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Potentials of earthworm and its by-products in animal agriculture and waste management - A review

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Abstract

A review work was conducted to unveil the potentials of earthworm (EW) and its by – products such as earthworm meal (EWM) and earthworm casts (EWC) in poultry nutrition and management of animal waste. Production of EW is called vermiculture and using it to decompose organic matter is vermicomposting while processing it into such product as EWM is known as vermitechnology. Being a hermaphrodite, breeding is simple and fast, requiring only two EW to come together irrespective of their sexes. Fresh EW could be fed to fish and chickens. Based on literature EWM is high in protein 62 to 65%, essential amino acids such as lysine 6 to 8%, methionine 2 to 5%, leucine 8 to 10%, isoleucine 4 to 6% and phenylalanine 4 to 6%; fat 5 to 8% and fibre< 8%. At dietary inclusion level of 0.2 to 0.6%, EWM reportedly increased feed intake, supported growth, improved carcass quality in broiler chickens, and marginally increased egg size and hen day in layers. Dry EWC could replace 5 to 10% maize in diet for finishing broiler chickens. Rich in macro plant nutrients (e.g. nitrogen 1.94%, calcium 4.4% and potassium 0.7%) EWC is nutritionally sound for growth of pasture crops especially legumes. Earthworm has cellulase, lichenase, chitinase and cellulolytic microorganisms which enable it to degrade organic waste. Cattle dung and other animal manure can be degraded by earthworm thereby reducing environmental pollution. In this era of organic farming and sustainable environment, EW could therefore have a potential place in animal nutrition and management of waste from animals.

Key words: earthworm, earthworm meal, vermiculture, composting, poultry nutrition

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Introduction

Productivity in animal production is a measure of output (meat, egg, wool, milk and hides and skin) and money to be realized from them which in turn reflects on the profit. Certain advances have been made to improve the performances of farm animals. Performance in terms of yield such as body weight, hen day, dairy and wool could be improved tremendously through advances in nutrition and management practices. Aspect of nutrition in farm animal enterprise has become expensive because of high cost of feed ingredients especially energy and protein feedstuffs especially for monogastric animals. In developing economies for instance, both prices of feeds and feedstuffs have risen. This has been attributed to direct competition between man and farm animals for such feedstuff. While farm animals directly consume these foodstuffs such as maize, fish meal, sorghum and cassava, man utilizes them for both domestic and industrial raw materials. Recently, this competition was intensified by the use of energy feedstuffs such as maize for biofuel production as alternative for fossil fuel. Consequence of this is that the expenditure regime of farmers on farm animals is further stressed. Though animal production has become expensive and more pronounced due to high cost of feeding, waste management to sustain the environment to a reasonable extent contributes to the pressure on expenditure. Waste management either by direct disposal or conversion to alternative uses such as biogas (methane) is extra cost to the farmer. Direct disposal of animal wastes has become expensive especially in the face of increasing urbanization, reducing dump sites, awareness of environmental risks, activities of environmental Activists and government interventions.

Earthworm seems to be a potential tool to overcome or reduce both feed cost and waste disposal challenges by conversion of negative wastes into beneficial materials. The recycling of wastes through vermiculture or vermicompositing

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has been reported to reduce problems of disposal of agricultural wastes (Tipathi and Bhardwaj, 2004). Earlier, reports by Edwards (1985) and Kale (2000) showed that vermicomposition was usable not only as an alternative source of organic fertilizers but also to provide economic animal feed protein for the fish and poultry industries worldwide. In his own contribution, Janardan (1997) reported that fast breeding ability and composting potential of earthworm may be effectively utilized in animal agriculture and management of animal wastes.

Therefore, the objective of this review was to gather information from available literature on earthworm and see how it could contribute positively to the advancement of animal nutrition and sustainable environment knowing fully well that other waste management systems such as incineration and use of dump sites are not environment friendly.

Classification of earthworm

Earthworm is an invertebrate, crawling, cylindrical soft - body, soil living animal without skeleton. Crawling or movement on the ground is by means of ring- like structures called chitae. Like the chicken, it has crop and gizzard including the intestine and hence could be regarded as monogastric animal. About 384 species of earthworm had been identified in different parts of India Janardan (1997). They belong to the *phylum Annelida* (Malik *et al*., 2010).

Based on habitation, earthworm is classified into two basic groups namely *endogeic* and *epigeic. Endogeic* also called *anecic* earthworms are those earthworms that burrow and live at 10-20 cm deep in the soil. Good example is *polypheretima spp*. *Epigeic* earthworms are those ones that live at the upper layer of the soil such as *Eisenia fetida* (Tripathi and Bhardwaj, 2004). They are also classified into temperate and tropical types such as Lumbricus *spp* (Edwards, 1985), and Eudrilus spp and Perionyx spp (Tripathi and Bhardwaj, 2004), respectively.

Reproduction in earthworm

Knowledge about reproduction in earthworm is necessary for effective utilization of its potentials in animal agriculture. This is because due to renewed interest in the use of earthworms in soil restoration schemes (Brun *et al.*, 1987); waste management (Tripathi and Bhardwaj, 2004) and Animal feeding (Taboga, 1980), recent researches are focused on examining ways of manipulating environmental conditions in order to maximize growth and reproduction rate. Maximization of reproduction rate may be possible with good knowledge of reproduction dynamics.

Table 1. Phytonutrients content of earthworm casts (Dickerson, 2008)

Nutrients	Quantity
Total nitrogen %	0.80 – 1.94
Nitrate nitrogen %	0.35 – 0.47
Calcium %	2.27 – 4.40
Potasium %	0.48 – 0.70
Sodium %	< 0.01 – 0.02
Magnesium %	0.57 – 0.96
Iron %	11690 – 7563
Zinc %	128 – 278
Manganese %	414 – 478
Copper ppm	17 – 27
Boron ppm	25 – 34
Aluminum ppm	7012 – 7380
Soluble salts mm/os/cm	3.6 – 11.70

It is worthy of note that due to differences in breeds, soil condition and environmental factors there are differences in reproduction indices. For instance in *Lumbricus tervestris* which is obligate biparental earthworm (Evans and Guild, 1947) it takes cocoon 12 – 13 weeks to develop (Meinhardt, 1974). Under conductive conditions, natural growth to maturity in Britain is usually attained within one year (Evans and Guild, 1948; Lakhani and Satchell, 1970) and 15 months for harsh conditions (Nordsfrom, 1976). L. *terrestris* according to Satchell (1967) could mate on soil surface except when conditions are unsuitable. Reproductive activities in this species expand from March – December (Gates, 1961).

Butt *et al*. (1994) examined for 3 years the reproduction pattern (life cycle) of L. *terrestris* under controlled environmental conditions. Parameters examined included; cocoon and hatchling masses, growth and reproductive rates. Mean cocoon and hatchling masses respectively were 60 and 53mg. This cocoon mass opposed 32mg (range of 21 – 63mg) reported by Pedersen and Bjerre (1991). Butt *et al*. (1994) reported that longevity was maximum at 47 months as against 72 months (6 years) reported by Lee (1985). In their opinion they maintained that Lee (1985) did not indicate whether the worms were reproductively active or even maintained in a group, suggesting that single raised worm could stay longer than worms raised in a group. This is because single raised worms lives longer if energy expenditure is confined to somatic growth and not directed towards reproduction.

In the same report, though production of cocoon decreased over the 3 years, cocoon viability was not affected suggesting that ability to mate and produce fertile cocoon tends not to diminish with age, but death of cohort members may be a greater factor in reducing overall fecundity. However, Venter and Reinecke (1987) had reported that in *Eisenia fetida* both cocoon production and viability decrease with age. In other indices measured in the same experiment (Butt *et al*., 1994) observed that L. *terrestris* could complete its life cycle in less than 30 weeks under normal conditions. A life mean of 55 cocoon production was established. In conclusion they maintained that anecic specie is not suited for vermiculture. Butt (1991) had reported that cocoon hatched most rapidly at 20 ^{OC} within 70days and that growth was significantly influenced by temperature, food type and earthworm density. Worms matured in 20 weeks at 15^{OC} and it was rapid he maintained.

Earthworm farming and production of worm casts

Different terminologies have been used to describe the production and use of earthworm for agricultural and waste management purposes. Such terms include vermicomposting (Dickerson, 2008); vermiculture and vermitechnology (Tripathi and Bhardwaj, 2004). Vermicompositing is the use of earthworm to biologically degrade organic wastes such as sewage, kitchen refuse, cow dung or pig manure. In this case, the interest is to recycle hazardous organic waste to a form that is not injurious to the environment. Vermiculture is the production of earthworm for a specific purpose, such as feeding of fish. Vermitechnology is the production of earthworm and transforming it into other forms that are beneficial to man. Good example is transformation of earthworm into a meal or powder which could be used in animal feeds (Ibanez, 1993) or for human medicine (Dickerson, 2008).

Table 2. Proximate and mineral composition of earthworm meal

Proximate (%)	Ibanez *et al.* (1993)	Jang Ho (2009)	Sogbesan *et al.* (2007)
Dry matter	91.60	96.00	91.40
Protein	65.20	62.70	63.04
Fat	8.80	16.00	5.90
Fibre	2.70	3.00	8.90
Starch	5.60	2.50	13.76
Ash	9.94	14.80	8.90
Minerals (g/100g)			
Calcium	0.53	No data	No data
Phosporus	0.94	No data	No data
Sodium	0.43	No data	No data
Potassium	0.62	No data	No data

Whether vermicomposting, vermiclture or vermitechnology, casts is produced. Casts is a dark substance voided by earthworms. It is made up of soil and organic matter, with fine texture, and rich in plant nutrients Dickerson (2008). A worm cast contains both macro and micro minerals necessary for normal plant growth (Table 1). In all, selection of good breed of earthworm is important (Velasquez *et al*., 1980). What to look in a breed are the rate of reproduction and feeding pattern. For this reason, *Eisenia fetida* has attracted a considerable interest. This is because, it has high reproduction rate and the ability to feed on wide range of organic matters is considerably high (Watanobe and Tsukamoto, 1976).

It is commercially produced by extensive and intensive methods. Extensive farming of earthworm takes place in the field, compost or manure pile, while intensive type takes place in bins and trays in a building called vermihouse. For field production of earthworm, vermiculture beds are constructed which may be a square or rectangular frame, 30 – 45cm high. Cow dung is a good organic matter substrate. Then introduce mature earthworms 300 – 1500 per square meter of bed (kitchen, 2010). Do not bury the worms but spray them on the surface of the beds after which burrowing follows immediately. The worms should be fed daily by sprinkling feed on the grass. Dry- ground - cow- dung could serve as feed. Spread the dry- ground- cow- dung on the surface of the beds and then sprinkle water.

Another method of worm farming is by digging a hole about 20 – 30cm deep. Bedding materials as in bin method are added, allowed to settle and cool before earthworms are added. Another method either to farm or hunt worms is by laying dry grass on the surface of the ground. The worms would come out of the ground and lay under the grasses which can then be rotated and the worms collected (Buck *et al*., 1999).

Earthworm casts and its potentials as nutrients carrier for forage crops

Earthworm casts or vermihumus is an excreta produced by earthworm which is rich in organic carbon, total nitrogen and inorganic phosphate (Table 1). These are essential for plant growth and invariably forage crops (legumes and grasses). Bahadori *et al*. (2015) reported earthworm casts to contain 1.86% humic acid and less than 0.10% folic acid. Due to their dominant part in soil animal biomass and high contribution to rates of soil turnover, earthworms are of special importance for nutrient cycling, soil structure and transport process (Buck *et al*, 1999). By feeding, burrowing and casting activities, they contribute to the incorporation of plant residues into the soil promoting decomposition and thereby the release of nutrients for plant use. Earthworms ingest both mineral and organic fragments and through intense comminution and mixing during digestion process, the soil material is subjected to a biochemical and physical modifications. Buck et al. (1999) concluded that worm casts offer mini environmental conditions very different from those occurring in the surrounding soil, resulting from both food selection and digestion process. For instance, plant nutrients are generally more concentrated in worm casts than in the parent soil (Mulongoy and Bedoret, 1989).

Going by the assertion of Buck *et al.* (1999) it amounted that both casts production and nutrient content of casts are subject to type of plant material which would serve as food to the worms, and species of the worm. In an experiment conducted to determine the effect of mulch types using maize, barley, lupine and sugar beet forages, Buck *et al*. (1999) reported that both casts mass and nutrient content (organic carbon, total nitrogen and organic phosphate) were higher in maize and sugar beet mulch types, than barley and lupine. This difference has been explained. Worms found it difficult to overcome high strength of barley due to high fibre content (Brouwer, 1972) and presence of silisic acid (List, 1972). On the part of lupin, it was refused by worms because of the presence of the following alkaloids; lupinin, lupinidin and lupanin (Mangold, 1951). Maize and sugar beet favoured higher production of worm casts due to presence of soluble carbohydrates that were preferably ingested by the worms (Buck *et al.,* 1999). In terms of species difference, cast production was more pronounced in *Lumbricus terrestris* than in deep burrowing species such as *Octelasion cyaneum*.

Table 3. Energy and amino acid content of earthworm casts (Bahadori et al., 2015)

Parameters	Percentage (DM basis)
Energy (KcalME/kg)	3258
Lysine	4.44
Methionine	1.20
Cystine	0.95
Methionine + cystine	2.15
Threononine	2.99
Arginine	4.41
Isoleucine	2.95
Valine	3.22
Histidine	1.74
Phenylalanine	2.72
Glycine	3.46
Serine	2.94
Proline	2.41
Alanine	3.44
Asparagine	6.54
Leucine	5.02
Glutamine	8.76

Higher mineralization of worm casts than the surrounding soil has been explained (Flegel *et al.*, 1998; Shaw and Pawluk, 1986; Daniel and Anderson, 1992; Parkin and Berry, 1994). Nitrogen accumulation in casts was explained to come from metabolic secretions such as rests of intestinal mucus, urine and muco-polysaccharides secreted from glands on the skin surface. In addition, accumulation of nitrogen in worm casts is related to the nitrogen of the organic matter used as food for the earthworm. Presence of phosphates (enzymes that break down organically bound phosphate to release inorganic phosphate) in casts increases the level of phosphate in casts than the surrounding soil (Juma and Tabatabai, 1976). Not only that vermihumus can support forage growth, report has shown that 1.0% of casts could be incorporated in the feed for broiler chickens without detrimental effect (Bahadori *et al.*, 2015)

Use of earthworm meal in feeding of farm animals

Production of earthworm meal, means processing of harvested earthworms into a meal or powder. This involves killing, drying and grinding of the worms into powder, according to Ibanez *et al.* (1993). After being washed thoroughly with water, the worms are killed in hot water at 90^{OC}. After which, they are dehydrated at 60^{OC} in a tray drier for 4 – 6 hours. The dry earthworms are then ground into a powder or meal.

Proximate composition and amino acid profile of earthworm meal have indicated that it is rich in nutrients essential for growth and reproductive performance of farm animals (Renecke and Albert, 1987; Ibanez *et al*., 1993). Hence, earthworm meal could represent a protein and amino acid source of high nutritional value as indicated by its chemical composition (Table 2). It is however poor in mineral composition because of absence of bone. According to Bahadori *et al*. (2015) earthworm meal is rich in lysine (4.44%), methionine (1.20%) and metabolizable energy (3258 KcalME/kg) as shown in Table 3. Experiment on biological parameters of earthworm meal such as net protein ratio and protein efficiency ratio conducted in rat showed encouraging result Ibanez *et al*. (1993).

Positive influence of earthworm meal on animals has been unveiled. Ibanez *et al*. (1993) reported that earthworm meal had no adverse effects on growth and reproduction of rats. Comparing earthworm meal with casein, they observed that body weight (g/100g body weight) for rats that consumed casein was 29 – 34.17g and earthworm meal treated group 25 – 30.88g. Reproduction record showed that mean range of pups per litter (mg/100g body weight) for the casein and earthworm meal-fed-rats were 8 – 11.5 and 9.1 – 12.2 respectively. In any case, they reported that rats that consumed earthworm meal diet had bigger gonads: 0.8 – 0.94g testicles as against 0.59 – 0.69g for rats that consumed casein. The ovarian size in the same group that consumed diet containing earthworm meal was bigger (47.15 – 49. 17g) as against 30.89.5g – 39.5g. Further investigations indicated that the gonads appeared normal under a microscope and the liver was not adversely affected.

Table 4. Performance of broiler chickens fed earthworm meal (Jang Ho, 2009)

Parameters	0.00%	0.20%	0.40%	SEM
Initial live weight (g)	177.10	171.20	170.70	11.20
Final live weight (g)	2211.90	2332.80	2506.20	54.90
Weight gain (g)	2063.8^{C}	2191.60^{b}	2365.50^{a}	52.40
Total feed intake (g)	4147.70^{C}	4423.10^{b}	4652.30^{a}	62.40
Feed: gain ratio	2.01	2.02	1.97	0.04

Means within the same row with different superscripts (a,b,c) differ significantly (p<0.05).

The importance of earthworm and its by-products in feeding of farm and game animals has been stressed. Taboga (1980) reported that the growth rate of chickens fed fresh earthworm or its meal performed significantly better than birds fed earthworm-free- diets. It has also been noted that earthworm meal accelerated growth, improves sexual performance, stimulated appetite and increased palatability of feeds in farm animals and other animals such as horse, dog, cat and fish (Dickerson, 2008).

The reports of Taboga (1980) and Dickerson (2008) were later confirmed by Jang Ho (2009). Using 0.20 and 0.40% levels of earthworm meal to feed broiler chickens he observed that it improved feed intake, protein digestibility and supported weight gain (Tables 4 and 5). Rezaeipour *et al*. (2014) compared soya bean meal with earthworm meal and reported that earthworm meal produced higher protein digestibility, breast weight and blood parameters were not adversely affected. In laying hen (Table 6) earthworm meal was found to improve egg quality and productivity (Jang Ho, 2009). He indicated that though hen day was not significantly higher in earthworm meal - fed –

birds, the hen day was marginally better than the hen day of birds fed earthworm-free-diet. The earthworm meal increased the levels of essential fatty acids (linoleic and linolenic acids) content of the chicken eggs (Table 7).

Table 5. Effects of earthworm meal on apparent nutrients digestibility of broiler chickens

Parameters	0.00%	0.20%	0.40%	SEM
Starter Phase (1-4 weeks)				
Dry matter (%)	72.47	73.44	73.31	1.31
Crude protein (%)	64.34[b]	67.36[ab]	72.26[a]	2.72
Crude fat (%)	86.48	88.46	88.46	2.72
Ash (%)	31.44	32.26	34.51	1.52
Finisher Phase (5-8 weeks)				
Dry matter (%)	71.16	72.70	72.72	1.01
Crude protein (%)	61.77[b]	63.47[b]	69.09[a]	1.28
Crude fat (%)	80.27	81.14	83.92	2.00
Ash (%)	40.32	41.65	42.37	1.85

Means within the same row with different superscripts (a,b,c) differ significantly (p<0.05)

Animal waste management using earthworm

The use of earthworm to manage waste is its ability to feed on organic materials. Earthworm could be regarded as monogastric animal because of its simple gut and pseudo-ruminant because of its ability to digest fibre. The digestive system is made up of the mouth, oesephagus, crop, gizzard and intestine. The gizzard contains grits (fine sand particles) that help to grind food particles. The major food for earthworm is decayed organic matter mixed with soil (Jager *et al*., 2003). Soil organic matter is digested by a mutual relationship developed with ingested micro flora (Martin, 1989., Trigo *et al.*, 1993). Hence there are both microbial and enzymatic breakdown of organic matter. Soil contains microbes in inactive form. In the gut it mixes with water and intestinal mucus which plays central role in their mutualistic digestion system. Part of the mucus is metabolized by the microorganisms and part reabsorbed and recycled inside the earthworm (Laltaud *et al*., 1997).

While getting to the gut in inactive form, the intestinal mucus activates the micro–organisms which in turn degrade the complex substances of the soil organic matter. The earthworm will be able to absorb through its gut walls a great part of the substances, after enzymatic breakdown. Enzymatic activities in the gut of earthworm has been studied (Laverack, 1963; Laltaud *et al*., 1997) and proved that breakdown of food material takes place most in the fore and hind gut. Enzymes implicated in digestion in the gut are cellulase, lipase, protease, maltase amylase, chitinase and lichenase (Tracy, 1951); N-acetylglucosaminase, laminarase and laminaribinase indicating that earthworms could degrade β-glucans, xylans, starch, cellulose, fat, chitin and protein. There is a school of thought that those enzymes may come from the microflora, but Lattaud *et al.*(1997) reported that these enzymes though may be produced by the microflora, were secreted by the earthworm. This according to them was because the enzymes were not only found in the gut of the earthworms but in their tissues and cultures.

Table 6. Performance of laying hens (45 weeks old) fed earthworm meal (Jang Ho, 2009)

Parameters	**0.00%**	**0.20%**	**0.40%**	**SEM**
Hen day (%)	79.72	82.41	81.47	0.77
Egg weight (g)	63.23	61.21	62.83	0.20
Feed intake (g/day)	141.20	142.06	142.00	5.02
Daily egg mass (g/day)	50.40	50.4	51.20	0.37
F.C.R (feed/ egg mass)	2.80	2.75	2.71	0.30

However, by the report of Zhang *et al*. (1993) there is a difference in enzymatic activities in different species of earthworm. Glucosidic activities were higher in *polypheretima elongate* than *pontoscolex orethrurus*. They concluded that both earthworms showed lower glycosidic activities than other invertebrates such as certain snail (*Halix aspersa*) and *Xylophagus* termites.

Earthworm has been regarded as ecosystem engineer (Malik *et al*., 2010) whereby it can transform any soil environment contaminated by industrial (e.g. textile sludge) waste into less contaminated and useful entity. Earlier, Sabine (1983) had noted earthworm to play a role in waste management by recovering organic materials that are transformed into vermicompost, which is used as a fertilizer and protein-rich worm biomass suitable for livestock feeding. Because of increasing human population, intensive agriculture and rapid industrial growth, organic wastes are extensively introduced into the ecosystem. This needs to be recycled and the environment cleaned from the negative materials (Tripathi and Bhardwaj, 2004). Most adopted waste management system is technology based, expensive and gives no further use of the materials. Earthworm has the potential for converting waste into beneficial material which is aspect of resource recycling and environmental cleaning. Hence, sustainable environment could be achieved with earthworm.

Table 7. Effects of earthworm meal on fatty acid composition of chicken eggs (Jang Ho, 2009)

Fatty Acids	0.00%	0.20%	SEM
Myristic acid (14:0)	0.31	0.30	0.30
Palmitic acid (16:0)	20.19	22.91	2.01
Palmitoleic acid (16:1)	5.70	4.98	5.78
Stearic acid (18:1)	8.31	7.27	2.00
Oleic acid (18:1)	42.49*	25.33	0.59
Linoleic acid (18:2)	15.20	25.46*	0.59
Linolenic acid (18:3)	0.22	3.18*	1.00
Dihomo linolenic acid (20:3)	4.56	3.99	0.01
Cervonic acid (22:6)	1.36	4.01*	1.00

* Significantly ($p < 0.05$) difference

In managing organic wastes with earthworm, some researchers have been carried out to determine the ability of certain species of earthworm to degrade organic materials. Tripathi and Bhardwaj (2004) comparing *Eisenia fetida* and *Lampito Mauritii* noted that rate of decomposition and mineralization were higher in *E. fetida* and concluded that *E. fetida* was a better specie for decomposition of kitchen manure and cow dung. Balasubramanian and Kasturi (1995) recommended *megascolex spp.* Nevertheless, it could be noted that the degradation ability of the earthworm is influenced by waste type. Using cow dung, water hyacinth and biogas plant effluent, the efficiency of waste breakdown by earthworm was found to be highest in cow dung followed by water hyacinth and then biogas plant effluent (Balasubramanian and Kasturi, 1995).

Conclusion

The nutrient level of earthworm meal is an indication of its potential as a vital feed ingredient in poultry and swine nutrition. Earthworm cast which is rich in plant nutrients could be good organic manure to manage pastures compared to inorganic fertilizers that introduce inorganic phosphates and nitrates to the environments. Decomposition of manures by earthworms as a means of animal waste management is more environments friendly than incineration and dumpsite methods that pollute the environment.

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