Journal of Traditional and Complementary Medicine Vo1. 2, No. 4, pp. 242-248

Journal of Traditional and Complementary Medicine
Journal homepage http://www.jtcm.org

Dilong: Food for Thought and Medicine

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ABSTRACT

Earthworms have several names in different countries (In Chinese: 地龍 dì lóng, Japanese: Mimizu, Korean: Jireongi, Spanish: Lombriz de tierra, French: Ver de terre, German: Regenwurm, Italian: Lombrico, Swedish: Daggmask, Portuguese: Minhoca). They have long been used as a food source as well as treatments of various ailments. Many alternative and traditional disciplines of medicine, such as those in China, Japan, and Korea, developed medicinal uses of dilong from an initial utilization as nutrition. Increased curiosity in the potential medicinal properties of dilong has come to fruition through bioprospecting and evidence based research. This increased questioning and searching spawned first from a growing knowledge base about the earthworm's innate immune system. Their importance in understanding the evolution of the innate immune system has long been overlooked because of the ecological importance in soil preservation, earthworm immune systems, being full of leukocytes and humoral products, offer significant advantages when used as medicines. Earthworms offer an unanticipated slew of potential health benefits without common drawbacks that come with other biological, alternative forms of medicine such as cost, ethical and pathological concerns of animal testing.

Keywords: Earthworms (Dilong); Food; Natural Products

INTRODUCTION

Earthworms as an experimental animal model

It is a bit curious that one lowly animal better known as bait for fish while dangling from a fishing rod has risen to a significant level of importance to biomedical research (Cooper et al., 2012). How did this happen? First the earthworm was a cherished creature during youth (Cooper, 2008). Of course this was hardly comparable to what was known during the earliest periods of biological research, especially with respect to transplantation (Loeb, 1945; Joest, 1897; Korschelt, 1896-1898; Leypoldt, 1911; Rabes, 1902). Much earlier of course came the book of Darwin on earthworm behavior which actually outsold his *Origin of Species* (1859) when it was first published. According to Charles Darwin (1881), "it may be doubted if there are any other animals which have played such an important role in the world as these lowly organized characters." His specific interests involved *Lumbricus terrestris's* ability to filter soil directly into their vertical burrows. In fact, Darwin's *The Formation of Vegetable Mold Through the Action*, a publication surveying his interest, superseded his *Origin of Species* in readership as well as popularity during

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his life. These environmental observations that include aspects of behavior have actually been replicated in recent times as well (Paoletti, 1999; Tanara, 1983).

Searching for the earthworm's immune system

Now let us move rapidly to the time for choosing projects during the early 1960s when immunology was budding. There was the zeal to demonstrate that the earthworm would be a perfect animal to add to the singular mouse model, as one to help decipher one aspect of immunity: the graft rejection response (Cooper, 1968a; Cooper, 1969a; Cooper and Roch, 1986). Exchanging grafts between two earthworms worked, i.e. this was not a technical feat – easy- and after the grafts healed and enjoyed a period of perfect acceptance accompanied by ingrowth of nerves and blood vessels. Something happened as predicted; self tissue, i.e. autografts healed and stayed permanently- never ever being disturbed by the hosts' putative immune system. However non-self grafts (xeno between species and also within species) did as proposed- healed but gradually underwent rejection: not-self was destroyed.

This was not enough as proof that earthworms did in fact possess an immune system! What if earthworms were confronted with another type of non-self material (e.g. soluble or particulate antigen)- what would the earthworm's immune system do to a bacterium or any other insult- particulate non-tissue? In a matter of a few minutes after encountered- there was an immediate destruction! Such reactions were consistent, without exception- host earthworms do not accept foreign material including cancer cells from other species. There is still much to be discovered. Earthworms kill other cancers but they do not develop cancer themselves- a still unexplained reaction in earthworms and all other invertebrates (Cooper, 1968b; Cooper, 1969b).

Bioprospecting aids a search for useful molecules

Curiosity is crucial to any creative activity including the now no longer curious immune system of earthworms nor any other invertebrates. However, bioprospecting a systematic search for therapeutic molecules lead to the discovery of dilong, the Chinese name for earthworm and the magically opened door to an area worthy of evidence based medicine (Cooper, 2004). Invertebrate organisms as a whole offer a wide range of interesting and complex topics for investigation in regards to understanding biological processes. While earthworms, the largest of the *Oligochaeta* phylum *Annelida*, have medicinal properties, they are also related to various other species, such as leeches, that have been shown to exhibit therapeutic benefit as well (Wells et al., 1993). Specifically, earthworms, have been vital to investigations of developmental organizations of the nervous (Herbert et al., 2009), immune (Bilej et al., 2010; Engelmann et al., 2011), and endocrine systems (Boros et al., 2010; Wilhelm et al., 2006). Not only are earthworms important in understanding biological processes of development, but also their well-known significance to ecosystems, specifically their ability to improve soil fertility (Syers and Springett, 1984). Aside from the importance to immune, nervous, and endocrine systems as well as ecology, we will now examine effects of whole earthworms and extracts on mammalian biological functions.

Historically and culturally, earthworms have been utilized as a form of nutrition as well as treatment for specific conditions as traditional forms of medicine such as those in Asia. The field of examining the potential health benefits of consuming earthworms owes its increasing interest to bioprospecting (Cooper et al., 2004; Cooper, 2005). Researchers have discovered that in addition to ecological benefit, specifically soil preservation, the long neglected earthworm innate immune system holds the key to these observed medicinal qualities (Cooper and Roch 2002, Salzet et al., 2006). Many other forms of alternative medicine are restricted by ethical and economic concerns of animal testing, but using earthworms largely avoids these restrictions and inhibitions. Let us first examine earthworms at an organismic level by looking at few examples of popular opinion within different cultures that utilize or have utilized earthworms as a food source. Then we will draw connections from their use as food to use as a therapeutic.

IS THERE A UNIVERSAL OPINION ABOUT EARTHWORM CONSUMPTION?

The idea of eating earthworms tends to be repulsive. When one first thinks of earthworms the words "slimy," "gross," and "dirty" commonly come to mind. Rozin et al. (1984) conducted a study that attempted to give the word "disgust" a wider gamut of semantic usage by establishing a scale that measures disgust. Darwin explained that the use of the word "disgust" has not only applied to descriptions of taste throughout history, but also the consumption of hazardous substances (1965). Following suit, earthworms would carry connotations with soil and therefore human and animal waste. Furthermore, psychologists have shown that this causes

a visual aversion, specifically in women, to parasitic-like organisms, like the earthworm (Angyal 1941). Also, Prokop and Fancovicova (2010) propose that natural selection played a role in development of this aversion. Since, alternative sources of protein are readily available in western nations, the earthworm is not commonly utilized as a nutritional source of food. Conversely, in tropical regions where these other sources of protein are not readily available, earthworms are regularly used as the primary protein source. As we can see, culture plays an enormous role in dictating accepted and popular dietary practices and customs. Here are specific instances of human earthworm consumption.

NUTRITIONAL BENEFITS OF A DIET OF EARTHWORMS (DILONG)

Earthworms have long been utilized as a form of nutrition. Sun et al., (1997) found that earthworms contain 78-79 g/L free aminos and they contain a high concentration of important vitamins and minerals such as iron and calcium. Furthermore, Paoletti et al (Paoletti et al., 2003) investigated the diet of Amerindians of the Amazonas in Venezuela. They found that these peoples used leaf and litter-feeding invertebrates as a primary source of proteins, fats, and essential vitamins (Paoletti and Dufour, 2005). Paoletti also found that the kuru and motto earthworm species eaten by the Ye' Kuana contain significant amounts of calcium, iron, and other nutrients (Paoletti and Dufour, 2005). Therefore, it seems that a new initiative becomes essential to establishing a sustainable population of earthworms; they could then be used for consumption and at the same time a source for maintaining biodiversity in natural ecosystems. Moreover, even in modern day society, there are individuals that eat earthworms and also teach others how to cook them via the internet (Louise, 2012). Claire Louise states on eHow.com, "Earthworms can be a nutritious addition to the human diet due to their high levels of protein, with some types of earthworms containing 60-70 percent protein. Their bodies contain very little fat and are easy to cook as there are no bones." It seems fortuitous that with the ingestion of earthworms as food, civilizations developed the capacity to use them for certain ailments, especially the ancient cultures of China and India (Solavan et al., 2004; Zhenjun et al., 1997).

WHAT ARE THE MEDICINAL PROPERTIES OF EARTHWORMS?

Earthworms have long been documented to exert medicinal effects as well as nutritional benefits (Reynolds and Reynolds, 1972, Stevenson, 1930). For example, earthworms are used to treat certain disorders often assigned to the realm of herbal medicine. Moreover, this medicinal quality is associated with nutritional benefit and vice versa. This seems to be the basis of herbalistic medicines: Traditional Chinese Medicine (TCM), Ayurveda (India), Western (Mediterranean origin), and Traditional Arabic and Islamic Medicine (TAIM). For example, effects on inflammatory, oxidative, hematological, and biochemical serum indicators by the use of an earthworm paste have been observed (Balamurugan et al., 2007; Balamurugan et al., 2008; Balamurugan et al., 2009; Prakash et al., 2007). Lumbrokinase, an organic compound derived from earthworms has been shown to offer a wide range of health benefits (Cooper and Balamurugan, 2010) (Table 1). Lumbrokinase is now used as a dietary supplement. Some of its use centers around reducing inflammation as a result of hypercoagulation in other diseases (Table 2).

Table 1. Health benefits of Lumbrokinase[1]

Dissolve blood clots and protect against ischemic heart disease and stroke
Lower fibrinogen levels in cancer patients, which betters outcomes, leads to less metastasis, and slows growth of tumors
Dissolve bacterial biofilms that protect microbes from antimicrobial medication in conditions like Autism and Lyme disease
Shows antiplatelet, anti-thrombotic, and anti-apoptotic activity, which regulates hypercoagulation

[1]Adapted from Cooper and Balamurugan, 2010.

Table 2. Conditions associated with hypercoagulation[1]

Cancer, Elevated serum fibrinogen, serum CRP, Lp[a], and homocysteine, Vascular dementia, Diabetes, Angina, Autism, Fibromyalgia, Heart Attack history, ADD/ADHD, Crohns's Disease, Transient ischemic attacks, Habitual miscarriages, Lyme Disease, Ischemic stroke history, Infertility, Multiple sclerosis, On birth control pills or hormone replacement therapy, Meniere's Disease, Thrombocythemia, Chronic Fatigue Syndrome, Deep venous thrombosis, Chronic Infections, Being on long air flights, Lupus, Hip fracture, Gulf War Syndrome, Ulcerative colitis, Excessive heavy metal burden, Polycythemia

[1]Adapted from Cooper and Balamurugan, 2010

MEDICINAL PROPERTIES THAT AFFECT THE NERVOUS SYSTEM

Additional biochemical benefits of earthworm extracts have been investigated. Noting the earthworm's ability to regenerate severed body members, Wei et al. (2009) used *Lumbricus*, a widely known earthworm in

Traditional Chinese Medicine, extract to show increased nerve cell regeneration in damaged nerves in rats. Also, Chang, Kuo, and Lai et al. (2009) showed that earthworm extracts could actually affect MAPKs (ERK ½, p38)-, Pas (uPA, tPA)-, and MMP (MMP2, MMP9) signaling pathways in Schwann cells. Chang, Shih and Chen et al. (2009) supported the claim that administered earthworm extracts promote nerve regeneration. Furthermore, Chen et al. (2010) found that another earthworm species, *Pheretima aspergillum*, promotes PC12 cell differentiation and development of new axons in peripheral nerve damage. In conclusion, Chang et al. (2011) found that Schwann cell development is largely associated with the healing of damaged nerves.

HEMISPHERIC DISTRIBUTION OF EARTHWORMS

The earth is divided up into hemispheres: North, South, East and West and earthworms are found across all of them, albeit only in very particular conditions. Earthworms require a delicate balance of pH, moisture, and availability of food in the soil that they live in. While each species of worm is different, generally they need wet and nutrient rich soil to survive. Since they respire through their skin, earthworms cannot stay out of the moist soil for very long. Earthworms would not be found in any part of any hemisphere that does not contain sustainable levels of moisture. Additionally, earthworms help to enrich the soil by breaking down organic matter. Earthworms can be found all around the world, in the various hemispheres, where the conditions are right. In this paper we will look specifically at regions divided between the Northern and Southern hemispheres where the conditions are right for food, medicine, accompanied by cultural rituals (Figure 1).

How are earthworms used in the Southern Hemisphere?

The Maori, or indigenous Polynesian population of New Zealand as well as various Australian aboriginal populations have been noted to use earthworms as food sources. Benham (1904) examines the Maori cultural practice of consuming earthworms and their naming, specifically, eight different kinds, (*Kuharu, Noru, Wharu, Tarao, Pokotea, Tai, Kurekure, and Whiti*) (Best, 1902). The last two, which are commonly known for their sweet taste, customarily are offered as a last sacrifice (*o matengo*) after a person has passed on. Australian aborigines incorporated earthworms and insects as additional dietary sources (Spencer and Gillen, 1904). Some of them have also been considered in conjunction with totemic animals. The Aranda aborigines have been known to participate in a special ceremony that symbolizes and stimulates the proliferation of earthworms, which are incredibly important to their survival (Grottanelli, 1965). Consumption of earthworms has also been observed

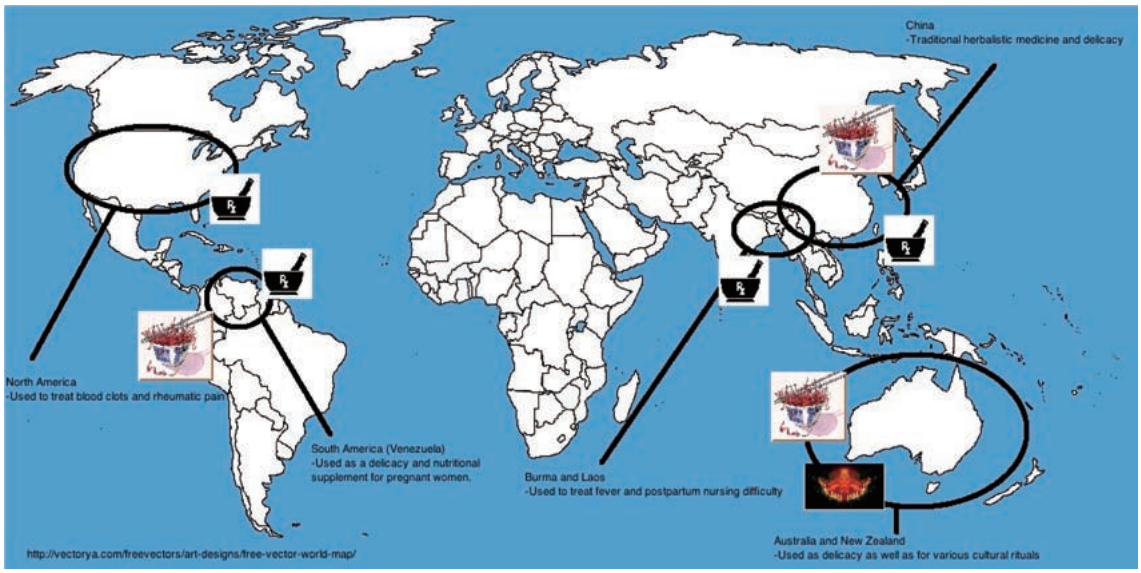

Figure 1. Medicinal, nutritional, and cultural uses of earthworms in North America, South America, Southeast Asia, China, Australia, and New Zealand. Legend: - Culture that utilizes earthworms for cultural ritual practices. (Source: http://jeanraffa.wordpress.com/2011/06/25/the-value-of-ritual/) - Delicacy- Culture that utilizes earthworms for nutrition (Source: unknown) - Rx- Culture that utilizes earthworms as medicine. (http://thegoodgravy.wordpress.com/2012/07/03/an-ode-to-rx/) Photos Adapted from: http://vectorya.com/freevectors/art-designs/free-vector-world-map/;

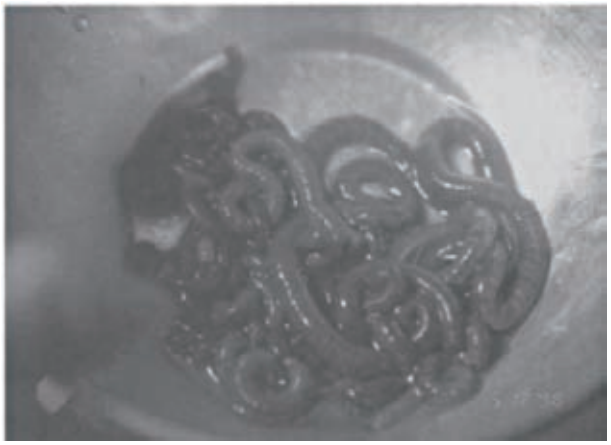

Figure 2. The Andiorrhinus motto earthworm, the species of earthworm that the Ye'Kuana tribe of the Amazon has particular interest in. (photograph M.G. Paoletti)

as a cultural practice in the nomadic culture along the Salumei River in Papua New Guinea (Tommaseo-Ponzetta, Personal Communication). The purpose of earthworm consumption can also be of practical nutritional value such as in the Ye'Kuana and the Piaroa of Alto Orinoco and the Maori (Paoletti et al, 2003).

Earthworms are an important source of not only food but also traditional, cultural practice as well in South America. The Ye'Kuana tribe of Alto Orinoco upholds the earthworm as a delicacy and is actually coveted more than fish and other meats. The tribe regularly consumes two species of earthworm and has classified sixteen (Paoletti and Dufour, 2005) using different names. There are also common traditional practices involving earthworms in this tribe. Women are commonly fed motto and kuru in the first month after childbirth as well as during the pregnancy (Paoletti et al., 2003). These sweet annelids are also used by immobile individuals as well as those suffering from anemia (Paoletti et al., 2003; Paoletti and Dufour, 2005). This requires further investigation. Ye' Kuana's interest in earthworms is evident by their consumption of the species, Andiorrhinus motto. (Figure 2)

Northern Hemisphere uses earthworms as different treatments

Traditionally, earthworms have been used to treat a variety of diseases in Burma and Laos. The main disease that earthworms are used to treat in Burma is called *ye se kun byo*, which is commonly associated with fever. Usually, the ashes of scorched earthworms are used either as a powder or mixed with other ingredients to make them taste better (Gates, 1926). Another application is for *meephwanoyeekhun thwaykhan*, which leaves women unable to nurse their newborns. Here, the remedy is created from earthworms in a liquid form. The consumption of earthworms does carry a stigma with it, so the patients are treated unknowingly.

Similarly in China, earthworms as well as other arthropods are a part of traditional herbalistic medicine (Bristowe, 1932; Zimian et al., 1982). Earthworms have been and currently are considered delicacies and medicines in Taiwan as well as Fujian and Guangdong provinces (Zhenjun, 2005; Gernet, 1959; Zeng et al., 1982). TCM has long found medicinal value in earthworms as evidenced by *The Eu Yan Sang Heritage: An Anthology of Chinese Herbs and Medicines*. (Cooper et al., 2004, Eu Yan Sang International Holdings Pte Ltd, 269A South Bridge Road, Singapore 05818). Also, various Middle Eastern cultures perceive earthworms as a massively effective treatment. For example, earthworms are used in a variety of ways and utilized to treat a number of diseases, such as bladder stones, jaundice, and alopecia (Gates, 1926).

North American Cherokee Indians used earthworm poultices to remove thorns (Carr, 1951). Also, the Nanticoke Tribe of Delaware has used earthworms to treat rheumatic pain (Carr, 1951; Price, 1901). While the biochemical mechanism is not well understood for these cures, there is some evidence that earthworm lipids contain specific fatty acids that confer a therapeutic effect. Cooper et al. concluded that an earthworm extract, the bronchial dilating substance lumbrokinase, can be isolated and used to treat blood clots (2004). Native American medical practices have long been perceived as merely fantasy and tribal custom, but we must remember that all established medicine at some point in history started out as this kind of mythical lore.

EARTHWORM PRODUCTS: POSSIBLE ROLE IN INTEGRATIVE MEDICINE

What is the current status of the discipline in the broadest context? Recently a special publication included a selection of research presented at the Ninth International Symposium on Earthworm Ecology (ISEE9) held in Xalapa, Veracruz, Mexico from September 5-10, 2010. For this meeting, there were several themes and the most pertinent of the eight themes: Earthworm Immunology and Physiology (Fuller-Espie et al., 2011; Mazur et al., 2011) In addition there was a relevant workshop Earthworms and Medicine organized by Zhenjun Sun (Li et al., 2011; Wang et al., 2011). The first of these papers in the medicine section is also pertinent to the very extensive review dealing with Lumbrokinase and its anti-platelet

and anti-Thrombotic Activity (Cooper, 2009); sources of medicinal molecules (Cooper and Balamurugan, 2010; Cooper et al., 2012).

PERSPECTIVES AND FUTURE DIRECTION

From this very brief review, we witness a promising and worth area of research. This could focus on the earthworm as a source of food. Moreover, there is clearly a need to extend the clinical applications of earthworms. While earthworms may not necessarily be the first dish that comes to mind when thinking of delicacy and nutrition, there is much proof that they should. Seeing that earthworms have been used so widely throughout history in various cultures and societies, it is surprising that we have not realized these qualities sooner. From the northern to southern hemispheres, earthworm consumption is seen everywhere that they naturally are found. Springing forth from dietary practice, the use of earthworms as medicine has a long and substantive history. Their observed benefits to cancer survival and circulatory health are just one facet of the ever growing knowledge base about the benefits of our friend the earthworm. We predict that the use of earthworms as nutrition and medicine will continue to gather speed and following as pertinent research and interest increases.

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