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Use of redworms (*Perionyx excavatus*) to manage agricultural wastes and supply valuable feed for poultry

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Abstract

Perionyx excavatus, cultured in Vietnam in early 1990s, showed an important role in managing organic wastes and supplying a very nutritious feed for animals. To develop vermiculture in practice, four treatments of different substrates including 100% fresh cattle manure (CM); cattle manure + pig manure in 50:50 ratio (CPM); cattle manure + pig manure + rice straw in 50:40:10 ratio (CPMRS) and pig manure + rice straw in 90:10 ratio (PMRS) were prepared to examine worms' growth and their decomposition efficiency. All substrates were composted 45 days before feeding to worms.

The result showed that cattle manure (CM) was the best substrate for worm growth (biomass gained 713 g after 45 days or 242.6% of growth rate). The worm biomass achieved in CPMRS and PMRS treatments was significantly lower than that in CM treatment. As compared to primary substrates, vermicomposts exhibited an excellent result with a great increase in the amount of total P (0.3 – 0.6%), total K (0.09 – 0.23%), Ca (0.51 – 0.79%) and a decrease in N-NH_3 and N-NH_4^+

A study was carried out to evaluate the influence of feed supplemented with worms on the growth and meat quality of broiler chickens (n=148). Starting at 4 weeks old the chickens were divided into a control group and three experimental groups corresponding to worm levels in the diet of 1, 1.5 and 2% on a dry matter basis according to a completely randomized design.

Chicken fed the diet supplemented with 2% worms had the highest live weight at 10 weeks (1925 g/head vs 1823 g/head for the control). Percentage of breast and leg meat was also higher than in the control group. Chickens in the three worm groups had better FCR. The different levels of red worm supplementation did not affect meat quality (pH, color, and the rate of dehydration after storage and processing).

Key words: chicken, growth, vermicomposting, vermiculture

Introduction

The life cycle and the potential of *Perionyx excavatus* for breaking down organic wastes and turning it into rich soil amendment has been documented by various authors under controlled conditions (Kale et al 1988; Reinecke and Hallatt 1989, Hallatt et al 1990; Reinecke et al 1992; Hallat et al 1992). Vermicomposting is considered as an eco – biotechnological process that transforms energy-rich and complex organic metters into stabilized humus-like product (vermicompost), which had lower levels of contaminants and higher nutrients and without impacting the environment (Suthar and Singh 2008). Besides, worm tissue contains 50–75% protein and 7–10% fat (Patra and Dash

1973). Hence vermiprotein has been used as a feed additive in commercial poultry production and fisheries (McInroy 1971; Sabine 1983; Edwards 1983). In Vietnam, *Perionyx excavatus* has been cultured since 1990s and developed nationwide. But little is known about the compost using this species and the efficiency as well as influence on quality of products when feeding animals. This paper aims to evaluate the growth and decomposition efficiency of *Perionyx excavatus* cultured in different treatments of organic wastes. Besides, the performance and meat quality of chickens fed by diets supplemented with different levels of worms were also examined. The outputs of this research will provide farmers the basis for vermiculture and usage of worms as feed for chicken.

Materials and methods

Experiment 1: Earthworm growth

Manure of cattle and pig and rice straw were prepared for four treatments, including 100% fresh cattle manure (T1); cattle manure + pig manure in 50:50 ratio (T2); cattle manure + pig manure + rice straw in 50:40:10 ratio (T3) and pig manure + rice straw in 90:10 ratio (T4). All substrates of T2, T3, T4 treatments were composted in 45 days before feeding worms. A completely randomized design was conducted to examine growth rate and decomposition efficiency of worms according to four treatments of substrates. In average of 500 g fresh weight of *Perionyx excavatus* were placed in each experimental block (1: 0.5: 0.5 m). Worms were totally harvested and weighted after 45 days to determine weight gain and growth rate.

Chemical analysis of substrates and vermicompost

Total N were measured by Kjeldahl method. Samples were treated with a mixture of concentrated sulphuric acid (H_2SO_4, d=1.84) and salicylic acid ($C_6H_4(COOH)(OH)$) and some catalysts (copper sulphate + selenium, potassium sulphate). For the determination of total P, samples were digested with concentrated perchloric acid ($HCLO_4$ 70%) and a colorimetric method based on vanadomolybdate was proposed. Quantitative analysis of some exchangeable cations in an extract (K, Na and Ca) were carried out with the technique of flame atomic emission spectrophotometry FAES. NH_4^+ was examined with Nessler (K_2HgI_4). NO_3^- was determined by Cataldo method. These analyses was conducted at the Central Lab of Land and Water Resource Management, Faculty of Land and Environment, Hanoi University of Agriculture

Experiment 2: Supplement of worms in diets of chickens

Broilers (Ho x Luong Phuong) were raised at poultry farm of Hanoi University of Agriculture using standard practices. Starting at 4 weeks old, a total of 148 broilers were divided into a control group and three experimental groups corresponding to worm levels in the diet of 1, 1.5 and 2% on a dry matter basis according to a completely randomized design. Birds were fed by a commercial corn - rice bran/starched rice based diets according to NRC guidelines, had access ad libitum to feed and water until processing (at 10 wk of age). From 22 to 42 days of age, chickens were received grower feed with 19% protein and 5% fat. From 43 days of age to finishing age (10 wk), chickens were fed with ration having 16% protein and 6% fat. Worms were supplied in the diet 2 times per day (in the morning and afternoon) by fresh form

Measurements

The birds were weighed at 4, 5, 6, 7, 8, 9 and 10 wk of age to determine the growth rate. Average body weight (g) and feed intake (kg) were calculated from pen data. The average feed conversion (kg/kg) per pen was calculated for the entire duration of the study (7 days) by dividing the total feed consumption during the study by the total body weight of the surviving broilers in the pen. At the end of experiment, 16 birds (with no visible abnormalities) were randomly selected from four groups and slaughtered by severing the jugular, scalding, plucking, eviscerating and data on carcass yield including carcass weight, deboned breast meat yield, thigh yield, abdominal fat, and relative weights of liver and heart (calculated as % of carcass weight without giblets) were recorded. Breast muscles were removed from the carcass at 30 min post mortem and stored at 2 to 4°C. The breast fillets were analyzed for pH (24 and 72 h PM) using a pH meter (Model 240, IQ Scientific Instruments Inc., San Diego, CA) and a piercing probe (pH 26-SS, IQ Scientific Instruments, Inc.). Color measurements (L* = lightness, a* = redness, b* = yellowness) were determined at 24 and 72 h PM with a colorimeter (Choma Meter Model CR-200, Minolta Corp., NJ, C.I.E. 1978) on the medial surface of each fillet by averaging 5 readings. Drip loss during storage (24 and 72 h PM at 2-4^{0}C in plastic bags) was calculated as weight of moisture loss divided by weight of the original meat. Breast fillets were then individually weighed and cooked on aluminum trays at 85 ^{0}C for 45 min in steam. Samples were cooled to room temperature for 15 min and were reweighed to calculate cooking loss as percentage of weight loss

The data were analyzed by analysis of variance (SAS Institute 1994) with significance assessed at the level of $P < 0.05$.

Results and discussion

Worm growth

The growth rate of worm depended much upon type and quality of substrates. In this study, biomass gain varied substantially among different treatments. As summarized in table 1, *Perionyx excavatus* exhibited highest weight gain (713 g after 45 days) or growth rate (243%) when feeding by 100% fresh cattle manure. These results were significantly higher than those of other treatments ($P<0.05$). In general, cattle manure has lower ammoniac levels (975 mg/kg) than that in pig manure (3293 mg/kg). So, worms developed better in cattle manure than in pig manure. However, farmers also applied T2 treatment (cattle manure + pig manure in 50:50 ratio) in case plenty of pig waste since also produce quite high of worm biomass.

Table 1. Worm biomass gain and growth rate

Parameters	T1 (n=4)	T2 (n=4)	T3 (n=4)	T4 (n=4)
Initial weight, g	500	500	500	500
Finished weight (after 45 days, g)	1213	937	750	700
Net weight gained, g (Mean ±SEm)	713 ± 12.6^a	437 ± 37.5^{ab}	250 ± 61.2^b	200 ± 61.2^b
Growth rate, %	242.6	187.4	150	140

Mean values followed by different letters are different (ANOVA, Duncan multiple-ranged test; P < 0.05)

Decomposition efficiency of earthworms

>From earlier studies, it is evident that vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants. At the end of the experiment, the total N content in vermicompost showed a slightly decrease as compared with it in the initial materials. However, most of N in waste solids was transformed into nitrates (NO_3^-), which easier for plants to uptake

than nitrogen form in organic matters. As showed in table 2, the amount of nitrates in vermicompost was much higher than that in initial substrates (increase about 38.0 to 216 mg/kg in four treatments).

After vermicomposting, all vermibeds showed higher concentrations of total P (mostly available P) than initial materials. The increase of total P was highest in T5 treatment (increase by 0.6%) followed by T1 (0.41%) and T3, T2 treatment (0.33% and 0.3%, Table 2). According to Lee (1992) the pass of organic residues through the gut of earthworm results in phosphorous converted to forms which are more available to plants. The release of phosphorous in forms available to plants is mediated by phosphatages, which are produced in earthworm's gut. Further release of P may occur by P-solubilizing bacteria in casts. Recently, Suthar reported about 36–115% increment in available P content, after inoculation of wastes (some agriculture and municipal waste resources) with earthworms. Earthworm gut flora provides enzymes required for P metabolism. These enzymes release phosphorous form ingested waste materials (Suthar 2007).

Potassium increase for different treatments was registered in the order: T4 (0.23%) > T1 (0.20%) > T2 (0.11%)> T3 treatment (0.09%) after 45 days of vermicomposting (Table 2). Delgado reported higher potassium content in vermicompost produced from sewage sludge (Delgado et al 1995). The present result is similar to those by Suthar (2007), who reported excellent increase in exchangeable content in vermicompost.

Table 2. Chemical composition of fresh/composted substrates (FS/CS) and vermicompost (VC)

Parameters	Fresh pig manure	T1 (100)		T2 (50-50)		T3 (50-40-10)		T4 (90-10)	
		FS	VC	CS	VC	CS	VC	CS	VC
Dry matter, %	33.9	19.2	23.0	30.0	32.9	34.2	28.4	38.0	31.3
Total N, %	1.87	1.73	1.55	1.83	1.01	1.54	1.24	1.34	1.05
Total P, %	1.01	0.84	1.25	0.83	1.13	0.87	1.20	0.86	1.46
K, %	0.57	0.63	0.83	0.56	0.67	0.52	0.61	0.43	0.66
Ca, %	1.24	0.89	1.60	1.15	1.66	0.95	1.74	1.27	1.92
Mg, %	0.77	0.59	0.77	0.72	0.71	0.66	0.75	0.67	0.80
$N-NO_3^-$, mg/kg	41.45	84.52	124	16.67	791	20.6	236	16.6	224
$N-NH_3$, mg/kg	3293	975	107	597	651	115	64.9	133	55.1
$N-NH_4^+$, mg/kg	4234	1254	137	768	83.7	148	83.44	171	70.8

The results in table 2 were also indicated that vermicompost contains higher amounts of some other micronutrients such as Ca and Mg than those in primary matters. These minerals enrich soil and therefore play an important role in plant nutrition.

Supplement of worms in chicken diets

Bodyweight of chickens were weighed and recorded regularly from 4 to 10 week of age. The results were presented in table 3

Table 3. Body weight of chickens at different weeks of age (g/head, Mean ± SEm, n=37)

Week of age	Control	Group 1 (1%)	Group 2 (1.5%)	Group 3 (2%)
4	530 ± 19.0	520 ± 18.1	526 ± 16.6	528 ± 17.4

5	700 ± 18.0	699 ± 18.0	697 ± 16.9	707 ± 16.0
6	894 ± 18.7	893 ± 18.0	916 ± 17.6	925 ± 19.2
7	1115 ± 18.2	1125 ± 24.5	1131 ± 19.9	1166 ± 21.1
8	1348 ± 19.9	1378 ± 22.6	1382 ± 22.6	1408 ± 27.4
9	1590 ± 17.7[a]	1638 ± 19.5[ab]	1649 ± 24.2[ab]	1684 ± 30.7[b]
10	1823 ± 20.0[a]	1842 ± 17.9[ab]	1911 ± 19.0[ab]	1925 ± 36.2[b]

Mean values followed by different letters are different (ANOVA, Duncan multiple-ranged test; P < 0.05)

>From 4 to 8 week of age, live bodyweight of chickens did not significantly differ (P>0.05) between groups. At 9 and 10 week of age, chickens' bodyweight of groups supplemented with worms were significantly higher than those at control group (P<0.05). Supplement with 2% of worms in the diets resulted in highest live bodyweight of birds (1925 g/head at finishing age). Harwood (1976), Mekada et al (1979) reported that worms were considered as a main source of protein for poultry and birds were fed by worms having equal or higher growth rate than those with traditional protein.

The feed intake and conversion efficiency of chickens at different groups were calculated and showed at table 4.

Table 4. Feed intake and conversion efficiency

Age week	Feed intake, g/head/day				Feed conversion efficiency, kg/kg			
	Control	Group 1	Group 2	Group 3	Control	Group 1	Group 2	Group 3
5	64.4	63.5	63.1	64.3	2.60	2.52	2.65	2.59
6	73.2	74.5	75.6	72.8	2.65	2.68	2.72	2.78
7	82.8	81.0	87.7	82.0	3.03	3.06	2.89	2.87
8	102	102	104	98.1	3.20	3.23	3.05	2.93
9	121	118	119	117	3.52	3.50	3.13	3.10
10	125	123	121	120	3.97	3.94	3.69	3.41
Average	94..9	93.7	95.5	92.4	3.16	3.16	3.02	2.95

The results in table 4 showed that from 4 to 7 weeks of age, feed intake of chickens was not different between groups. Three last weeks before slaughter age, feed intake of chickens at worm-supplemented groups tended to decrease and became lower than that in control one. Therefore, feed conversion efficiency of chicken fed by worms was better as compared with control group and the most efficiently of conversion was achieved at group 3 (supplemented with 2% of worms) (2.95 kg in average). It means that supplement with 2% of worms in chickens' diet help to reduce 0.21 kg of feed per each kg of weight growth (equal to 6.8%). Harwood, Mekada concluded that chickens fed by worms had similar growth rate but lower feed consumed than those in control groups Harwood 1976 , Mekada et al 1979). Worm tissue contains 50–75% protein and 7–10% fat (of dry mass) (Patra and Dash 1973) that meet the nutrition requirement of animal. Therefore, chickens consumed smaller quantity of feed and had great growth.

At ten weeks of experiment, 16 broiler having mean weight of group to be slaughtered to examine carcass yield and quality. Results were showed in table 5

As presented in table 5, increasing worm level supplemented in the diet from 1; 1.5 to 2% resulted in higher yield of carcass. Yield of breast and thigh meat of chickens at group 3 (2% worms) were highest (19.4% and 22.9% respectively) because that they had highest growth rate as compared with other groups. It means that chickens fed by worms had better muscle growth or muscle development, therefore had higher performance of meat production.

When examining meat quality, the results in table 5 showed that supplemented levels of worms did not significantly affect meat quality of chickens. About the pH value, there were not significantly different between groups at both 12 and 72 h PM. ; this is often associated with increased meat tenderness. For non-stressed birds the pH achieved end value after approximately 30 minutes of slaughter (around 5.6 and 6.0)

Table 5. Carcass characteristics and quality

Parameters		Control (n = 4)	Group 1 (n = 4)	Group 2 (n = 4)	Group 3 (n = 4)
Carcass, %		68.1	67.7	68.3	69.9
Thigh meat, %		21.0	21.5	22.0	22.9
Breast meat, %		17.2	17.1	18.1	19.4
Abdominal fat, %		4.44	4.33	3.98	4.52
Eatable internal organs, %		8.84	9.23	9.61	8.81
pH at 12h PM		5.65 ± 0.02	5.62 ± 0.02	5.62 ± 0.20	5.58 ± 0.01
pH at 72h PM		5.68 ± 0.03	5.65 ± 0.02	5.64 ± 0.02	5.62 ± 0.02
Drip loss at 12h PM, %		2.04 ± 0.07	2.17 ± 0.14	2.11 ± 0.03	2.04 ± 0.07
Drip loss at 72h PM, %		2.28 ± 0.04	2.26 ± 0.06	2.10 ± 0.06	2.13 ± 0.05
Cooking loss at 12h PM, %		23.9 ± 0.30	23.9 ± 0.22	23.0 ± 0.43	22.7 ± 0.23
Cooking loss at 72h PM, %		25.7 ± 0.55	24.7 ± 0.21	24.5 ± 0.22	25.4 ± 0.51
Color at 12h PM	L*	57.1±0.12 *(57.29±0.25)*	57.2±0.10 *(57.18±0.42)*	57.5±0.15 *(57.5±0.14)*	57.5±0.17 *(57.39±0.34)*
	a*	8.41±0.28 *(10.4±0.45)*	10.3±0.42 *(10.3±0.37)*	10.3±0.36 *(10.4±0.54)*	10.2±0.38 *(10.5±0.33)*
	b*	20.9±1.33 *(19.8±0.64)*	20.0±0.45 *(20.2±0.79)*	18.6±1.25 *(19.3±0.89)*	20.7±0.74 *(19.6±0.43)*
Color at 72h PM	L*	58.4±0.27 *(58.2±0.21)*	58.3±0.12 *(58.4±0.27)*	58.3±0.30 *(58.4±0.16)*	58.2±0.38 *(58.4±0.44)*
	a*	8.41±0.28 *(8.02±0.25)*	9.01±0.29 *(8.48±0.31)*	9.61±0.28 *(9.0±0.72)*	8.81±0.31 *(9.3±0.24)*
	b*	19.8±0.52 *(19.3±0.55)*	17.6±0.92 *(19.3±0.63)*	17.8±0.53 *(18.8±0.76)*	19.4±0.69 *(18.1±0.51)*

Meat color values inside the brackets expressed for hen, outside the brackets expressed for cocks

Water-holding capacity is an important attribution of meat quality and can be measured by drip or cooking loss. If water-holding capacity is poor, whole meat and further processed products will lack juiciness. There was no significant difference in drip loss and cooking loss due to supplemented levels of worms. However, in this study, drip loss (about 2-2.3%) were higher than those of slow-growing and medium-growing genotypes of chicken (1.17 and 1.14% respectively) reported by Fanatico et al 2007. The author concluded that drip loss and cooking loss were affected ($P < 0.05$) by genotype, with the highest losses occurring with the slow- growing genotype and the lowest losses occurring with the fast-growing and medium-growing genotypes (Fanatico et al 2007).

Meat color is one of the first characteristics noted by customers, especially in fillet products, and is also an indicator of meat quality. In this study, there was not significant difference about L*, a* and b* values between groups. However, the L* values for all treatments in this study were in a high range due to classification of Qiao et al 2001; Woelfel et al 2002. Bianchi and Fletcher (2002) reported that fillet thickness significantly impacted on color; thicker fillets had lower L* values than thinner fillets. Although thickness was not quantified in this study, the fillets from slow-growing birds like (Ho x Luong Phuong) were noticeably thinner through informal observations. For a* (redness) and b* (yellowness) value, there were not significant difference between groups. Notably, redness and yellowness of broilers (Ho x Luong Phuong) were much higher than those of slow-growing and medium-growing chickens according to results reported by Fanatico et al 2007 (3.66 and 4.43 for a*; 2.19 and 1.63 for b*, respectively). Other authors had found that meat of slow-growing bird is redder and darker than fast-growing or high-performance birds (Le Bihan-Duval et al 1999; Berri et al 2001; Debut et al 2003). This is one of the most advantages of broilers (Ho x Luong Phuong) meeting requirements of domestic consumers.

Conclusions

- In vermiculture, manure of cattle and pig or other organic materials such as rice straw can be used in different ratios. However, the highest earthworm biomass and growth rate was gained when worms fed by fresh cattle manure (net weight gained by 713 g or 243 % in growth rate after 45 days) ($P<0.05$). Besides, other mixtures of different wastes, notably cattle and pig manure in 50:50 ratio were also good for worms growth and production.
- *Perionyx excavatus* plays an important role in manage organic wastes and supply a valuable source of feed for poultry. Many types of complex organic matters such as animal manure, straw rice, etc can be transformed into stabilized humus-like product (vermicompost) which contains higher nutrients (increase by 0.3 - 0.6% P, 0.1 - 0.2% K and Ca, Mg), especially in available and exchangeable forms (NO_3^-, NH_4^+) so that can be easily and readily uptaken by plants.
- Experiment in broilers (Ho x Luong Phuong) implied that *Perionyx excavatus* is a very nutritious feed for poultry. Chickens were fed by diet supplemented with 1, 1.5 or 2% of *Perionyx excavatus* had higher growth rate ($P<0.05$) and consumed lower amount of feed and had better feed efficiency than those in control group. Moreover, supplementing worms in the diet resulted in higher yield of carcass, breast and thigh meat without any significantly affecting meat quality (pH, color, drip and cooking loss). The best results found at group added with 2% worm in the diet (1925 g/head of bodyweight at 10 weeks of age, reduced 0.21 kg or 6.8% feed consumption as compared with control group).

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