accumulation of excrement of a bird occurs in quantities, ecologically unsafe for the environment and the human. The situation is aggravated by the fact that there are no enough efficient techniques of its utilization so far developed. The existing methods of the processing of a dung based on receiving from it fodder additives, granuloused mineral fertilizers, a combustible gas and also preparation the peat and premised composts do not eliminate all the losses of biogenic elements, they are power-intensive, demanding the considerable expenses of labor and engaging of a large number of equipment [1].

In a vermicomposting in comparison with an initial substratum, the number of bacteria are 3-3.5 times higher (an exception – sporous forms), the share of yeast and an Azobacter (70%) increases. Moreover, at an implementation of a vermicomposition into the soil the number of the most important groups of microorganisms of the soil increases in it. Some literary data give the information about the use of a biohumus in crop production increases resistance of plants to diseases [2, 3].
The content of the common nitrogen in the vermicompositions fluctuates from 0.8 up to 3.0%; \( \text{P}_2\text{O}_5 \) – from 0.5 to 5.0%; \( \text{K}_2\text{O} \) – from 3.0 to 2.5%; carbon – from 12 to 29%; organic matters – from 24 to 64%; calcium – from 4.5 to 10%; a magnesium – from 0.6 to 2.5; iron – from 0.6 to 3.8%. Besides, vermicompositions contains the complete set of minerals necessary to plants, a huge number of bacteriemic flora (to 2 billion/cm\(^3\)), with the phytohormones in their structure (gibberellina, tsitokinina, auxins) and other plants growth factors. The importation of a vermicomposition considerably improves agrochemical and agrophysical properties of the soil [3, 4].

Worms are capable to processing and turning into valuable organic fertilizer of such organic maximum deflections as an anaerobic ooze of sewer waters, dung water, a dung etc. Such maximum deflections in the result of their processing by earthworms lose a fetor, are exempted from a harmful microflora, gain grain structure, lose toxicity for roots of plants [5].

High potential opportunities of a method of a vermicomposing promoted an appearance in the USA, in the countries of Europe, in Russia and the Commonwealth countries in the farms specializing in processing of various organic wastes by means of earthworms [6].

Some researchers consider that use of a vermiculture as fodder means could promote a solution of the problem of deficiency of protein feeds in livestock and cattle production and the production of industry poultry farming.

However, the cultivated worms impose particular requirements to environmental conditions. An optimum temperature for worm activity should be – 15-20 Celsius degrees. Low and high temperatures depress earthworms equally. Optimum humidity – 80-90%. Acidity of a substratum should be maintained at the level pH 6-7. Periodic hashing of substrata provides the cultivated worms with oxygen. Recycling after completion of processes of fermentation of organic chemistry is the most expedient [7].

Under optimum conditions for activity, it is possible to receive up to 2000 young individuals a year from couple of worms. Each adult individual postpones on one cocoon once in 5-7 days in which can be from 1 up to 3 eggs. Compost worms have high life expectancy which in certain cases can reach 16 years, against 3-4 years at their wild relatives. The adult worm consumes the amount of food equal to the mass of its body every day [8].

The purpose of the real researches consisted in determination of optimum parameters of the environment for quick adaptation of the Eisenia foetida worms to the processed substrata based on a bird's dung. On the bases of such data; it would be possible to improve methods of utilization, disinfecting, deodorization of a bird's dung by means of a vermicomposing.

According to a goal sat the studying of dynamics of the population, biomass, various age groups of population of worms, reproductive abilities of Eisenia foetida was provided using these data further we can judge about the adaptation abilities of a vermiculture to the substrata on the basis of a bird's dung. The results of studying can become a scientific basis for a further intensification of a vermiproduction.

2. Experimental research

The population of the Eisenia foetida (Sav.) worms was used for experiences. In the series of experiments in a series of all experiences the adaptation abilities of Eisenia foetida were studied (Sav.) to the substrata containing a bird's dung after 7-8 months of fermentation. When carrying out the experiments, except a substratum without excipient (a bird's dung of 100%), the mixes of a dung and peat were used, a dung and straw, a dung and a fallen leaves, a dung and cardboard and paper wastes, with the following ratio of ingredients: 90:10; 80:20; 70:30; 60:40; 50:50, and also the substrata containing a dung, peat and straw in the ratio 90:5:5; 80:10:10; 70:15:15; 60: 20:20% of all the volume.

Carefully mixed ingredients were put in plastic capacities of 1.5 dm\(^3\). In the prepared and humidified substratum the worms were populated at the rate of five adults of an individual on one capacity. The duration of an exposition made up 4.5 months. The experiment was made in three repetitions.
Up upon the termination of an exposition in the I series of researches dredging of worms was carried out from all volume of plastic capacity then carried out calculation of worms and defined Eisenia foetida population biomass.

In the work, the following ecology-physiological indexes were studied: a population density, number of the individuals who are at different stages of ontogenetic development, quantity and quality of young, adult individuals, quantity of cocoons, the sizes of a body of worms, reaction of worms to exogenetic factors.

Statistical processing of the obtained data with calculation of well-known indexes as average size (M), mean squared deviation (δ), error of average size (m), the coefficient of variation (Cv), criterion of reliability (tα), was carried out by the techniques given in the famous instructions and manuals [2].

3. Results and considerations

3.1 Adaptation of the Eisenia foetida worms (Sav.) to dung-peat substrata

The technology of a vermiproduction provides particular preparation of substrata for a vermicomposting. The most appropriate use of waste after the completion of organic fermentation processes. At a settling of population of the worms in substrata prepared from not fermented wastes, death of objects can occur because of the temperature increase and fuming of gases (methane, ammonia, hydrogen sulfide, etc.) which are formed as a result of rotting of a wastes is possible. Reduction of terms of preparation of substrata – is an important condition of an intensification of a vermiproduction. To the existing ways of acceleration of terms of preparation of a substratum we can correlate: crushing, homogenization and washing up from raw materials with water, aeration, neutralization of the environment, and use of absorbers (straw, rotten hay, sawdust, some peat and soil quantity). Practical application of these ways allows reducing at 3-30 times terms of preparation of substrata, in comparison with traditional [9].

Use of excipients at the preparation of substrata for a vermiculture gives the chance in the shortest possible time optimize such factors of the environment to admissible values as high pH, (depending on concentration of ammonia) and a lack of oxygen (a corollary of excess humidity).

Nowadays the main way of utilization of dung at a poultry production farms is composting of it in peat mixes. The technology of a composting of dung also provides the use of excipients, hashing, homogenization of a feedstock and storage before the end of processes of fermentation for some time. At the introduction in the conditions of poultry farms of a vermiproduction as substrata for worms, it would be possible to use, the dung-peat mixes intended for a composting. Usually at their preparation, components are mixed in the ratio 1:1. Higher content of peat in the composted mixes is inexpedient as it leads to delay in them biological decomposition process of organic matters, to decline in quality of composts and effectiveness of their action on plants. Studying of a possibility of use in a vermiproduction of substrata with the low content of peat was of special interest for us. In this regard, substrata were prepared for settling of the objects on the basis of chicken dung after 7-8 months of fermentation and peat. The option of a substratum I when the excipient was not used the weight was accepted for control – a dung of 100%. Substrata with a ratio of a dung and peat in ratios: 90:10% of volume – the II option; 80:20 – III option; 70:30 – IV option; 60:40 – V option; 50:50 – VI option.

The data characterizing adaptation abilities of Eisenia foetida (Sav.) are presented in this paper, grown up on dung-peat substrata. During experiments (4.5 months) the largest number of worms by the end of researches was recorded in a substratum with a ratio of ingredients 50:50 (the VI option) where the quantity of the worms found made up 53.33 individuals/dm³. In the V option (a ratio of ingredients 60:40), the number of population made 25.33 individuals/dm³, in IV (a ratio of ingredients 30:70) – 13.67 and in III (a ratio of ingredients 80:20), - 7.67 individuals/dm³.

The analysis of the data obtained at cultivation of worms on experienced substrata revealed a reliable difference in 28.0 individuals/dm³ between VI and V (P <0.05); in 39.7 individuals/dm³ between VI and IV (P <0.01) options. Between VI and III options the difference made up 45.66 individuals/dm³ (P <0.01). Density of worms in the III option was reduced on 6.00 individuals/dm³ lower, than in IV (P >0.1) and on 17.66 individuals/dm³ lower, than in V (P <0.05) options. However, by the end of an exposition in a substratum of the VI option we noted reduction of number of adult worms in unit volume approximately on 1 individual.
The greatest biomass of worms is recorded in the VI option of a substratum (with a ratio of components 50:50) where by the end of an exposition it made 3.78 g/dm$^3$. It is 0.24 g/dm$^3$ more, than in V and on 0.24 g/dm$^3$, than in the IV variants. However, because of reduction of number of adult individuals, the difference on this index is not significant.

The reliable distinctions on the number of the young worms also VI are recorded between III, between V and VI experienced options of substrata.

When carrying out researches we were also interested in the sizes of a body of worms. As data of the Ukrainian researchers testify, we can establish the age of the worms taking into account their length. So, the sizes of the Eisenia foetida worms in the first days (since a hatching from a cocoon) reach 1 mm; at the age of 7 days - 7 mm; 15 days - 12 - 15 mm; 90 days - 30 mm; 210 days – 60-80 mm. The maximum length of a body of adult worms is 80 mm [1].

We also considered this gradation of the linear sizes of the E. foetida worms depending on an age in the work. As the data show obtained by us, the length of a body of the found young worms fluctuated from 1 to 15 mm, and, what more young worms with a length of body from 8 to 15 mm in number of 5.67 individuals/dm$^3$ were found only in the VI variant of experience. In the same option of a substratum the largest number of juveniles with a length from 1 to 15 mm (44.33 individuals/dm$^3$) was found.

The greatest number of cocoons was revealed also in the VI option of a substratum (5.67 pieces/dm$^3$, against 2.67 in III and 4.67 - in IV and V options). The coloring of a body of worms in all options of experience was the characteristic of this kind and the age - brown-red at adult individuals, grayish - at juveniles with a length of body of 1 - 7 mm and pink - with a length of 8 - 15 mm.

In I and II experienced options of a substratum the condition for life activity of worms appeared to be unsuitable.

Thus, the results of our researches demonstrate that from the substrata containing a dung and peat in the ratio: 90:10; 80:20; 70:30; 60:40 and 50:50% of all the volume, the best for activity of the worms Eisenia foetida (Sav.) the substrata with the maintenance of 50% of a dung and 50% of peat appeared to be.

3.2 Adaptation of the Eisenia foetida worms (Sav.) to the substrata containing a bird's dung and fallen leaves

City parks, gardens and squares where in the fall there are fallen leaves gathered and taken out of city line leaves can become one of sources of the raw materials containing cellulose necessary for preparation of substrata. In this series of experiments as an excipient we used fallen leaves. When carrying out researches in the I option of a substratum the excipient was not used (a dung of 100%); in II, III, IV, V and VI options as a substratum used mix of a dung and fallen leaves in the ratios: 90:10; 80:20; 70:30; 60:40 and 50:50% of volume.

As the results of researches show (tab. 4) the increase in number of population of worms took place in substratum options from 50, 40 and 30% filler content. In these experimental options of a substratum the population of the Eisenia foetida for exposure time (4.5 months) increased, respectively, in 17.5; 16.3 and 12.1 times. So, in substratum option with the content of 50% of a dung and 50% of a fallen leaves the number of worms reached 87.67 individuals/dm$^3$ that is on 6.34 individuals/dm$^3$ more, than in option with a ratio 60:40 (P>0,1); on 27.34 individuals/dm$^3$ more, than in a substratum with a ratio 70:30 (P < 0.05); on 82.0 individuals/dm$^3$ more (P < 0.001), than in option with the content of 20% of fallen leaves.

In this option, the greatest biomass of worms is registered. By the end of an exposition it made up 5.97 g/dm$^3$ that is on 0.14 g/dm$^3$ larger (P >0.1), than in option 60:40; is on 1.19 g/dm$^3$ larger (P <0.1), than in option 70:30 4.38 g/dm$^3$ more (P >0.001), than in option 80:20.

The greatest number of cocoons was revealed in option with the content of 50% of a dung and 50% of fallen leaves – 6.67 pieces/dm$^3$. In options with a ratio of ingredients: 60:40% - 6.33 cocoons/dm$^3$; 70:30 - 5.67 cocoons/dm$^3$; 80:20 - 2 cocoons/dm$^3$. In substrata with the content of fallen leaves from 30 up to 50% young individuals were found with the length of their bodies which reached 30 mm. In substratum options with a ratio of a dung and fallen leaves 80:20 the length of a body of young
worms fluctuated from 1 up to 7 mm. The coloring of bodies of worms in all options of experience was the characteristic of this kind and the age.

The experimental options of a substratum with 10% of fallen leaves and without the excipient (a dung of 100%) turned out to be the unsuitable for cultivation of worms.

Thus, results of our researches demonstrate that from the substrata containing dung and fallen leaves in the ratio: 90:10; 80:20; 70:30; 60:40 and 50:50% of volume, the best for activity of the Eisenia foetida worms were the substrata with the content of 50% of a dung and 50% of fallen leaves.

4. Conclusion

Thus, the results of our researches demonstrate that from the substrata containing a dung and a cardboard and paper wastage in the ratio: 90:10; 80:20; 70:30; 60:40 and 50:50% of volume, were the best for activity of the Eisenia foetida worms substrata with the maintenance of 50% of a dung and 50% cardboard and paper.

The highest ecology physiological rates characterizing adaptation abilities of Eisenia foetida (Sav.), are recorded at cultivation them on substrata with high (more than 30%) filler content.

Based on the analysis of the obtained data it should be noted that for preparation of the substrata needed for cultivation of the Eisenia foetida worms it is possible to use a bird's dung after 7-8 months of fermentation in mix with an excipient. Peat, straw of grain crops, fallen leaves, and a cardboard and paper wastes well proved for use in this quality of an excipient by preparation of substrata for a population of a vermiculture. The best results are received in experiences when using as excipients of a fallen leaves and a cardboard and paper wastes.

However, at the organization of a vermiculture in the conditions of the production of poultry farms there can be difficulties, bound with the searching, collecting and transportation of a large amount of these raw materials that will lead to the additional financial expenses. The use of a fallen leaves and a cardboard and paper wastes can be expedient at preparation of substrata in small amounts, for cultivation of parent culture. For the industrial production and cultivation of worms in the conditions of poultry farms dung -peat, dung -straw and dung -peat-straw substrata are suitable.

The obtained data on definition of optimum ratios of the utilized chicken dung and an excipient in substrata for a vermiculture will promote the greatest possible realization of biotic potential of population of compost worms and, finally, an intensification of processing of recyclable wastes.

References
[1] Okhotnikov S I 2017 Bull of the MarSU 11 32-9
[2] Aguilera M L 2003 Purification of wastewater by vermicfiltration. Doctoral Thesis (University of Montpellier, France)
[3] Gupta R and Garg V K 2008 Journal of Hazardous Materials 162 430–9
[4] Arancon N Q et al 2004 Bioresource Technology 93 145–53
[5] Zhenjun S 2003 Vermiculture & verminprotein (China Agricultural University Press, China)
[6] Sinha R K and Valani D 2011 Vermiculture Revolution: The Technological Revival of Charles Darwin’s Unherlled Soldiers of Manking (Nova Science Publishers Inc, US)
[7] Bouché M B and Soto P 2004 Zoology and Ecology 3 1–13
[8] Haimi J and Huhta V 1986 BiolFertil Soils 2 23–7
[9] Edwards C A and Niederer A 2011 Taylor and Francis Group 323-34