Revista em Agronegócio e Meio Ambiente, Maringá (PR)
DOI: 10.17765/2176-9168.2019v12n3p1123-1141

ECONOMIC AND PRODUCTIVE PERFORMANCE OF EARTH WORMS *Eudrilus eugeniae* ON DIFFERENT DIETARY SOURCES

Fábio Silva do Carmo Lopes*
Elvino Ferreira**
Marlos Oliveira Porto***
Rute Bianchini Pontuschka****
Maykel Franklin Lima Sales*****
Jucilene Cavali******

ABSTRACT: *Eudrilus eugeniae* is a foreign species that is well adapted to captivity system adopted in Brazil. The objective was evaluate the productive and economic performance of earthworms in different substrates in two 100 days. In aim 1, the control substrate composed by cattle manure and forage grass (CMG) was supplemented with minerals (MM), soybean meal (SB) and ground corn (GC). The substrate containing GC was higher than in average weight (AW) of 127% and average weight gain (AWG) of 332% when compared to CMG substrate, superior in 193% AW and 252% AWG when compared to MM and 251% AW and 403% AWG when compared to the substrate with SB. In aim 2, were used different amounts of GC in substrate. The production of the substrate that contained 5% GC was superior in 9%, 12% and 20% with regard to those that had a composition of 10%, 15% and 20% of GC, respectively. As for the difference between the costs and the benefits of each of the substrates, the 5% GC substrate showed a positive return of BRL$ 35.32 for each BRL$1.00 invested and an economic performance that was 205% superior to MM, the second best option among substrates. 5% GC performed better and more efficient and economically viable production of worms.

* Mestrado programa de Pós-graduação em Ciências Ambientais (PGCA), Universidade Federal de Rondônia (UNIR), Brasil. E-mail: enge.pesca.fabio@gmail.com

** Doutorado em Agronomia (Ciências do Solo/UFRRJ. Docente, de Pesquisa e Extensão na Universidade Federal de Rondônia (UNIR), Brasil.

*** Doutor em Zootecnia pela Universidade Federal de Viçosa. Docente adjunto da Universidade Federal de Rondônia (UNIR); Diretor do Campus de Presidente Médici, Brasil.

**** Doutorado em Ciência dos Alimentos pela Faculdade de Ciências Farmacêuticas (USP). Docente no curso de Engenharia de Pesca da Universidade Federal de Rondônia (UNIR), Brasil.

***** Doutorado em Zootecnia pela Universidade Federal de Viçosa. Pesquisador A da Embrapa Acre, Brasil.

****** Doutora em Zootecnia pela Universidade Federal de Viçosa. Docente Adjunto III da Universidade Federal de Rondônia (UNIR), Brasil.

KEY WORDS: Corn; Economic indicators; Substrates; Worm breeding.

DESEMPENHO PRODUTIVO E ECONÔMICO DE MINHOCAS *Eudrilus eugeniae* EM DIFERENTES FONTES ALIMENTARES

RESUMO: *Eudrilus eugeniae* é a espécie exótica de minhoca que melhor se adapta aos sistemas de criação em cativeiro adotados no Brasil. Objetivou-se avaliar o desempenho produtivo e econômico das minhocas em diferentes fontes alimentares em dois ensaios de 100 dias experimentais. No Experimento 1, um substrato basal composto por fezes bovina e grama batatais (FBGB) foi suplementado com mistura mineral (MM), farelo de soja (FS) e grão de milho triturado (GC). O substrato contendo 5% de milho (GC) foi superior ($P < 0,05$) em peso médio e ganho de peso das minhocas em 127% e 332% ao tratamento controle FBGB, em 193% e 252% a mistura mineral e 251 e 403% ao tratamento contendo farelo de soja, respectivamente. No Experimento 2; foram usadas diferentes quantidades de GC no substrato. A produção do substrato que continha 5% GC foi superior em 9%, 12% e 20% em relação aos que tinham uma composição de 10%, 15% e 20% de GC, respectivamente. Na avaliação econômica da utilização dos diferentes substratos, o substrato GC apresentou retorno positivo de R$ 35,32 e maior retorno econômico relativo superior em 205% a MM (R$ 3,52). Observou-se retorno negativo de R$ -33,22 para o tratamento contendo 10% de GC, de R$ -12,36 para 15% de GC e R$ -39,98 para 20% de GC em relação ao tratamento contendo menor nível adicionado, considerando-se o custo dos ingredientes no mercado local aos 100 dias de avaliação. O tratamento com 5% de GC apresentou melhor desempenho sendo mais eficiente e economicamente viável à produção de minhocas.

PALAVRAS-CHAVE: Indicadores econômicos; Milho; Minhocultura; Substrato.

INTRODUCTION

Eudrilus eugeniae is an exotic, detritivore, epigenic species of earthworm in Brazil that is of great importance for the humification of various substrates (NETO et al 2013; NAJAR and KHAN 2013). It is among the best adapted species to the production system in captivity (VASANTHI et al 2013). Sold as bait for sports fishing and in dehydrated form as earthworm flour (CYRINO et al 2010), it is used as an alternative protein source in animal nutrition in the elaboration of animal feed ration, especially in fish farming (DEDEKE et al 2010; ANITHA and JAYRAAJ, 2012), besides the production of humus (NETO et al 2013; MEENATCHI et al 2009). According to Anitha and Jayraaj (2012) the protein content of the earthworm flour can vary between 68 and 82% depending on the substrate. It provides high digestibility of crude protein and shows excellent amino acid and fatty acids profiles.

Owing to its great potential, the species has been studied with regard to its nutritional parameters, to the physiological processes involved in vermicomposting (RAVINDRAN et al 2011; RAVINDRAN et al 2014), and to its genetic characteristics. Monebi and Ugwumba (2013), while comparing *E. eugeniae*substrates, reported better performance in cellulose compost substrate compared to the mix of soil and cellulose in a 12 week experiment. Depkat-Jakob et al (2012) compared the *eugeniae* genes to other species and observed genetic predisposition to increased production of methane, stimulated by ingested substrate. The authors highlight *E.eugeniae*´s increased production of methane in substrates with lower amounts of organic material, such as degraded soils.

The optimization of the vermicomposting system considers physical, chemical and biological variables (CORREA, 2007). The use of supplemental minerals, proteins and energy sources in the preparation of substrates, linked to appropriate forms of management, may increase production and microbial efficiency and reflect in a more productive and reproductive performance of earthworms, allowing them to express their full genetic potential.

The aim of this study was to evaluate the productive and economic performance of *E. eugeniae* on substrates containing different nutritional sources.

2 MATERIALS AND METHODS

The research was conducted in President Medici - Rondônia, Brazil, in geographic coordinates 11° 10’ 18’’ S, 61° 54’ 12’’W and altitude of 191 m, from Apr. 2011 to Dec. 2012 in two 100 day experiments, under CEUA number 19/2014. E. *eugeniae* earthworms, known as the African night crawler, previously adapted to the basal substrate containing cattle manure and forage grass (*Paspalum notatum*

Flügge) in the ratio of 4:1, were evaluated according to different sources of previously matured substrates. During maturation, after homogeneous mixing of the ingredients, the substrates were stored for 25 days in a covered area at ambient temperature in order to promote the pre-decomposition action of microorganisms so that earthworms might use substrates to the maximum extent. During maturation, the substrate was turned over weekly to promote aeration and to keep its moisture at 70%. In the maturation process, the average temperature of the substrates was of 44°C, adjusted by the addition of water and aeration of the substrate. We used 0.072 m^3 boxes made from recycled wood and caulked with clay. They had a lower opening for collecting the effluent which had a mesh to prevent the escape of worms.

Experiment 1: The experiment was conducted in the period between apr. and dec. 2011 by distributing 825 grams of *E. Eugeniae* in four different substrates according to a completely randomized design as follows: 1 - cattle manure and grass (CMG); 2 - CMG and mineral mixture (MM); 3 - CMG, mineral mixture and soybean meal (SB); 4 - CMG, mineral mix, ground corn grain (GC) (Table 1). Each substrate was distributed into six boxes, totaling 24 boxes or experimental units containing 10.1kg of matured substrate each. The production performance was obtained by the difference between the initial and final weights on the 50th and 100th day of the experiment, while the humus was replaced by new substrates of the same composition on the 50th day of the experiment (Table 1).

Table 1. Composition of the substrates and chemical composition and pH in percentages

(Continua)

	Substrates			
Ingredients	Cattle manure and grass (CMG)	Mineral mix (MM)	Soybean meal (SB)	Ground corn grains (GC)
	Proportions (%)			
Cattle manure	70.0	69.5	67.0	67.0
Grass	30.0	29.5	27.0	27.0
Soybean meal	-	-	5.0	-
Ground corn grain	-	-	-	5.0
Mineral mix[1]	-	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0

(Conclusão)

Ingredients	Substrates			
	Cattle manure and grass (CMG)	Mineral mix (MM)	Soybean meal (SB)	Ground corn grains (GC)
	Proportions (%)			
Ingredients	Quimical composition			
Dry matter	92.67	92.67	92.08	92.54
Nitrogen	1.13	1.13	1.54	1.14
pH	7.58	7.59	7.70	7.46
Carbon	60.60	60.05	61.22	61.49
Phosphorus	2.64	3.47	3.74	3.52
Calcium	4.55	4.959	4.88	4.79
Magnesium	1.89	1.967	1.98	1.90
Potassium	13.14	13.05	14.15	12.79

[1]Commercial mineral mixture assurance levels per kg: calcium 150g; cobalt 60 mg. cooper 1.300 mg. chromium 12 mg. sulfur 12 mg. phosphorus 75g; fluoride 750 mg. iodine 50 mg. magnesium 9g. manganese 1000mg. crude protein 100g. selenium 18mg. sodium 130g. zinc 5600mg.

Experiment 2: Conducted from Sept. to Dec. 2012, this experiment used the substrate that showed the best results during Experiment 1: substrate 4 (GC) containing CMG, mineral mix and ground corn grain. A total of 1238.1 grams of adult *E. Eugeniae* earthworms were distributed in four different substrates, each of them distributed into six boxes, totaling 24 experimental units containing 14.88 kg of matured substrate. All substrates contained cattle manure, forage grass and mineral mixture, with varying amounts of ground corn grain, namely 5%, 10%, 15% and 20% of the total ingredient composition of the substrate, as presented in Table 2.

Table 2. Composition of the substrates containing different levels of ground corn and chemical composition and pH of the substrates

	Levels of ground corn in the substrate			
Item	5%	10%	15%	20%
	Proportions (%)			
Cattle manure	67.0	64.5	62.0	59.5
Grass	27.0	24.5	22.0	19.5
Ground corn grain	5.0	10.0	15.0	20.0
Mineral mix[1]	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0
Ingredients	Levels of ground corn in the substrate			
	5%	10%	15%	20%
Dry matter	92.54	92.41	92.28	92.15
Nitrogen	1.15	1.17	1.18	1.20
pH	7.47	7.34	7.22	7.09
Carbon	61.49	62.93	64.37	65.81
Phosphorus	3.52	3.58	3.63	3.68
Calcium	4.80	4.63	4.47	4.31
Magnesium	1.90	1.84	1.77	1.71
Potassium	12.79	12.53	12.27	12.01

[1]Commercial mineral mixture assurance levels per kg: calcium 150g; cobalt 60 mg. cooper 1.300 mg. chromium 12 mg. sulfur 12 mg. phosphorus 75g; fluoride 750 mg. iodine 50 mg. magnesium 9g. manganese 1000mg. crude protein 100g. selenium 18mg. sodium 130g. zinc 5600mg.

The humidity level of the substrate in the boxes was monitored daily so as to keep a homogeneous substrate texture and not to produce excessive effluent (vermiwash). The boxes were arranged in four rows in a covered area and their places were swapped weekly to reduce the environmental effects on the substrates. The monitoring of the ambient temperature was performed daily at 5pm.

For both experiments, samples were collected from the ingredients used in the preparation of substrates and from the matured substrates (before vermicomposting). Samples were dried in a drying oven at 55°C for 72h00, processed and sent to Embrapa Acre's Laboratory of Animal Nutrition for a physical-chemical analysis of: dry matter (DM), calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+}), phosphorus

(P), carbon (C), nitrogen (N) and pH according to the methodology by Detmann et al (2012).

The economic indicators of both experiments show the difference between the costs and benefits of using different substrates in comparison with the control substrate. Were considered 100 days of experiment for the calculation of costs involving ingredients, such as cattle manure with forage grass, mineral mixture, ground corn grain and the purchase of 100 breeding worms weighing about tree grams each. From the sum of all costs involved, was calculated the relative economic return, which is obtained by calculating the weight gain divided by the cost of the substrate, with all ingredients in natural matter basis.

The experiment data were analyzed in a completely randomized design, considering each box as an experimental unit. Upon completion of the variance analysis, comparisons between the averages of the substrates were performed using Tukey's test ($\alpha = 0.05$).

3 RESULTS AND DISCUSSION

3.1 PRODUCTIVE PERFORMANCE OF *Eudrilus Eugeniae*

Among the substrates, *Eudrilus eugeniae* presented higher average weight ($p < 0.05$) for those containing mineral mix (MM) (131,97 g) and ground corn grains (GC) (163.20 g), followed by the substrates with SB and by the control substrate containing cattle manure and forage grass (CMG) (Table 3).

Table 3. Average weight and average weight gain of *E. eugeniae* earthworms for substrates on the 50th and 100th experimental days

	Substrates				
Ingredients	Cattle manure and grass (CMG)	Mineral mix (MM)	Soybean meal (SB)	Ground corn grains (GC)	VC (%)
	Assessment on the 50th experimental day				
Average weight (grams)	73.57 c	131.97 ab	97.18 bc	163.20 a	24.69
Average weight gain (grams)	39.17 c	97.57 ab	62.78 bc	128.80 a	35.03
Ingredients	Assessment on the 100th experimental day				
Average weight (grams)	75.83 b	89.02 b	68.50 b	172.12 a	35.46
Average weight gain (grams)	41.43 b	54.62 b	34.10 b	137.72 a	53.61

$p<0.05$.

The substrate containing only MM did not differ significantly ($p>0.05$), but presented 24% lower average weight rate and 32% lower average weight gain compared to the substrate containing GC. The MM substrate did not differ from the substrate containing SB ($p>0.05$), showing no significant differences in average weight (97.18 g) and average weight gain (62.78 g) did not differ ($p>0.05$) from the control substrate (CMG) which showed average weight and weight gain of 73.57 g and 39.17 g, respectively.

To different sources avaluated, the inclusion of energy and protein sources to the substrate that contained only cattle manure and forage grass, commonly used in the creation of annelids, was important for the most productive performance of *E. Eugeniae* earthworms in the first 50 days of experiment. The low production obtained with the exclusive use of the CMG substrate may be related to the inability of the worms to extract nutrients from the fiber fraction of the substrate, especially cellulose, limiting their ability to obtain energy. According to Garg and Kaushik (2005) substrates having high levels of pulp were not suitable for vermicomposting for the *Eisenia foetida* species, in a setting where the proportion of solid waste from textile industry was greater than 40%.

In the assessment performed on the 100th day, the substrate containing corn, showed the best average weight for *E. eugeniae* worms (172.12 g), being 127% higher ($p < 0.05$) than the CMG control substrate, 193% higher than MM and 251% higher than the SB substrate (Table 3). Also, the medium average weight gain observed in the GC substrate (137.72 g) was superior ($p < 0.05$), proving to be 252% higher that MM, 332% higher than CMG and 403% than SB. In other words, the average weight and average weight gain in the GC substrate were superior, even when compared to the average of all the other substrates that were 77.78 g for average weight and 43.38 g for average weight gain. Thus, corns added with minerals supplied via mineral mixture, provided a better supply for *E. eugeniae's* nutritional requirements, favoring their performance potential. This result indicates that the minerals and energy coming from corn starch are decisive factors for the performance of these annelids, and the inclusion of these nutrients in the preparation of substrates is necessary when aiming at intensive crop production.

It is noteworthy that the substrate containing soybean meals (SB), presented high moisture retention, foul odor (putrefaction) and the presence of larvae in the final period of evaluation. The protein level of soybean, coupled with high ambient temperatures of 28.5°C in average during the 100 days, may have favored the rise of the pH of the substrate. According to Neto et al (2013), the climatic influence of the environment can lead to changes in substrate temperature. This may have been a factor limiting the activity of *E. eugeniae,* since humidity promotes greater activity of microorganisms, especially undesirable ones as the genus *Clostridium*. High moisture causes the water to occupy empty spaces of the mass preventing the free passage of oxygen, what can cause anaerobiosis in the medium. On the other hand, low moisture levels inhibit microbial activity, decreasing the stability of the substrate.

The type of organic compound used in the substrate promotes fluctuations in moisture, in enzyme activity, especially for cellulase enzymes, causing a thermal effect in humus (CENCIANI, et al 2008). According to Meenatchi, et al (2009), bacterial and fungal population vary with the type of food and the species of earthworm.

The data obtained from Experiment 2 with different amounts of corn showed no interaction ($p > 0.05$) between the amounts of corn on the substrate and the days of evaluation for any of the *E. eugeniae* performance variables. From 75th day had a great reduction ($p < 0.05$) in body weight, weight gain and average daily gain (ADG), a reduction of the population of earthworms and considerable increase of larvae and insects accompanying the increased amounts of ground corn in the substrates (Table 4). The different amounts of corn from 75th day had a great reduction of the population of earthworms and considerable increase of larvae and insects accompanying the increased amounts of ground corn in the substrates because starch undergoes enzymatic hydrolysis breaking molecular bonds and producing glucose molecules, what becomes food for fungi, bacteria and insect larvae, confirming the information by Cenciani et al (2008). According to Moraes et al (2012) there is a rapid biological process of insect larvae on substrates of agricultural wastes that are rich in starch, turning them into protein and fat, producing the malodorous humus. This corroborates what we observed visually in our experiment. (Table 4).

Table 4. Average weight and average weight gain of *E. eugeniae* earthworms for the substrates containing different group corn levels (Continua)

Variables	Ground corn substrates				VC (%)	P-value	Regression equation	R^2
	5%	10%	15%	20%				
	Initial assessment							
Average weight (g)	51.7	51.5	51.5	51.6	1.02	-	-	-
Number of individuals	43	42	41	42	8.93	-	-	-
	Assessment on the 50th day							
Average weight (g)	172.1	175.0	151.0	163.0	15.3	0.2777	Y=165.27	-
Weight gain (g)	120.4	123.5	100.0	111.4	22.2	0.2807	Y=113.82	-
Daily average gain (g)	2.41	2.47	1.99	2.22	22.5	0.2756	Y=2.27	-
Number of individuals	201	177	159	182	19.1	0.2610	Y=179.75	-
	Assessment on the 75th day							
Average weight (g)	354.5	347.5	327.2	305.5	12.3	0.0025	Y=400.45833-5.3430*M	72,3
Weight gain (g)	302.7	296.0	275.6	253.9	15.4	0.0024	Y=348.8000-5.33733*M	98,0
Daily average gain (g)	4.03	3.94	3.67	3.38	15.1	0.0025	Y=4.648333-0.07103*M	97,8
Number of individuals	992	1021	887	709	17.4	0.0064	Y=1118.0833-17.8533*M	98,8

(Conclusão)

Variables	Ground corn substrates				VC (%)	P-value	Regression equation	R^2
	5%	10%	15%	20%				
	Assessment on the 100th day							
Average weight (g)	255.7	175.2	230.8	164.7	25.0	0.0109	Y=277.69166-5.35200*M	52,9
Weight gain (g)	204	123.7	179.2	113.1	33.0	0.0108	Y=226.03333-5.34633*M	49,8
Daily average gain (g)	2.04	1.24	1.79	1.13	33.0	0.0110	Y=2.260000-0.0534400*M	50,1
Number of individuals	688	598	738	614	21.2	0.7549	Y=659.5	-

*Significant 5% by Tuckey-test

The number of individuals and the performance, as given by the average weight, weight gain and ADG varied ($p < 0.05$) along the experiment (Table 5). A considerable increase in reproductive activity was observed, reaching a maximum number of individuals on the 72nd day, and productive activity as the performance index of earthworms reached its maximum on the 76th day of vermicomposting. Subsequently, a reduction in all evaluated parameters was perceived up to 100 days of evaluation. The maximum presence of young worms and adults (894 worms) occurred on the 75th days. This contributed to a maximum result of 333g of body mass of earthworms, meaning 282 g.75 day's gain or 3.7 g.day results. According to Dominguez (2004) the *Eudriliae* family species reaches sexual maturity at 50 days. They multiply themselves by 0.5 cocoons per day with 2.5 earthworms per cocoon, hatching in 12 to 16 days. Such information corroborates the results of this study as on the 75th day the presence of young worms was noted in addition to the adult ones, fact confirmed by the total number of worms found in the substrates (Table 5).

Table 5. *Eudrilus eugeniae* earthworms weight, weight gain and daily average

Variables	Composting period				VC (%)	P-value	Regression equation	R2
	Initial	50th day	75th day	100th day				
Average weight (g)	51.58	165.28	333.67	210.79	21.86	<0.0001	Y=41.6163+5.34920-0.03358*M	86.0
Weight gain (g)	-	113.70	282.08	159.20	25.90	<0.0001	Y=1096.854+35.8616-0.2330*M	69.0
Daily average gain (g)	-	2.27	3.76	1.60	23.74	<0.0001	Y=11.6608+0.42486-0.00292*M	70.0
Number of individuals	42.0	180.04	894.91	659.62	26.45	<0.0001	Y=4.34356+8.38296-0.00700*M	90.0

*Significant 5% by Tuckey-test

On the 75th day of the experiment it was possible to spot the presence of earthworm eggs and larvae as well as high mobility young and adult earthworms, besides intense reproductive activity. Also according to visual assessments, on the 100th day the number of adult individuals had decreased and the number of juveniles had increased. From the 75th day on, the weight, weight gain and daily average gain were affected ($p< 0.05$) by higher levels of corn in the substrate. The reduction of the number of adult individuals may be related to natural mortality of earthworms at the end of the cycle (DOMINGUEZ, 2004), and to the reduction of the weight of the worms when they enter the reproductive phase, a fact confirmed by both the reduction in weight of earthworms (Table 5) as well as by visual assessment, when it was no longer possible to find large, lush earthworms, but only smaller, pale, with open clitella, reproductive phase worms, and some worms mating.

After the 75th day of experiment, the 5% ground corn composition substrate, when compared to the other substrates containing ground corn, showed a reproduction rate that was 9.58% higher than the one containing 10% ground corn, 12% higher than the 15% ground corn, and 21% higher than the substrate containing 20% ground corn, and reached maximum productivity due to rapid rates of growth, reproduction and sexual precocity. The temperature of the humus in this study stabilized at around 29 °C after 60 days of vermicomposting (Figure 1). The production with *E. eugeniae* earthworms was of 9.25 kg m^3 at 75 days and 5.85 kg m^3 at 100 days of vermicomposting. (Figure 1).

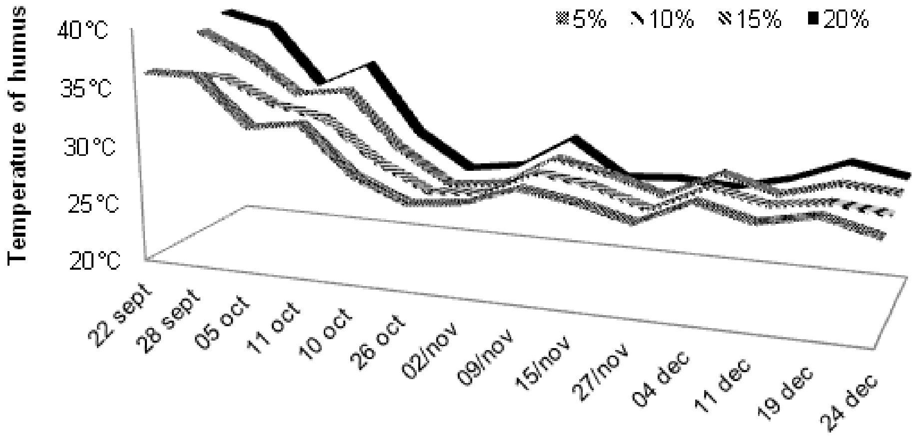

Figure 1. Temperature curve (Celsius) of the E. eugeniae humus for the different levels of corn in substrates

After 75th day on, the weight, weight gain and daily average gain were affected by higher levels of corn in the substrate ocurred reduction of the number of individuals by the 100th day may be related not only to the natural mortality of adult worms that governs 5% of the original population during the life cycle (PERESSINOTO, 2003), but also to the physical saturation of the medium, as it was possible to see, from the 75th day onwards, a higher number of young earthworms. According to Nadolny (2009) and Dominguez et al (2001) reductions in reproduction and death of breeding earthworms due to overcrowding and/or competition for food may occur. The main decomposers of organic matter during composting are bacteria, fungi and protozoa that, besides earthworms, produce material in the substrate. It is important to highlight that, according to visual observation, the total decomposition of dead breeding earthworms took place in a maximum of 24h00 hours.

E. eugeniae earthworms present excellent reproductive rates when under suitable conditions such as pH 6 to 8; humidity at 70% and temperature of 20ºC to 28ºC (VASANTHI et al 2013). The temperature of the humus in this study stabilized at around 29ºC after 60 days of vermicomposting consider that the ideal temperature for growth and reproduction of *E.eugeniae* should be 26 ± 1 ºC (VASANTHI et al 2013). Dominguez et al (2004) reported that high temperatures (above 30ºC) promoted microbiological activity in the vermicomposting system that tended to consume the available oxygen and thus had negative effects on earthworm activity.

3.2 ECONOMIC INDICATORS OF PRODUCTION

Some economic indicators can show the difference between the costs and benefits of each of the different substrates as compared to the control one, which contained only CMG.

In relation to economic indicators of production the GC substrate provided the best supply for the nutritional needs of *E. eugeniae* worms, favoring their potential performance. The practice to supplement the substrate with alternative food sources aims not only at maximizing production performance through increased efficiency of the substrate, but it also aids in the identification of viable alternative food sources in the region that can be included into the composition of the substrate so as to reduce the cost of purchase and transportation (FIGUEIREDO et al 2007).

The average weight gain of *E. eugeniae* earthworms for the substrates were of 41.43 g for CMG, 54.62 g for MM, 34.10 g for SB and 137.72 g for GC, during the 100 days of assessment. Were observed a positive rate of return of 3.52 (understood as an economic return of BRL$ 3.52 for each BRL$ 1.00 invested) for the substrate containing MM and 35.32 for the one containing GC during Experiment 1 (Table 6). It´s show the relationship between the economic viability of systems by adding nutritional sources to the substrate and the cost of the substrate. The substrates containing MM and GC were able to obtain positive rates of return (Table 6), but the one that obtained the highest rate of return was the GC substrate (35.32).

Table 6. Economic indicators of substrates in comparison with the control substrate containing cattle manure and grass (CMG) (Experiment 1) and with different levels of ground corn in comparison with the substrate containing 5% ground corn (Experiment 2)

Item	Substrates[5]		
	Mineral mix	Soybean meal	Ground corn grain
Differential gain compared to CMG (g)[1]	79	-44	578
Total cost of CMG (BRL$)[1, 2]	1.28	1.28	1.28
Cost of substrates (BRL$)[1, 2]	1.73	2.92	2.36
Cost of 100 grams of earthworms[3]	6.63	6.63	6.63
Differential in cost of substrate (BRL$)	0.45	1.65	1.09
Differential in gains in 100 days (BRL$)	5.25	-2.92	38.32
Economic return in 100 days (BRL$)	3.52	-5.84	35.96
Rate of return[1,4]	11.56	-1.77	35.32
Item	**Substratos[5]**		
	10%	15%	20%
Differential gain in 100 days (g)[1]	-482	-148	-546
Total cost of the 5% corn amount in 100 days (BRL$)[1, 2]	4.59	4.59	4.59
Cost of substrates 100 days (BRL$)[1, 2]	5.85	7.12	8.38
Cost of 100 grams of earthworms[3]	6.63	6.63	6.63
Differential in cost of substrates (BRL$)	1.26	2.53	3.79
Differential in gains in 100 days (BRL$)	-31.96	-9.83	-36.19
Return in 100 days (BRL$)	-33.22	-12.36	-39.98
Rate of return[1,4]	-25.31	-3.89	-9.56

[1]Considering 100 days of experiment; [2]Cost of ingredients (BRL$ per kg): cattle manure with grass: BRL$ 0.09; mineral mixture: BRL$ 1.86 (Experiment 1) and BRL$ 1.60 (Experiment 2); soybean meal: BRL$ 1.00; ground corn beans: BRL$ 0.55. [3]Considering the cost of 100 earthworm matrices weighing around 3 grams each = BRL$ 19.90; [4]Rate of return = Differential gain in 100 days BRL$ ÷ Differential of substrate cost (BRL$). [5]Considering 25kg of ingredient mixture natural materials without addition of water in substrates. [5]Considering 25kg of ingredient mixture in Experiment 1 and 50kg of ingredient mixture Experiment 2 in natural materials without addition of water in substrates.

Therefore, the substrate containing ground corn, despite having higher cost

(BRL$ 2.36) compared to the control substrate (BRL$ 1.28), provided financial advantages owing to higher production, justifying the addition of energy sources in the preparation of the substrate. There is a direct relationship between the economic viability of systems by adding nutritional sources to the substrate and the cost of the substrate. This means that it was 205% higher than the rate of return obtained with the MM substrate (11.56).

As for Experiment 2 and the substrates containing different amounts of ground corn, economic indicators show the difference between the costs and benefits of each substrate compared to the 5% ground corn one, as follows. A negative rate of return of -33.22 was obtained for the substrate containing 10% corn; -12.36 for the 15% corn; and -39.98 for the 20% corn, as can be seen in Table 6.

Adding minerals to the basal substrate (cattle manure and forage grass) proved to be an important nutritional supplement in the expression of the genetic potential as well, towards better production and economic performance of the worms. It is noteworthy that the purchase prices of inputs and the price of breeding earthworms in the market are determinant factors for the profitability of the production system.

The inclusion of ground corn grains in the preparation of the substrate provided the highest economic return for the *E. eugeniae* production system. The inclusion of this energy source to the substrate is, thus, recommended.

4 CONCLUSIONS

The energetic substrate containing grain of corn crunched, besides minerals, showed the highest average weight and weight gain of earthworms *Eudrillus eugeniae* to 100 days of production.

The mineral source is required in the substrate preparation source-independent protein or energy being.

The 5% of ground corn grain inclusion in substrate showed highest number of earthworms, better productive performance and economic viability in the production system.

5 ACHNOWLEDGEMENTS

The authors thank CNPq and Elciomar Silva Farm fishier for the financial support given to this research and mothers *E. eugeniae* worms.

REFERENCES

ANITHA, J.; JAYRAAJ, I.A. Nutritional and antioxidant evaluation of earthworm powder. **Int. Res. J. Pharm**. v.3, p.177-180. 2012.

CENCIANI, K.; FREITAS, S.D.O.S.; CRITTER, S.A.M. *et al.* Microbial enzymatic activity and thermal effect in a tropical soil treated with organic materials. **Sci. Agr**. (Piracicaba, Braz.), v.65, p. 674-680, 2008.

CYRINO, J.E.P.; BICUDO, A.J.A.; SADO, R.Y. Fish farming and the environment: the use of environmental friendly feeds in fish culture. **Rev. Bras. Zootec**. v.39, p. 68-87, 2010.

CORRÊA, R. S.; FONSECA, Y. M. F.; CORRÊA, A. S. Production of agricultural biosolid by composting and vermicomposting sewage sludge. **Rev. Bras. Eng. Agr. Ambient**. v.11, p. 420-426, 2007.

DEPKAT-JAKOB, P. S.; SINDY, H.; SCHULZ,K. *et al.* Emission of Methane by Eudrilus eugeniae and Other Earthworms from Brazil. **Appl. environ. microbiol**. v.78, p.2014-2019, 2014.

DOMINGUEZ, J. State of the art and new perspectives on vermicomposting Research. In: EDWARDS, C. A. **Earthworm ecolog y**. 2. ed. Florida: CRC Press. 2004, p. 401-424.

DOMINGUEZ, J.; EDWARDS, C. A.; ASHBY, J. The biology and population dynamics of *Eudrilus eugeniae* (Kinberg) (Oligochaeta) in cattle waste solids. **Pedobiologia**. v.45, p. 341-353, 2001.

DEDEKE, G.A.; OWA, S.O.; OLURIN, K.B. Macromineral profile of four species of earthworm *hyperiodrilus africanus, Eudrilus eugeniae, libyodrilus violaceus* and *alma millsoni* from Nigeria. **Curr. Res. J. Biol.Sci.** v.2, p.103-106, 2010.

DETMANN E.; SOUZA, M.A.; VALADARES FILHO, S.C. *et al.* **M**étodos para Análise de Alimentos**.** INCT - Ciência Animal. Viçosa: UFV. 214 p. 2012.

FIGUEIREDO, D.M.; OLIVEIRA, A.S.; SALES, M.F.L. *et al.* Economic analysis of four supplementation strategies for growth and finish beef cattle in a pasture-supplement system. **Rev. Bras. Zootec**. v. 36, p.1443-1453, 2007.

GARG, V.K.; KAUSHIK, P. Vermistabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm *Eisenia foetida*. **Bioresour. Technol**. v. 96, p.1063-1071, 2005.

MEENATCHI, R.; GIRADDI, R.S.; AWAKNAVAR, J.S. *et al.* Effect of food substrates and earthworm species on microbial activity in vermicompost and vermiwash. Karnataka. **J. Agri. Sci**. v. 22, p.1020-1022, 2009.

MONEBI, C. O.; UGWUMBA, A. A. A. Utilization of the earthworm, Eudrilus eugeniae in the diet of Heteroclarias fingerlings. **Int. J. Fish. Aquac**. v. 5, p.19-25, 2013.

MORAES, M.J.; OLIVEIRA FILHO, D.; MARTINS, J.H. *et al.* Electric signals for separation of earthworms (*Eudrilus eugeniæ*). **Rev. Bras. Eng. Agr. Ambient**. v.16, p.1137–1142, 2012.

NAJAR, I.A.; KHAN, A.B. Management of fresh waterweeds (macrophytes) by vermicomposting using *Eisenia fetida.* **Environ. Sci. Pollut. Res**. v.20, p. 6406-6417, 2013.

NETO, A.A.; PERON, A. J.; BRITO, T. R. C. *et al.* Reproduction and development of african night crawler earthworms (*Eudrilus eugeniae*) in Sewage Sludge produced in the city of Gurupi, State of Tocantins. **J. Biotech. Biodivers**. v.4, p. 216-221, 2013.

NADOLNY, H.S. **Reprodução e Desenvolvimento das Minhocas *Eisenia andrei* e *Eudrilus eugeniae* em Resíduo Orgânico Doméstico**. 2009. Dissertação (Mestrado em Ciência do Solo) - Federal University of Parana, Curitiba, 2009.

PERENISSOTO, A. **Pratic manual of earthworm's culture**. 4. ed. Anhumus Agroambiental, 2003.

RAVINDRAN, B.; SRAVANI, R.; MANDAL, A. B. *et al.* Instrumental evidence for biodegradation of tannery waste during vermicomposting process using *Eudrilus eugeniae*. **J. Therm. Anal. Calorim,** v.111, p. 1675-1684, 2011.

RAVINDRAN, B.; CONTRERAS-RAMOS, S.M.; WONG, J.W. *et al.* Nutrient and enzymatic changes of hydrolyzed tannery solid waste treated with epigeic earthworm *Eudrilus eugeniae* and phytotoxicity assessment on selected commercial crops. **Environ. Sci. Pollut. Res. Int**. v. 21, p. 641-51, 2014.

VASANTHI, K.; SENTHILKUMARI, M.; CHAIRMAN, K. *et al.* Influence of temperature on growth and reproduction of earthworm *Eudrilus eugeniae*. **Int. J. Curr. Microbiol. Appl. Sci**. v.7, p. 202-206, 2013.

Recebido em: 13/04/2016

Aceito em: 24/05/2018