

- https://link.springer.com/chapter/10.1007/978-3-319-24708-3_5

Important Digestive Enzymes of Earthworm

Katheem Kiyasudeen S

- Mahamad Hakimi Ibrahim

- Shlrene Quaik

- Sultan Ahmed Ismail

15 December 2015

Part of the [Applied Environmental Science and Engineering for a Sustainable Future](#) book series

The living cell is the site of tremendous biochemical activity called metabolism. This is the process of chemical and physical change which goes on continually in the living organism. The greatest majority of these biochemical reactions do not take place spontaneously (Bennett and Frieden. Modern topics in biochemistry. Macmillan, London, pp 43–45, 1969). The phenomenon of catalysis makes possible biochemical reactions necessary for all life processes.

The catalysts of biochemical reactions are enzymes and are responsible for bringing about almost all of the chemical reactions in living organisms (Holum. Elements of general and biological chemistry, 2nd edn. Wiley, New York, p 377, 1968). Without enzymes, these reactions take place at a rate far too slow for the pace of metabolism (Martinek. J Am Med Tech 31:162, 1969).

All known enzymes are proteins. They are high molecular weight compounds made up principally of chains of amino acids linked together by peptide bonds (Pfeiffer. Enzymes, the physics and chemistry of life. Simon and Schuster, New York, pp 171–173, 1954). A protein molecule consists of one or more polypeptide chains which continue without interruption throughout the molecule folded into a uniquely defined configuration held together by hydrogen bonds between the peptide nitrogen and oxygen atoms also between the charged sidechains (Blow. Structure 8(4):R77–R81, 2000).

It has long been assumed that most invertebrates do not possess the enzymatic complement to digest polysaccharides, but now the opposite is often shown for different groups of soil fauna, enabling us redefine species diets and therefore their ecological function. Enzymatic activities have been widely used as an index of soil fertility or ecosystem status because they are involved in biological transformation of native and foreign compounds in soils (Tate. Soil microbiology, 2nd edn. Wiley, New York, 2000).

The digestive enzymes of the litter feeding animals, particularly oligochaetes, are responsible for decomposition and humification processes (Parthasarathi and Ranganathan. Trop Ecol 41(2):251–254, 2000). The interpretation of data arising from enzyme assay is complicated since enzyme activity depends on several factors and different locations of enzymes in the studied system (Nannipieri et al. Enzyme activities and microbiological and biochemical processes in soil. In: Burns RG, Dick R (eds) Enzymes in the environment. Marcel Dekker, New York, pp 1–33, 2002).

So far only a few enzymatic studies on earthworm casts have been published,

and they are limited to observations on soil only (Parthasarathi and Ranganathan. *Trop Ecol* 41(2):251–254, 2000). Some authors have described a direct role of earthworms in the decomposition of plant debris, and presume the existence of their own digestive enzymatic activities.

Worms being hermaphrodites with simultaneous functioning gonads may require more energy and increased enzyme activities during this active phase of reproduction. Enzyme activity is influenced also by type of food.

The differential enzyme-activity is perhaps related to the type of food and rate of eating of each species (Table 5.1). Earthworm which feed and depend on microbes, litter, and grit present in soil should contain battery of enzymes.

Earthworm castings are known to be a rich source of plant growth promoting substances viz., growth hormones, enzymes and vitamins (Karthikeyan et al. *AgroIndia* 7:34–353, 2004). Earthworm castings also contains a number of beneficial microorganisms, nitrogen fixing, phosphorous solubilizing and cellulose decomposing organisms, which help in improving soil productivity. Earthworms have an in-house supply of enzymes like Nitrate reductase, acid phosphatase and alkaline phosphatase, which are involved in the metabolism of nitrogen and phosphate materials present in the compost.

The earthworms speed up the composting process and transform wastes into nutrient rich castings with the help of the enzymes (Prabha et al. *South Asian J Socio-Polit Stud* 2:129–130–156, 2005).

References

1. Aira M et al (2006) *Eisenia fetida* (Oligochaeta, lumbricidae) activates fungal growth, triggering cellulose decomposition during vermicomposting. *Microb Ecol* 52:738–746 [CrossRef](#) [Google Scholar](#)
2. Aira M, Monroy F, Dominguez J (2007) Earthworms strongly modify microbial biomass and activity triggering enzymatic activities during vermicomposting independently of the application rates of pig slurry. *Sci Total Environ* 385:252–261 [CrossRef](#) [Google Scholar](#)
3. Aira M, Monroy F, Dominguez J (2009) Changes in bacterial numbers and microbial activity of pig slurry during gut transit of epigeic and anecic earthworms. *J Hazard Mater* 162:1404–1407 [CrossRef](#) [Google Scholar](#)
4. Bachmann SL, McCarthy AJ (1991) Purification and cooperative activity of enzymes constituting the xylan degrading system of *Thermomonospora fusca*. *Appl Environ Microbiol* 57:2121–2130 [Google Scholar](#)
5. Barois I, Lavelle P (1986) Changes in respiration rate and some physicochemical properties of a tropical soil during transit through

Pontoscolex corethrurus (Glossoscolecidae, Oligochaeta). Soil Biol Biochem 18:539–541[CrossRef](#)[Google Scholar](#)

6. Baskaran S, Palanichamy S, Arunachalam S, Balasubramanian MP (1986) Changes of acid and alkaline phosphatases during the development of the tropical earthworm Pontoscolex corethrurus. Natl Acad Sci Lett 9:159–162[Google Scholar](#)
7. Bennett TP, Frieden E (1969) Modern topics in biochemistry. Macmillan, London, pp 43–45[Google Scholar](#)
8. Biely P (1985) Microbial xylanolytic systems. Trends Biotechnol 3:286–290[CrossRef](#)[Google Scholar](#)
9. Blow D (2000) So do we know how enzymes work? Structure 8(4):R77–R81[CrossRef](#)[Google Scholar](#)
10. Chapin FS, Matson P, Mooney H (2002) Principles of terrestrial ecosystem ecology. Springer, New York[Google Scholar](#)
11. Charrier M, Rouland C (1992) Les osidases digestives de l'escargot *Helix aspersa*: localisations et variations en fonction de l'état nutritionnel. Can J Zool 70:2234–2241[CrossRef](#)[Google Scholar](#)
12. Engelstad F, Stenersen J (1991) Acetylesterase pattern in the earthworm genus Eisenia (Oligochaeta, Lumbricidae): implications for laboratory use and taxonomic status. Soil Biol Biochem 23:243–247[CrossRef](#)[Google Scholar](#)
13. Flack FM, Hartenstein R (1984) Growth of the earthworm *Eisenia foetida* on microorganisms and cellulose. Soil Biol Biochem 16:491–495[CrossRef](#)[Google Scholar](#)
14. Fredericq L (1878) La digestion des matières albuminoïdes chez quelques invertébrés. Arch Zool Expdr vii:391–400[Google Scholar](#)
15. Garvín MH, Lattaud C, Trigo D, Lavelle P (2000) Activity of glycolytic enzymes in the gut of *Hormogaster elisae* (Oligochaeta:Hormogastridae). Soil Biol Biochem 32:929–934[CrossRef](#)[Google Scholar](#)
16. Ge T, Sun ZJ, Fu SH, Liang GD (2005) Cloning of thrombolytic enzyme (lumbrokinase) from earthworm and its expression in the yeast *Pichia pastoris*. Protein Expr Purif 42:20–28[CrossRef](#)[Google Scholar](#)
17. Holum J (1968) Elements of general and biological chemistry, 2nd edn. Wiley, New York, p 377[Google Scholar](#)

18. Honsi TG, Stenersen J (2000) Activity and localisation of the lysosomal marker enzymes acid phosphatase N-acetyl-b-d-glucosaminidase, and b-galactosidase in the earthworms Eisenia fetida and E. veneta. *Comp Biochem Physiol B* 125:429–437[CrossRef](#)[Google Scholar](#)
19. Jyotsna PK et al (2011) Isolation, characterization of cellulose producing Lysinibacillus sphaericus MTCC No. 9468 from gut of Eisenia fetida. *Bioscan* 6(2):325–327[Google Scholar](#)
20. Karthikeyan et al (2004) Earthworms. *AgroIndia* 7:34–353[Google Scholar](#)
21. Keilin D (1920) On the pharyngeal gland of the earthworm. *Q J Microsc Sci* 2–65:33–61[Google Scholar](#)
22. Kim DY et al (2009) Isolation and characterization of a cellulase-free endo- β -1,4-xylanase produced by an invertebrate-symbiotic bacterium, Cellulosimicrobium sp. HY-13. *Process Biochem* 44(9):1055–1059[CrossRef](#)[Google Scholar](#)
23. Kumar R, Singh BL, Shweta (2010) Enzyme activities and microflora of earthworm gut and vermicreactors as indicators of the stabilization of wastes degradation process. *Biorem J* 14(3):150–157[CrossRef](#)[Google Scholar](#)
24. Lattaud C, Zhang BG, Locati S, Rouland C, Lavelle P (1997a) Activities of the digestive enzymes in the gut and in tissue culture of a tropical geophagous earthworm, *Polypheretima elongata* (Megascolecidae). *Soil Biol Biochem* 29:335–339[CrossRef](#)[Google Scholar](#)
25. Lattaud C, Locati S, Mora P, Rouland C (1997b) Origin and activities of glycolytic enzymes in the gut of the tropical geophagous earthworm *Millsonia unonzala* from Lamto (Côte d'Ivoire). *Pedobiologia* 41:242–251[Google Scholar](#)
26. Lattaud C, Mora P, Garvin M, Locati S, Rouland C (1999) Enzymatic digestive capabilities in geophagus earthworms – origin and activities of cellulolytic enzymes. *Pedobiologia* 43:842–850[Google Scholar](#)
27. Lavelle P, Lattaud C, Trigo D, Barois I (1995) Mutualism and biodiversity in soils. *Plant and Soil* 170:23–33[CrossRef](#)[Google Scholar](#)
28. Marialigeti K (1979) On the community-structure of the gutmicrobiota of Eisenia lucens (Annelida, Oligochaeta). *Pedobiologia* 19:213–220[Google Scholar](#)

29. Martin A, Cortez J, Barois I, Lavelle P (1987) Les mucus intestinaux de ver de terre, moteur de leurs interactions avec la microflore. *Rev Ecol Biol Sol* 24:549–558[Google Scholar](#)
30. Martinek R (1969) Practical clinical enzymology. *J Am Med Tech* 31:162[Google Scholar](#)
31. Mihara H et al (1990) A novel fibrinolytic enzyme extracted from the earthworm, *Lumbricus rubellus*. *Jpn J Physiol* 41:461–472[CrossRef](#)[Google Scholar](#)
32. Mishra SL (1993) Digestive enzymes of the tropical earthworm *Perionyx millardi*. *J Ecobiol* 5:77–79[Google Scholar](#)
33. Mishra PC, Dash MC (1980) Digestive enzymes of some earthworms. *Experientia* 36:1156–1157[CrossRef](#)[Google Scholar](#)
34. Morris GM (2005) Secretory cells in the clitellar epithelium of *Eisenia fetida* (Annelida, Oligochaeta): A Histo chemical and ultrastructural study. *J Morphol* 185:89–100[CrossRef](#)[Google Scholar](#)
35. Nakajima N et al (2003) Earthworm serine protease: characterization, molecular cloning, and application of the protease functions. *J Mol Cat B Enzym* 23:191–212[CrossRef](#)[Google Scholar](#)
36. Nannipieri P, Kandeler E, Ruggiero P (2002) Enzyme activities and microbiological and biochemical processes in soil. In: Burns RG, Dick R (eds) *Enzymes in the environment*. Marcel Dekker, New York, pp 1–33[Google Scholar](#)
37. Needham AE (1962) Distribution of arginase activity along the body of earthworms. *Comp Biochem Physiol* 5:69–82[CrossRef](#)[Google Scholar](#)
38. Nozaki M, Miura C, Tozawa Y, Miura T (2009) The contribution of endogenous cellulose to the cellulose digestion in the gut of earthworm (*Pheretima hilgendorfi*: Megascolecidae). *Soil Biol Biochem* 41:762–769[CrossRef](#)[Google Scholar](#)
39. Paez M et al (1999) Activity and partial characterisation of xylanolytic enzymes in the earthworm *Eisenia andrei* fed on organic wastes. *Soil Biol Biochem* 31:1735–1740[CrossRef](#)[Google Scholar](#)
40. Pan R, He RQ et al (2011) An enzyme from the earthworm *Eisenia fetida* is not only a protease but also a deoxyribonuclease. *Biochem Biophys Res Commun* 407:113–117[CrossRef](#)[Google Scholar](#)

41. Park SC, Smith TJ, Bisesi MS (1993) Bioactivation of bis[p-436 nitrophenyl] phosphate by phosphoesterases of the earthworm *Lumbricus terrestris*. *Drug Chem Toxicol* 16:111–116 [CrossRef](#) [Google Scholar](#)
42. Parle JN (1963) Microorganisms in the intestine of the earthworms. *J Gen Microbiol* 31:1–11 [CrossRef](#) [Google Scholar](#)
43. Parthasarathi K, Ranganathan LS (1998) Pressmud vermicasts are the ‘hot spots’ of fungi and bacteria. *Ecol Environ Conserv* 4:81–86 [Google Scholar](#)
44. Parthasarathi K, Ranganathan LS (1999) Longevity of microbial and enzyme activity and their influence on NPK content in pressmud vermicasts. *Eur J Soil Biol* 35:107–113 [CrossRef](#) [Google Scholar](#)
45. Parthasarathi K, Ranganathan LS (2000) Profiles of enzyme activity in the gut of *Lampito mauritii* and *Eudrilus eugeniae* reared on various substrates. *Trop Ecol* 41(2):251–254 [Google Scholar](#)
46. Paul EA, Clark FE (1996) Soil microbiology and biochemistry, 2nd edn. Academic Press, San Diego [Google Scholar](#)
47. Pfeiffer J (1954) Enzymes, the physics and chemistry of life. Simon and Schuster, New York, pp 171–173 [Google Scholar](#)
48. Prabha ML, Priya MS (2011) Comparative studies on enzymatic levels of vegetable wastes decomposed by *Eudrilus eugeniae* and *Eisenia fetida*. *Adv Biotechnol* 1(4):3–5 [Google Scholar](#)
49. Prabha et al (2005) Macro and micro nutrient changes in vermicomposting of vegetable wastes using *Eudrilus eugeniae*. *South Asian J Socio-Polit Stud* 2:129–130, 156 [Google Scholar](#)
50. Qiao F, Wu C, Li L, Fan R (2001) Some features of intestinal absorption of intact fibrinolytic enzyme III-1 from *Lumbricus rubellus*. *Biochim Biophys Acta* 1526:286–292 [CrossRef](#) [Google Scholar](#)
51. Ramalingam R (1997) Studies on the life cycles, growth, and population dynamics of *Lampito mauritii* (Kinberg) and *Eudrilus eugeniae* (Kinberg) cultured in different organic wastes and analysis of nutrients and microbes of vermicomposts. PhD thesis, Annamalai University, India [Google Scholar](#)
52. Ranganathan LS (1999) Pressmud as organic fertilizer for sustainable farming. *Worm Dig* 22:18–19 [Google Scholar](#)
53. Richmond PA (1991) Occurrence and functions of native cellulose. *Biodegradation* 5:5–23 [Google Scholar](#)

54. Rouland C, Lepage E (1991) The role of the symbiotic fungus in the digestive metabolism of several species of fungus-growing termites. *Comp Biochem Physiol* 99A:657–663[CrossRef](#)[Google Scholar](#)
55. Satchell JE, Martin K (1984) Phosphatase activity in earthworm faeces. *Soil Biol Biochem* 16:191–194[CrossRef](#)[Google Scholar](#)
56. Schimel JP, Bennet J (2004) Nitrogen mineralization: challenges of a changing paradigm. *Ecology* 85:591–602[CrossRef](#)[Google Scholar](#)
57. Shcrader S, Martin F (2000) Importance of food quality on selected enzyme activities in earthworm casts (Dendrobaena octaedra, Lumbricidae). *Soil Biol Biochem* 32:1191–1196[CrossRef](#)[Google Scholar](#)
58. Shwetha M (2012) Cellulolysis: a transient property of earthworm or symbiotic/ingested microorganisms? *Int J Sci Res Publ* 2(11), ISSN 2250-3153[Google Scholar](#)
59. Spier TW (1977) Studies on climosequence of soils in tussock grasslands. 11. Urease, phosphatase, and Sulphatase activities on top soils and their relationships with other properties including plant available sulphur. *N Z J Sci* 20:159–166[Google Scholar](#)
60. Sruthy PB et al (2013) Screening of earthworm *Eudrilus eugeniae* gut as a transient microbial habitat. *Adv Zool Bot* 1(3):53–56[Google Scholar](#)
61. Strasdine GA, Whitaker DR (1963) On the origin of the cellulase and chitinase of *Helix pomatia*. *Can J Biochem Physiol* 41:1621–1626[CrossRef](#)[Google Scholar](#)
62. Tabatabai MA (1984) Soil enzymes. In: Page AL, Miller R, Keeny DR (eds) Methods of soil analysis. Soil Science Society of America, Madison, pp 903–947[Google Scholar](#)
63. Tang Y, Liang DC, Jiang T, Zhang J, Gui L, Chang W (2002) Crystal structure of earthworm fibrinolytic enzyme component A: revealing the structural determinants of its dual fibrinolytic activity. *J Mol Biol* 321:57–68[CrossRef](#)[Google Scholar](#)
64. Tate RL (2000) Soil microbiology, 2nd edn. Wiley, New York[Google Scholar](#)
65. Tillinghast EK, MacDonnel PC (1973) The distribution of ammonia-generating enzymes along the intestine of the earthworm, *Lumbricus terrestris* L. *J Exp Zool* 185:153–1523[CrossRef](#)[Google Scholar](#)

66. Tiwari SC, Tiwari BK, Mishra RR (1989) Microbial populations, enzyme activities and nitrogen-phosphorus-potassium enrichment in earthworm casts and in the surrounding soil of a pineapple plantation. *Biol Fertil Soils* 8:178–182[CrossRef](#)[Google Scholar](#)
67. Tracey MV (1951) Cellulase and chitinase of earthworms. *Nature* 167:776–777[CrossRef](#)[Google Scholar](#)
68. Trigo D, Barois I, Garvín MH, Huerta E, Irisson S, Lavelle P (1999) Mutualism between earthworms and soil microflora. *Pedobiologia* 43:866–873[Google Scholar](#)
69. Ueda M, Noda K, Nakazawa M (2008) A novel anti-plant viral protein from coelomic fluid of the earthworm *Eisenia foetida*: purification, characterization and its identification as a serine protease. *Comp Biochem Physiol B* 151(4):381–385[CrossRef](#)[Google Scholar](#)
70. Urbasek F (1990) Cellulase activity in the gut of some earthworms. *Rev Ecol Biol Soil* 27:21–28[Google Scholar](#)
71. UrbaSek E, Pizl V (1991) Activity of digestive enzymes in the gut of five earthworm species (Oligochaeta; Lumbricidae). *Rev Ecol Biol Sol* 28(4):461–468[Google Scholar](#)
72. Vinceslas-Akpa M, Loquet M (1996) Activity and origin of cellulasic enzymes in gut of the earthworm *Eisenia foetida Andrei*. *Acad Sci* 319:1113–1117[Google Scholar](#)
73. Vinoth SP et al (2000) Enhanced phosphatase activity in earthworm casts is more of microbial origin. *Curr Sci* 79(9 (10)):1158–1159[Google Scholar](#)
74. Wenli L, Wang C, Sun Z (2011) Vermipharmaceuticals and active proteins isolated from earthworms. *Pedobiologia* S54:S49–S56[Google Scholar](#)
75. Willem V, Minne A (1899) Eechcrches sur l'excretion chez quelques annelids. c Mfan. couronnes ot Mem. des Savants etrangers. Acad. R. de Belgique, Classe des Sciences lviii, p 72, Pis. i–iv[Google Scholar](#)
76. Wu C, Li L, Zhao J (2002) Effect of aaMon earthworm fibrinolytic enzyme III-1 from *Lumbricus rubellus*. *Int J Biol Macromol* 31:71–77[CrossRef](#)[Google Scholar](#)
77. Wu JX, Zhao XY, Pan R, He RQ (2007) Glycosylated trypsin-like proteases from earthworm *Eisenia fetida*. *Int J Biol Macromol* 40:399–406[CrossRef](#)[Google Scholar](#)

78. Xu Z, Yang Y, Gui Q, Zhang L, Hu L (2010) Expression, purification, and characterization of recombinant lumbrokinase PI239 in Escherichia coli. *Protein Expr Purif* 69:198–203[CrossRef](#)[Google Scholar](#)
79. Yousuf AS, Gohary EZ (1994) Ultrastructural localization of acid and alkaline phosphatases, glucose-6-phosphatase and sodium-potassium ATPase enzymes in the neurosecretory and oesophageal cells of earthworm. *Qatar Univ Sci J* 14:113–121[Google Scholar](#)
80. Zhang BG, Rouland C, Lattaud C, Lavelle P (1993) Activity and origin of digestive enzymes in gut of tropical earthworm *Pontoscolex corethrurus*. *Eur J Soil Biol* 29:7–11[Google Scholar](#)
81. Zhao J, Qi SP, Wu J, Li L, He RQ (2005) Bioactive natural products (Part K): earthworm fibrinolytic enzyme. *Stud Nat Prod Chem* 30:825–847[CrossRef](#)[Google Scholar](#)

© Springer International Publishing Switzerland 2016