Ribogospod. nauka Ukr., 2018; 4(46): 26-48
DOI: 10.15407/fsu2018.04.026
УДК: 639.3:595.142.39

Received 03.09.18
Received in revised form 18.09.18
Accepted 24.10.18

RED CALIFORNIAN EARTHWORM (*EISENIA FOETIDA ANDREI*) AS A VALUABLE FOOD ITEM IN FISH FARMING (REVIEW)

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Purpose. *To analyze a selection of professional literature and summarize the information on the vermiculture of the Red Californian earthworm (Eisenia foetida andrei). To present the achievements of modern biotechnology of this species. To consider the features of different cultivation methods, as well as the possibilities and prospects of its use as a food item in aquaculture.*

Results. *This work contains brief information on the biology and artificial selection of this species of lower invertebrates, its use in fish farming, as well as in other branches of the national economy. Currently, the market presents several hybrids of this species, adapted to local climatic conditions. This is the reason to consider the features of the production characteristics of hybrids of the Red Californian earth worm from different countries.*

The article provides recommendations on the specificity of procurement of the breeding culture, optimal methods of further cultivation depending on the needs of the farms, the main requirements for the substrate and feed, as well as methods for assessing the quality of the obtained biomass. Data on the amino acid composition of flour made of the Red Californian earthworm are given, its fodder value in comparison with traditional feeds for fish, and the specifics of feeding various species of fish. The work presents a method for preparation of starter feed for carp fish using technology developed by Yevtushenko M. Yu.

An overview of scientific studies has revealed that the Red Californian earthworm is optimally used not only as a valuable high protein feed for multi-aged fish groups, but also for the production of organic fertilizers – biocompost. The latter was widespread not only in crop production, but also in the recultivation of different soils.

Practical significance. *The summarized information will be useful for researchers who are exploring ways to optimize fish feeding. The presented technology of cultivating red Californian earthworms is most palatable for fish farms of different types of aquaculture. Obtaining biocompost as a valuable by-product of vermiculture provides an opportunity for their integrated development and obtaining additional profit.*

Key words: *red Californian earthworm (Eisenia foetida andrei), vermiculture, aquaculture, fodder organisms, biocompost.*

ЧЕРВОНИЙ КАЛІФОРНІЙСЬКИЙ ЧЕРВ'ЯК (*EISENIA FOETIDA ANDREI*) — ЦІННИЙ КОРМОВИЙ ОБ'ЄКТ У РИБНИЦТВІ (ОГЛЯД)

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Мета. *Проаналізувати масив спеціальної літератури та узагальнити отриману інформацію щодо вермикультури червоного каліфорнійського черв’яка (Eisenia foetida andrei). Дати уявлення щодо досягнення сучасної біотехнології даного виду, розглянути особливості його культивування різними методами, а також можливості і перспективи використання в якості кормового об'єкта в аквакультурі.*

Результати. *Дана робота містить коротку інформацію з біології та селекції цього виду нижчих безхребетних, його застосування як в рибництві, так і в інших галузях народного господарства. На даний час на ринку представлено кілька його гібридів, пристосованих до місцевих кліматичних умов. Саме тому розглянуто особливості продукційних характеристик гібридів червоного каліфорнійського черв’яка з різних країн.*

У статті викладені рекомендації щодо специфіки закупівлі маточної культури, оптимальні методи подальшого культивування в залежності від потреб господарств, основні вимоги до субстрату і корму, а також способи оцінки якості отриманої біомаси. Наведено дані стосовно амінокислотного складу борошна з червоного каліфорнійського черв’яка, показники його кормової цінності в порівнянні з традиційними кормами для риб, специфіки згодовування різним видам риб. Представлено варіант приготування стартового корму для коропових риб за технологією, розробленою М. Ю. Євтушенком.

Огляд наукових праць виявив, що червоного каліфорнійського черв’яка оптимально використовувати не лише в якості цінного високобілкового корму для різновікових груп риб, але й для виробництва органічного добрива — біогумусу. Останній отримав широке поширення не тільки в рослинництві, а й при рекультивації різних ґрунтів.

Практична значимість. *Масив узагальненої інформації буде корисним для науковців, які досліджують шляхи оптимізації годівлі риб. Представлена технологія культивування червоного каліфорнійського черв’яка оптимальна для рибницьких господарств різних типів ведення аквакультури. Отримання біогумусу в якості цінного побічного продукту вермикультури дає можливість для їх інтегрованого розвитку і отримання додаткового прибутку.*

Ключові слова: *червоний каліфорнійський черв'як (Eisenia foetida andrei), вермикультура, аквакультура, кормові організми, біогумус.*

КРАСНЫЙ КАЛИФОРНИЙСКИЙ ЧЕРВЬ (*EISENIA FOETIDA ANDREI*) — ЦЕННЫЙ КОРМОВОЙ ОБЪЕКТ В РЫБОВОДСТВЕ (ОБЗОР)

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Цель. *Проанализировать массив специальной литературы и обобщить полученную информацию касательно вермикультуры красного калифорнийского червя (Eisenia foetida* *andrei). Представить достижения современной биотехнологии данного вида. Рассмотреть особенности его культивирования различными методами, а также возможности и перспективы использования в качестве кормового объекта в аквакультуре.*

Результаты. *Данная работа содержит краткую информацию по биологии и селекции этого вида низших беспозвоночных, его применения как в рыбоводстве, так и в других отраслях народного хозяйства. В настоящее время на рынке представлено несколько гибридов этого червя, приспособленных к местным климатическим условиям. Рассмотрены особенности продукционных характеристик гибридов красного калифорнийского червя из разных стран.*

В статье изложены рекомендации относительно специфики закупки маточной культуры, оптимальные методы последующего культивирования в зависимости от потребностей хозяйств, основные требования к субстрату и корму, а также способы оценки качества полученной биомассы. Приведены данные по аминокислотному составу муки из красного калифорнийского червя, показатели его кормовой ценности в сравнении с традиционными кормами для рыб, специфике скармливания различным видам рыб. Представлен вариант приготовления стартового корма для карповых рыб по технологии, разработанной Н. Ю. Евтушенко.

Обзор научных трудов выявил, что красного калифорнийского червя оптимально использовать не только в качестве ценного высокобелкового корма для разновозрастных групп рыб, но и для производства органического удобрения — биогумуса. Последний получил широкое распространение не только в растениеводстве, но и при рекультивации различных почв.

Практическая значимость. *Массив обобщенной информации будет полезным для ученых, исследующих пути оптимизации кормления рыб. Представленная технология культивирования красного калифорнийского червя оптимальна для рыбоводных хозяйств различных типов ведения аквакультуры. Получение биогумуса в качестве ценного побочного продукта вермикультуры даёт возможность для их интегрированного развития и получения дополнительной прибыли.*

Ключевые слова: *красный калифорнийский червь (Eisenia foetida andrei), вермикультура, аквакультура, кормовые организмы, биогумус.*

PROBLEM STATEMENT AND ANALYSIS OF LAST ACHIEVEMENTS AND PUBLICATIONS

Vermiculture is the general name of intensive biotechnology, based on the breeding worms for biomass and organic fertilizer called biocompost. Worms are further used as high-quality protein feed, and biocompost is a valuable fertilizer for plants [1]. Most often, the following *Lumbricidae* species are used for this purpose: *Eisenia foetida* — a manure worm (the most popular and most common species of earthworm) and a red Californian earthworm (*Eisenia foetida andrei*) [2]. Currently, many farms grow different hybrids of these worms, adapted to local climatic conditions. For example, the hybrid “Staratel” was obtained by Russian Professor A. M. Igonin by crossing in 1982 two populations of manure worms: the southern Chui and the northern Vladimirsky one [1]. Domestic hybrids of the red Californian earthworm, as well as worms from European manufacturers, are widely represented on the Ukrainian market, the comparative figures of which are discussed below (Table 1) [3].

The incubation period of cocoons is the time from laying the egg cocoon until larvae appear from it. The shorter this period the higher population productivity. Hatchability rate is the number of viable larvae that emerged from one cocoon. The term of sexual maturity of compost worms is the number of days after the larva hatching from the cocoon to becoming a mature individual capable of producing offspring [4]. The shorter it is, the more productive the population is.

Table 1. **Production characteristics of hybrids of the red Californian earthworm, presented on the Ukrainian market**

Production features	Country of origin		
	Hungary	Italy	Ukraine
The number of cocoons, coc. / week.	1	1	0.82
The incubation period, days.	20.3	21.7	23.7
Hatching, larv./coc.	4.7	3.0	2.8
The average weight of an adult worm, g/ind.	0.79	0.66	0.73
The term of puberty, days.	64.9	71.2	67.2

The Red Californian earthworm was bred to accelerate the disposal of organic waste in the late 50s in the United States under the leadership of Thomas Jason Barrett (Thomas J. Barrett, 1884–1975). Working at the University of California, Barrett is the founder of industrial vermicultivation in the United States [1].

The Red Californian earthworm breed is the result of breeding work between a manure worm (*Eisenia foetida*) and a brandling worm (*Eisenia andrei*) from the family of earthworms (*Lumbricidae*) of the suborder of earthworms (*Lumbricina*)[5]. It should be noted that a mixture of closely related species of *E. foetida, E. andrei, E. veneta* and others ia often a cultivated in many Vermiculture farms under the trade name "Red Californian earthworm". These species differ for the worse in their biotechnical indicators from the red Californian earthworm, and it is not easy to distinguish them by morphology. At the same time, it is necessary to take into account that the red Californian earthworm is a breed of intensive type: it is more demanding in terms of feeding and living conditions [6]. Thus, during breeding work, its mobility was reduced, which is convenient when cultivated on vermi farms, but leads to mass death with a decrease in ambient temperature — during frosts it does not go deep into the substrate.

The developed technology of breeding Californian earthworms allowed them to be produced in large quantities and exported to other countries, but their export to the territory of the former USSR was prohibited. Since 1979, the cultivation of the Californian earthworm has acquired significant proportions in Western Europe and Japan [1]. As a result of the selection, a worm was obtained, which differs from its ancestor, the usual earthworm (*Lumbricus terrestris*) in next features [7]:

– reduced mobility (does not attempt to leave the reservoir for cultivation);

– increased vital activity (about 600 kg of biocompost are produced from 1 ton of substrate, and biomass growth is 100 kg);

– increased fertility (up to 22 individuals in a cocoon compared to 3 of an earthworm);

– increased life span (up to 15 years compared to the 4th year of the earthworm);

– high recycling rate (it eats twice as much of its own weight per day).

Californian earthworm is traditionally used for [8]:

– recycling organic waste;
– production of biocompost;
– liquid fertilizer production;
– high-protein feed for fish and animal farming;
– receiving protein flour;
– raw materials for pharmaceuticals (treatment of thrombosis, cancer, trypanosomal infections, microbial infections, as well as diseases of the immune system and inflammation);
– bait for fishing.

Below we consider the main stages of the use of the red Californian earthworm in fish farms: the purchase of brood stock, the actual cultivation and the specificity of the fish feeding.

STUDY RESULTS AND THEIR DISCUSSION

The systematic characteristic of the red Californian earthworm. Domain: eukaryota (*Eukaryota*), kingdom: animals (*Animalia*), group: bilaterians (*Bilateria*), taxon: protostomes (*Protostomia*), clade: spiral (*Lophotrochozoa*), phylum: annelid worms (*Annelida*), class: clitellates (*Clitellata*), subclass: oligochaemal worms (*Oligochaeta*), order: haplotaxids (*Haplotaxida*), suborder: earthworms (*Lumbricina*), family: earthworms (*Lumbricidae*) [3].

Biological characteristic of the red Californian earthworm. The body of a red Californian earthworm is elongated, adults`s body is slightly flattened in the middle. The color of the covers varies from dark red to brownish red, sometimes with a pearl shimmer [4]. The body is divided into segments with two setae on each. The number of segments ranges from 101 to 117. The body diameter ranges from 3 to 5 mm, the average length is from 6 to 14 cm. Weight is from 0.4 to 1 g, body temperature is 16–22 ° C. Lifetime is 13–15 years [9]. The dermo-muscular body wall of the earthworm surrounds a body cavity filled with fluid, where internal organs are located (Fig. 1).

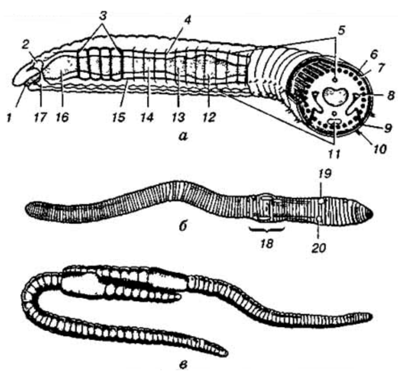

Fig. 1. **Red Californian earthworm *Eisenia foetida andrei***

a – scheme of the structure; b – view from the ventral side; c – two individuals during copulation; 1 – mouth; 2 – suprapharyngeal and 17 - subpharyngeal ganglia; 3 – "hearts"; 4 – segmental, 5 – dorsal and 15 – ventral blood vessels; 6 – skin; 7 – segmental and 8 – longitudinal muscles; 9 – excretory tube (metanephridium); 10 – setae; 11 – ventral nerve chain; 12 – the stomach; 13 – goiter; 14 – the esophagus; 16 – throat; 18 – clitellum; 19 – male, 20 – female genitals.

The body cavity is divided with transverse partitions into chambers by the number of segments. The cells that make up the partitions make up the third layer — the middle layer. It covers the entire body cavity of the earthworm: surrounds the organs of the digestive system and from the inside covers the skin-muscular sac. This layer of cells is present in all multicellular animals, starting with worms [2].

They feed on decaying plant debris, obtaining them from the soil, passing it through the intestines. Food gets first in the foregut, which consists of the pharynx, esophagus, goiter and stomach, then in the mid-intestine, then in the hind intestine, with ending in the anus [9].

Californian earthworms breathe with whole body surface. The sensory organs are weakly developed, and environmental stimuli are perceived by light-sensitive cells scattered throughout the entire cover. The receptors of touch, taste, smell are also located there. The structure of nervous and blood circulatory systems is the same as in all annelids (see signs of type). In each segment of the worm on the ventral side there is a small ganglion. All ganglia are interconnected, forming the ventral nervous chain. In front of this chain, under the pharynx, there is a large subpharyngeal ganglion, and above the pharynx there is the largest nasopharyngeal ganglion. The epopharyngeal and subpharyngeal ganglia are connected by nerve bridges surrounding the pharynx laterally [4]. Both nerve ganglia and bridges form the pharyngeal nerve ring. The nerves come to the different parts of the body of the worm from all the ganglia. The worm has no special sense organs, but it feels a touch on its body, a taste of food, and distinguishes light from darkness. Irritations are perceived by sensitive skin cells that are connected by nerves to nerve ganglia [9]. Great amount of sensitive cells are located at the front end of the body, and the nerves go from them to the ganglia of the pharyngeal nerve ring. The earthworm`s reflexes are much more complex than the reflexes of the coelenterate and flatworm. The earthworm, in contact with the needle, can wriggle in one direction or another, constricting only the front or only the back end of the body. It depends on the more complex structure of its nervous system. They, like the hydra, are capable of regeneration (rebuilds lost or damaged parts of the body) that is a protective function [3].

Reproduction of the Californian earthworm. The Californian earthworm is hermaphrodite and is not capable of self-fertilization. Mature individuals mutually fertilize each other. In front of the body there are the ovaries and testes. Two individuals touch each other with the front ends, where there is a clitellum. By this time, the worm's sperm accumulates in them. Sperm are exchanged: sperm from the clitellum of one individual is transferred to the seminal receptacle of another one [7]. After that, the worms go off. Fertilized eggs are separated from the body of the worms and placed in a protein ring, or capsule (cocoon), which is first yellow and then brown. As a result of mating of two individuals, 2 eggs or capsules are formed, 1 for each of the individuals. Cocoons open after aging in 3–4 weeks (depending on the temperature, humidity and acidity of the substrate). From 2 to 22 individuals are born from each capsule [9]. Cocoons contain liquid rich in protein that feeds young animals by the time of hatching. Young worms are white. Under optimal conditions, maturity begins 2–3 months after leaving the cocoon. The fertility of the Californian earthworm is up to 2 thousand individuals per year. In the cold season, sexual activity decreases, as well as in particularly hot months. The highest sexual activity occurs at a substrate temperature of 20 ° C. Under optimal conditions, mating can occur every week [8].

Purchase of breeding stock of red Californian earthworm is the first stage of its biotechnology breeding. Worms shouls be bought along with the substrate only in specialized vermi farms [10]. The seller must have permission to sell worms, issued by the quarantine service. Sometimes nematodes are sold instead of young Californian earthworms, so purchaser should be cautious. The substrate must contain young worms and cocoons. High-quality breeding stock of red Californian earthworm (family) has at least 1500 individuals [11]. Worms must be motile and red. At first they are kept in their native substrate, to get used to the new feed. The seller must inform in detail exactly what the worms ate before selling. Such additional feed should be given to the worms in the new conditions at the first time, gradually giving them other types of feed. At first they are kept in their native substrate, to get used to the new feed. Sometimes nematodes are sold instead of young Californian earthworms. The seller must have permission to sell worms, issued by the quarantine service [12].

Cultivation of the red Californian earthworm is carried out by several methods, based on its ability to spread over three levels of depths. The first level is the surface horizon (5–7 cm); it is a fresh substrate, which is a food for worms. Its quantity is constantly changing, since the worms feed on it constantly, and this layer is applied periodically [13]. The middle level is 10–30 cm; it is the working area where the major amount of worms live. The third level is the accumulator of biocompost; as the worms work it is constantly increasing in height. Based on this zoning and biotechnological requirements, various vermicomposters are most often used; these are boxes (wooden or plastic), storage pits (beds), less often compost heaps or pits [10, 14].

Storage pits, baskets and boxes are used most actively. The main disadvantages of vermicomposting using piles, wedge system and storage pits are: intensive manual labor, large areas, difficulty in maintaining humidity, slow processing of waste, difficulties in collecting vermicompost without worms [10, 12, 15] .

There are 2 main types of technology for the cultivation of worms: open one (not indoors, rarely applicable for the Californian earthworm) and closed one (in vermicomposters of various designs). When using any technology, it is necessary to have a stock culture in case of unforeseen circumstances such as the death of the main culture [11, 16].

An open or trench method of growing worms involves breeding worms in piles or storage pits on the ground. The following parameters of storage pits are used: width: 1.2–2 meters; height 20–30 cm; length: any. It is recommended to leave the passage between them of such a width to ensure the maneuverability of the tractor with a trailer. When cultivating worms using this technology, there are two variations. In the first case, a wooden frame with a height of 40 cm is knocked down on the sides of the pile [17]. In the case of using boards, a more favorable microclimate is created for the activity of worms. In the second case, the pile is formed without boards. In this case, labor productivity increases, but the worms poorly process the substrate ventilated from the edges. In the bottom the pile is underlain by plastic wrap to protect against moles. The film must be perforated to drain water. With a large number of moles, a fine-mesh metal net is used [13, 14, 18].

Settling the worm into storage pits. Although the Californian earthworm easily gets used to a different feed, when using different composts we recommend a trial settlement. For this, they a little amount of ready substrate is put into the storage pit and 50-100 adult worms are put there, permissible waste after 24 hours is no more than 10 individuals, otherwise the substrate is not suitable for further settlement. Increased acidity or alkalinity may be the cause of death of worms [12, 19]. It is very important not to allow any contact with the metal, which is a strong oxidizing agent. With increased acidity, limestone or chalk is added, with increased alkalinity – straw, sawdust or tops of plants. The optimum stocking density is from 1 to 3 families per 1 m^2. The optimal number of adult worms for vermicultivation is from 750 to 1500 individuals per 1 m^2, with a substrate height of 25 cm [13, 18, 20].

Removing worms from storage pit. Breeding Californian earthworms is better to start in the warm season, then after a couple of months can be collected. The worm is chosen in this way: the worms are not fed for 2–3 days to be hungry, then 7–10 cm of fresh compost is put at the top of the pit or box and removed after one day. 60–80% of mature worms enter fresh compost; young worms and cocoons remain in the lower substrate [20, 21]. The removal of worms is repeated several times. Nevertheless, it is not possible to collect all the worms in this way, 3-4% remains in recycled compost, which is already a fertilizer, the biocompost. The collected worms are put in new pits or used in feeding fish [16, 22].

Wintering worm in storage pits. The most significant disadvantage of the Californian earthworm is the weak self-preservation instinct. At negative temperatures, they do not go deep into the ground, gather in one lump and die. It can be concluded that the cultivation of the red Californian earthworm in the winter period is connected with the maintaining optimum temperatures necessary for their vital activity. At a temperature of 14 ° C, the worms stop feeding, at 10 ° C they clean out the digestive tract and fall into anabiosis [19, 21, 23]. To insulate the storage pits, 25–40 cm of fresh compost or fermented manure is laid on them, watered and covered with 40–50 cm of hay or straw. No more than 10 cm of substrate freezing is allowed [18, 19, 24].

The closed method involves the use of containers with lids and an approximate size from 70 x 40 x 15 cm to 100 x 50 x 30 cm. At the bottom of such boxes, several small holes are drilled to drain water during irrigation. The same holes are drilled in the lids for ventilation. Boxes can be placed in piles in any convenient place, protected from direct sunlight, as well as from cold. The optimal location for them are greenhouses or workshops. This method is the most effective for breeding the Californian earthworm and we will take a closer look at it below [11, 16, 25].

The whole space of the shop is filled with racks, at least 100 cm wide (doubled). Single racks 50 cm wide are also used, but they are placed along the walls. There should be a distance of 120 cm between the racks, between their shelves – at least 50–60 cm (depending on the height of the containers). The height of the racks depends on the height of the room. It is best to use perforated boxes for vegetables 60 x 40 x 20 cm and trays 60 x 40 x 10 cm. Plastic is a durable material that is resistant to aggressive media [15, 26]. Ventilation, runoff of excess water and the migration of worms is provided by perforation. The density of worms stocking is 20 thousand worms per one box, and 10 thousand per the tray. All worms must be of different ages: adults 4–8 cm long (3–5%), fry 1.5–2 mm

(60–80%), ring-shaped cocoons 5 mm in diameter from the outside and 3 mm inside [27, 28]. The substrate is poured into containers 5 cm thick. This method of preparation when using 1 m^2 of floor allows obtaining up to 200 kg of substrate. To make offensive gases not reach the racks, good ventilation is required [14, 2, 28].

Assessment of the state of the worms population is carried out on the basis of growth and development indicators by monthly counting their number and determining the age composition. This is carried out as follows. In different places of the bed (in a staggered order or diagonally), samples of the substrate with worms of 10x10 cm are taken from all its depth. All worms are selected from these samples, their number is calculated and the biomass is determined (that is, weighted). Then the obtained average results are multiplied by 100 and thus the average number and biomass of worms per 1 m^2 is determined [29]. However, an increase in the mass of worms is not a single indicator. When feeding nutritious food you can get a significant increase in the mass of worms, but they will not put off the cocoons. Worm reproduction is affected by population density. With its increase, the stress from overpopulation negatively affects reproduction. Therefore, during the quantitative recording of the number of worms, the age composition of the population is also determined by counting the cocoons, young and adult worms separately, and the average number of embryos in the cocoons is determined [30]. The ratio of different age groups gives an understanding not only about the general state of the population, but also about the possible future. If adult worms and cocoons predominate over young forms in the population, this indicates that the conditions of vermicultivation impede the development of embryos and the appearance of young worms. Correct analysis will provide an opportunity to make changes in the conditions and optimize the parameters of the process of vermicultivation [31].

Cultivated worms are not amenable to epizootic diseases. They can die only in violation of the breeding technology. Most often, protein poisoning during the unfinished fermentation of the substrate causes the death of worms. As a result, the worm becomes “acidic” and emits harmful gases that are lethal to other worms [32].

The main requirements for the workshop for the cultivation of the Californian earthworm:

1. Temperature:
a) optimal 18 ° C – 25 ° C
b) permissible 15 ° C – 30 ° C
c) extreme 4 ° C – 35 ° C

2. Illumination
a) optimal 60 watts per 20 m^2.
b) maximum up to 80 watts per 20 m^2.
c) minimum 40 watts per 20 m^2

3. It should be remembered that direct sunlight is detrimental to worms.

4. Humidity level
a) optimal 75–80%
b) minimum 65%
c) maximum 90%

5. Ventilation: natural or forced, for air exchange not more than 0.5 m / s;

6. Protection against pests: Californian earthworms are a treat for centipedes, ants, mothes, rats, moles, shrews, birds, toads, frogs, etc .. The room must not be accessible to them; the floor should be hard (concrete), the walls and the ceiling (concrete, metal) should be impenetrable [14, 23, 31, 33].

The main technological steps in breeding the Californian earthworm are:
1. Preparation of compost (nutrient substrate);
2. Settling worms;
3. Food preparation;
4. Removal of worms;
5. Wintering [11, 16, 24, 29, 34].

Substrate for red Californian earthworm. Basic rules for the preparation of the substrate (compost) for further settlement of the worm:
1. mineral content – up to 10%;
2. The content of crude protein is not more than 25%;
3. Acidity 6.5–7.5 pH;
4. the required humidity of the compost is 70-80%;5.
5. use only the water settled during 48 hours to moisten the compost;
6. temperature in the compost from 15 to 22 ° C;
7. it is necessary to mix the substrate about twice a week to enrich it with oxygen;
8. It is prohibited to use fresh manure, as in the process of manure burning out, its temperature rises to 70–80 ° C, which leads to the death of the worm;
9. It is not recommended to use old manure that has lain for more than 3 years, because it contains a small amount of nutrients for worms [12, 15, 22, 35, 36].

Cattle and pigs manure, bird droppings are used for the preparation of the substrate for worms. Manure for vermifarming, as a rule, is mixed with various fillers (at least 20–40%, and much more for bird droppings), such as cut straw, last year's grass, leaf litter, cardboard, peat, silt [37]. Peat is good because, having a high moisture capacity, reduces the moisture content of the substrate, absorbs and retains ammonia and other aggressive substances [19, 27]. Mixing different substrates is good for breeding worms. Mixing pig and cow manure (respectively, with fillers) gives good results [32]. Horse manure the most favorably effects the development of worms, but adding cow manure (about 25%) to it gives an even greater positive effect than single horse manure. Fresh manure is unsuitable due to the large amount of ammonia and chlorides [14, 23, 31]. Liquid manure is mixed with the same amount (by weight) of straw, hay, sawdust, etc. Organic for worms is composted only in storage pits or heaps, 1.5–2 m high, but in no case in pits [17, 21]. Complex mineral fertilizers are applied to composted organics at the rate of: 2–3 kg of double superphosphate (a mixture of Ca $(H_2PO4)_2$ * H_2O and $CaSO_4$), 1 kg of potassium sulfate (K_2SO4), 2–3 kg of ammonium sulfate $(NH_4)_2SO_4$), 1 kg of magnesium sulfate ($MgSO_4$), 60 g of boric acid (H_3BO_3), 3-5 kg of lime or dolomite flour per 1 t of composted organics [25, 36]. Storage pit should be well moistened (up to 60% humidity) and covered with ready compost or a 5–20 cm layer of soil in summer or 30–40 cm in winter [33]. The compost heap begins to heat up and in 5–7 days in summer the temperature reaches + 53 ° C and higher. At this temperature, the destruction of weed seeds, helminth eggs, pathogenic microflora, nematodes occurs within 5–7 days, and the substrate is ready in 45–60 days [25, 28]. The main criterion for substrate readiness is the absence of ammonia odor in it. The readiness of the substrate is determined in the following way: a dozen worms are put on a wet substrate, if they crawl into the substrate within a few minutes, then it is ready to be occupied. If the worms lie on the surface and lift the heads up, then the substrate requires additional composting [34, 35].

Feed for worms. Naturally, all the food given to the worms should be processed in a meat grinder or chopped in another way [38]. The prepared feed is laid out in boxes of 5 cm each. It is recommended to leave a free space of 3–5 cm wide, so in case if for any reason fermentation processes begin in the feed mixture with release of poisonous gases, the worms could move into this safe zone [39, 40]. The worms should be fed once a week, adding 5 centimeters of food substrate. Under optimal temperature conditions, worms can live without food for several months, so if there is no certainty that the fermentation processes in the substrate have stopped, it is better to wait 7–10 days before giving it to the worms [33, 41]. Organic waste is used as feed: manure, bird droppings, plant haulm, fallen leaves, straw, wood chips, sawdust, food vegetable waste, cardboard, paper, etc. [18, 26, 42]. Citrus and meat products should be completely excluded from the diet of worms. Feeding needs to be rationed, since large doses of feed are extremely harmful for worms, because fermentation processes cause oxidation of the substrate. The addition of egg shells or sand to ground food favorably effects the digestion of worms [22, 36, 43].

The specificity of feeding the fish with the red Californian worm is caused by the fact that it is a highly nutritious food organism with convenient storage requirements for its by-products [44]. It is used for feeding not only breeders and fingerlings, but also as a promising component of feed for early juvenile fish [45]. It should be noted that feeding with the Californian worm in a live form contributes to the development of feeding behavior in juvenile fish [46]. The biomass of this worm is used in feeding fish raw, dry and boiled state.

The chemical composition of the Californian worm has the highest energy value, mainly due to the high protein content and its amino acid composition in comparison with other important natural food organisms for fish (Tables 2, 3) [47, 48].

Table 2. **Comparative chemical composition of food organisms,% of dry matter**

Organisms	Proteins	Fats	Carbohydrates
Red Californian earthworm (*Eisenia foetida andrei*)	51.1	5.67	19.83
Common earthworm (Lumbricus terrestris)	61.3	9.0	3.0
Waterflea (*Daphnia pulex*)	58.04	6.58	13.63
Daphnia magna	44.61	5.15	16.75
Rotifers (*Rotifera, Rotatoria*)	49.7	7.37	14.0

The body of the Californian earthworm contains 89.37% of dry matter, and in the common earthworm contains 92.9%. For comparison, in chironomid larvae, this indicator ranges from 12.94 to 15.12% [49, 50].

Table 3. **Comparative content of essential amino acids in invertebrates, g/100g**

Organisms	Amino acids					
	Arginine	Histidine	Tryptophan	Methionine	Cystine	Tyrosine
Waterflee (*Daphnia*)	10.92	2.69	3.62	3.45	1.17	4.27
Chironomid larvae (*Chironomidae*)	4.75	2.38	2.06	1.48	1.05	3.16
Caddis worm Larvae (*Trichoptera*)	5.36	2.28	2.98	1.72	1.21	3.34
Pot worms (Enchytraeidae)	5.62	1.86	1.79	1.69	1.05	3.37
Pond snail (*Lymnaea ovata*)	4.44	1.33	–	1.68	1.17	2.45
Common pond snail (*Limnaea stagnalis*)	4.92	1.24	–	1.04	1.02	2.24
Freshwater shrimp (*Amphipoda*)	4.76	1.69	1.72	1.56	0.99	2.24
Hemipterans (*Corixidae*)	4.50	2.15	1.64	2.02	1.92	3.04
Californian earthworm (*Eisenia foetida andrei*)	3.96	1.18	1.05	1.35	0.45	2.21

In qualitative evaluation in points of protein products, the meat of worms exceeds that of fish and pork, as well as soybean and is almost as good as veal meat [51].

The raw biomass of the Californian earthworm has a rich vitamin content, as well as high total lipids, which make up 9 – 11% of the wet mass [46]. The share of structural lipids, in particular, phospholipids, reaches 40 – 55% [53]. Phospholipids contain phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine, phosphatidylinositol, lysophosphatidylcholine [50]. In the raw biomass of this invertebrate there are both saturated (47 – 54%) and unsaturated fatty acids, among which monoenic acids are equal to 25%, and polyene acids – 13% [50]. In addition, there is significant amount of branched chain fatty acids, which are common for microorganisms (up to 23%), as well as with an odd number of atoms (up to 25%) [53].

Thus, the biomass of the Californian earthworm in chemical composition of the body and nutritional value fully meets the physiological needs of fish for nutrients [48].

When using raw biomass it is crushed to a homogeneous state, making sure that the fraction size is not more than 0.5 mm, because otherwise it will not be available for the fish larvae to eat [47].

Homogeneous mass can be fed separately or added into the combined feed [48]. The chemical composition of the raw crushed biomass of the Californian earthworm does not change after drying and fully satisfies the nutritional needs of the larvae for protein, lipids and vitamins [44]. The table 3 shows that the stuffing of worms contains protein 3 times more than cow milk, and only a third less than pigs meat [49].

Table 4. **Comparative composition of raw biomass of worms, cow milk and animal meat, %**

Component	Worm	Cow milk	Meat		
			Pork	Veal	Chicken
Water	85.0	88.0	52.0	51.0	65.0
Fat	1.0	3.6	29.0	25.1	5.4
Protein	9.8	3.2	15.1	17.1	24.1
Ash	0.8	0.8	2.8	4.2	4.1

The dry biomass of the Californian eartworm consists of 70% protein with a greater amount of essential amino acids than meat and fish products, especially lysine (8%) and methionine (3%) prevail [50]. The Californian earthworm as a food organism contains 67–72% of protein, 7–19% of fats, 18–20% of carbohydrates, 2-3% of mineral substances, and also biologically active substances. The value of feed when adding worm biomass increases by 20–25%. The worm is also processed into protein flour containing 67% protein and 20% of fat [51]. The technology of drying the worms biomass and obtaining protein flour is not significantly different from the technology of preparing fish and meat and bone flour or milk powder.

At the same time, it should be noted that when feeding young fish with dry biomass of the Californian earthworm, there is a somewhat smaller absolute and relative growth than when using raw biomass [50]. This is due to the fact that during the drying of crushed worms biomass at a temperature of 100 ° C, a certain amount of biologically active substances contained in the raw biomass and necessary for the full development of juvenile fish are destroyed [51]. This is especially about enzymes involved in the digestion of protein, fat and carbohydrate components, which come in the composition of starter feed mixtures [52].

To obtain dry biomass, worms are collected, kept for a day without a food substrate for emptying the intestine and cleaning the body surface from it, dried in drying chambers at a temperature of up to 65 ° C and crushed in special threshers to 0.1–0,5 mm fractions receiving flour. It is added into the compound feed or fed separately, according to the developed standards for feeding different species of fish with natural food [53]. The value of vegetable feed when adding dry worm biomass increases by 20–25%. This is due to the fact that it is rich in protein with a greater amount of essential amino acids than meat and fish products [54]. Lysine (8%) and methionine (3%) especially prevail among them – Table 5.

Table 5. **Comparison of the amino acid composition of the dry biomass of the Californian earthworm and other fish feed [51, 53]**

Amino acids	Feed				
	Worm flour	Fish flour	Meat flour	Casein	Soy protein
Asparagin	12.07	12.33	11.95	7.19	7.45
Glutamine	17.76	21.48	22.69	22.41	9.71
Serine	8.53	6.61	6.21	6.9	9.13
Glycine	13.94	8.75	9.33	4.48	7.17

Continue of table 5

Amino acids	Feed				
	Worm flour	Fish flour	Meat flour	Casein	Soy protein
Histidine	4.23	2.92	4.07	2.91	2.78
Threonine	8.11	3.76	7.22	6.27	4.37
Alanine	9.83	10.27	10.66	4.96	7.53
Proline	11.11	6.88	8.36	14.36	5.63
Tyrosine	3.96	3.34	3.35	3.83	1.29
Valine	6.81	7.34	7.47	5.95	3.9
Methionine	4.47	3.92	3.35	2.83	–
Isoleucine	3.92	5.51	5.97	4.83	5.58
Leucine	8.74	11.56	12.35	10.77	7.51
Phenylalanine	2.88	4.85	7.34	7,41	2.8
Lysine	9.11	10,83	10,74	4,94	6,38
Tryptophan	8,57	8,76	6,71	–	–
Arginine	7,98	6.27	6.9	–	6,31

The addition of feed from the biomass of Californian earthworms improves the taste and presentation of fish meat [50, 55].

Being dried, but not chopped, the biomass of worms contains more than two times more protein than pork, beef, milk and a little more than chicken meat (Table 5) [56].

Table 6. **Comparative composition of dry biomass of worms, cow milk and animal meat, %**

Component	Worm	Cow milk	Meat		
			Pork	Veal	Chicken
Water	8.0	9.0	7.9	8.0	7.9
Fat	10,1	30,0	50,3	50,8	18,3
Protein	69,1	26,1	30,0	28,8	60,0
Other components	12.8	34,9	11,8	12,4	13,8

In this state, the biomass of worms is stored for a long period (up to 3–6 months, with no signs of caking, or deterioration) in dry and cool rooms in plastic bags, which makes it possible to keep this feed raw material in the season favorable for the cultivation of the Californian earthworm [51, 57].

The manufacturing techniques of starter feed for fish from the red Californian earthworm, developed by M.Yu. Evtushenko, provide feeding the larvae with 50% resorption of yolk, with special microgranules from crushed worms [60]. The feed amount is 7% by weight of the larvae body, they are fed three times a day, during the daylight hours. Thus during the first 10 days grain diameter is 0.2 - 0.4 mm, and the following 10 days, the figure is 0.5 - 0.7 mm. This feeding regime promotes complete and gradual filling larvae intestinal tract, and, accordingly, complete digestion of feed.

The main point of the technology developed by M.Yu. Evtushenko is that, first of all, the collected worms are exposed to low temperature (-15 - -18 ° C) by freezing them in the freezer [58]. The advantage of the cooling factor, which is absent in other technologies, is that it leads to a gradual decrease in the body's metabolism, which over time is almost completely inhibited, and the animals fall into a state of anabiosis. In this case, synthesis of the mucopolysaccharide component is minimized, which is the natural reaction of the worm's organism to stress, including when exposed to high temperatures during drying. However, even in small quantities, it can inhibit the process of digestion in young fish [50]. Therefore, at the next stage of the process, in order to remove the formed substances of mucopolysaccharide origin and stabilize the hydrolytic enzymes and their complexes, the frozen biomass of worms is treated with a cooled, non-ionic, organic solvent, often with acetone. For this, it is crushed and placed into a container, which is then poured with cooled acetone, in the ratio of the worms biomass to the acetone volume as 1:2. Then it is mixed for 30 ', while acetone displaces water in bound form from the tissues, thereby eliminating the immobilization of its molecules. In addition, this process contributes to the stabilization and preservation of the native properties and structure of proteins and their complexes (including hydrolytic enzymes), does not cause the destruction of the tissues by hydrolysis enzymes and allows maintaining the nutritional properties of the food made from them for a long time. Further, the wasted acetone is separated from the biomass, and it is dried for 120 ', in a stream of warm air, at a temperature of 40 ° C [58]. The dried biomass is chopped and dried again during 60 'at the above mentioned temperature.

For starter feed pellets with defined size dried powder mass is sieved through a sieve of desired mesh size. Thus, feed fraction with beads of any size can be obtained from the dried and fragmented biomass [55].

The starter feed fabricated using this technology is long-storage, and the technology received the patent of Ukraine under No. 32168 dated 12.05.2008 [58].

Biocompost is a highly valuable product of the processing of various kinds of organic waste by worms. Its value is determined by the high content of nutrients, and the appearance is a dense black or brown (depending on the type of manure or organic residues) lumps without smell. It surpasses traditional organic fertilizers in effect on the growth, development and yield of various crops [59]. In agrochemical indicators, biocompost is better than humus traditionally used in garden plots (Table 7).

Table 7. **Agrochemical indicators of biocompost and humus (%)**

Composition	Biocompost	Humus
Organic matter	45.7	23.6
Humic acids	3.3	2.3
Fulvic acids	2.3	0,6
Organic carbon	3.26	1,7
Nitrogen	3.16	1,54
C: N ratio	1.03	1,10

Biocompost contains significantly more nitrogen, phosphorus, potassium, calcium, and almost all of the trace minerals necessary for plants. The use of biocompost contributes to increasing the yield of maize and cereals by 30–40%, potatoes by 30–70%, and vegetable crops by 35–70% [60]. Moreover, the grown products meet the sanitary and hygienic requirements and are recommended for the nutrition of nursing mothers, for dietary and baby food. Given the low rate of application of biocompost (2.5–3.0 t/ha at a full and 200-300 kg/ha at a local application), the material and labor costs per unit area compared to the costs of using traditional organic fertilizers are reduced by 3 – 5 times [61]. At the same time, net income, for example, when growing vegetables using biocompost as an organic fertilizer, is 3–4 times higher than using bird droppings, and 20 times higher than using cattle manure [62]. Biocompost contributes to the formation of an agronomically valuable soil structure, creates an optimal composition of the soil solution; nutrients of biocompost, balanced by NPK and microelements, are slowly soluble and provide long-term consumption by plants.

CONCLUSION AND PERSPECTIVES OF FURTHER DEVELOPMENT

The Red Californian earthworm (*Eisenia foetida andrei*) is an intense breed bred by hybridization of manure worm (*Eisenia foetida*) and brandling worm (*Eisenia andrei*). Like any intensive breed, it has its own advantages (reduced mobility, increased vital activity and fertility, high recycling rate and nutritional value) and disadvantages (more demanding in terms of feeding and living conditions) compared to wild species. It should be noted that under the trade name "red Californian earthworm" unscrupulous vermi-farms sell wild closely related species, such as *E. foetida, E. andrei, E.veneta*, etc. Only red Californian earthworm is a highly valuable food for fish due to its chemical composition (rich in protein), and due to the promotion of the development of feeding behavior in young fish. The dry biomass of the Californian earthworm consists of 70% protein with more essential amino acids, especially lysine and methionine, than meat and fish products. There are 2 main types of technology for the cultivation of worms: open one (in storage pits) and closed one (in vermicomposters). Cultivated worms are not amenable to epizootic diseases, their death can be only caused by violations of breeding technology. Thus, the red Californian earthworm is a promising food organism for fish farming.

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