Saprophytic Filamentous Fungi against Helminths Affecting Captive Wild Animals

Subjects: Mycology

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In recent decades, important modifications have been introduced in zoos in order to guarantee the welfare of captive wild animals. Thus, many of these species are housed in enclosures with access to vegetation, where they can enjoy habitats close to those in their natural surroundings, interact with the environment, etc. These habitats present beneficial conditions for some species of parasites to survive and spread. This is a very similar problem to that affecting livestock, and the same solution, based on deworming, is currently being applied. However, the free-living stages of certain parasites that develop in the soil are responsible for high rates of ground contamination throughout the year, so that animals become infected soon after successful deworming, resulting in chemical parasiticides being frequently administered. Preventive measures are seldom considered, which worsens the situation. This entry summarizes the usefulness of the dissemination of certain saprophytic filamentous fungi with proven antagonism against some of the parasites.

Keywords: Mucor circinelloides ; Duddingtonia flagrans ; prevention ; parasites ; zoological park

Wild animals bred in captivity in zoos are often found permanently in the same plot of land, a circumstance that favors high concentrations of parasites in the environment [1]. This situation can be worsened by problems of stress, feeding, hygienic conditions in the plots, and confined spaces, which increase the possibility of parasitic infections [2]. Accordingly, control is primarily focused on deworming the animals, and it has been stated that individuals that receive these treatments regularly do not exhibit clinical signs of infection [3], and this could be interpreted to mean that the infection has fully disappeared. Nevertheless, the periodic administration of anthelmintics does not prevent challenge infections among captive species; it is suggested that a lack of quarantining newly entered animals as well as free-ranging stray animals could be possible sources of infection [4]. Other issues that need attention are the frequent use of parasiticide drugs in combination with inappropriate dosage and administration methods, which may lead to the development of resistant strains of some species of gastrointestinal nematodes [5]. Reports have noted the existence of trichostrongylids resistant to both levamisole and fenbendazole in captive Armenian red sheep, in wapitis to levamisole, and in giraffe to macrocyclic lactones and imidazothiazoles [6][7]. As can be easily understood, this problem is identical to the problems reported for decades in farm animals, which remain unsolved to date. More attention should be paid to prevention with the aim of limiting the risk of infection and, thus, decreasing the need for deworming.

Main Parasites Affecting Captive-Bred Animals

Different parasites involving protozoa, helminths, or ectoparasites have been described among wild captive animals, but helminths are the most frequently detected. These are organisms with a direct life cycle, with part of their development occurring in the environment for days to weeks, and they are frequently detected in the feces of animals kept in captivity [8]. This happens because the animals are separated, housed in parks that normally prevent the entry of other animals and in more or less stable conditions in terms of the condition of their plots. All of this hinders the development of parasites with an indirect life cycle, in which the collaboration of intermediate hosts is necessary [9]. The most frequent groups or families of helminths are ascarids, strongylids, and trichurids.

Ascarids

Ascarids, also known as roundworms, belong to the class Nematoda. The adult stages usually occur inside the small intestine, where females shed unembryonated eggs, which reach the environment through the feces [10][11]. After several weeks under optimal temperature and humidity conditions, one larva 2 (L2) develops inside [12], and the egg become infective. Infection in wild captive species occurs through the accidental ingestion of an infective egg while grazing [13][14], and the species more commonly described in carnivores and omnivores are *Toxocara* spp., *Toxascaris leonina*, and *Baylisascaris* spp. [3][15][16]. In herbivores (cow, buffalo, bison, eland), infection with *Toxocara vitulorum*, a roundworm without zoonotic characteristics (they cannot parasitize humans), is described with some frequency, while in monogastric herbivores, *Parascaris equorum* is the most commonly diagnosed ascarid species [15].

Strongylids

Strongylids also belong to the class Nematoda, and usually cause mixed infections involving more than one species. These infections cause a chronic process with low mortality, but, although they do not cause serious health changes, they do cause alterations in growth, poor coat, gastrointestinal disorders, etc. Most grazing animal species are affected depending on the conditions in which they are kept (overcrowding, hygiene, etc.). These parasites are frequently found in temperate areas (9–27 °C) and high relative humidity (≥70%) conditions [17]. The most frequently identified species belong to the genera *Ostertagia* (cattle), *Teladorsagia* (sheep, goats, and deer) and *Trichostrongylus*, although there are others such as *Haemonchus*, *Cooperia*, *Bunostomum*, *Nematodirus*, and *Oesophagostomum*. Infected animals excrete the eggs into the environment when defecating, which emerge already embryonated, and in a few days, the larva 1 (L1) forms inside, hatches, and the leaves the egg, transforming into an L2 that feeds on organic matter present in the feces. Depending on the temperature and humidity conditions, L2 larvae molt into L3 larvae (the infective stage), which leave the feces and move towards the apical portion of plant species, especially grasses, and are ingested by herbivores while pasturing.

Trichurids

These nematodes (also called whipworms) constitute a genus of gastrointestinal parasites belonging to the roundworm family Trichuridae, characterized by a direct life cycle involving unembryonated eggs that are passed in the feces of infected animals [18]. The eggs develop outside until a first-stage larva, or L1, is formed inside and turns into the infective stage. Infection occurs when embryonated eggs are ingested, and the L1 hatches in the gut and moves to the large intestine, where the adult stage is attained and the larva feeds on blood.

Infection with *Trichuris* spp. is commonly detected among captive wild animals [18][19], enhanced by eggs shed in the feces. The feces provide a sticky cover that ensures they can remain not only in soil, but on different structures that exist in animal refuges such as hangers, perches, or swings. Accordingly, the prevention of infection is very difficult.

Bronchopulmonary Nematodes

Bronchopulmonary nematodes of the families *Protostrongylidae* and *Dictyocaulidae*, also known as lungworms, are parasites characterized by the location of adults in the lower respiratory tract of domestic and wild mammals [20]. Most infections are asymptomatic, but eventually they can cause respiratory problems such as bronchopneumonia and parasitic bronchitis that could evolve into severe disease. Adults lay their eggs in the lung tissues, where the first-stage larvae hatch and climb up to the throat to be swallowed and finally expelled with the feces. Soil contamination occurs through the spread of L1 larvae in the feces of parasitized animals. There are some differences in the way animals become infected, as *Dictyocaulidae* has a direct life cycle with a free-living stage, while in *Protostrongylidae*, a terrestrial mollusk acts as an intermediate host [21]. Animals become infected when grazing through the ingestion of the L3 free-living stage for *Dictyocaulidae* or the intermediate host carrying the L3 for *Protostrongylidae*.

Adults of *Dictyocaulus* spp. produce embryonated eggs in the airways that hatch briefly after oviposition, while the eggs of lungworms are unembryonated. When they both hatch, the first-stage larvae reach the trachea and are passed in the feces. Once in the soil, *Dictyocaulus* spp. molt to L2 and L3, the infective stage, while the larvae of pulmonary nematodes need to penetrate mollusks to reach the infective L3 stage. After release in the abomasum, the L3 of *Dictyocaulus* spp. must penetrate the intestine and migrate via lymph nodes to reach the lungs as L4s. The third-stage larvae of *Protostrongylidae* leave the intermediate host from the stomach and penetrate the intestine, reaching the lungs, and form nodes with L4s within the lungs after thoracic duct–heart–pulmonary artery migration [22].

Clinical Importance and Detection

Even though parasites are one of the leading causes of death in captive wild animals, especially on those with a heavy parasitic burden, the great majority of these infections are subclinical and so clinical signs are hardly noticeable by veterinarians and zookeepers [9]. As ascarids, strongylids, and trichurids are mainly localized in the gastrointestinal tract, if a clinical syndrome is observed, the clinical signs will be mostly digestive or due to the parasite's hematophagy. Hence, it is possible to observe anemia, edema, lethargy, malnutrition, and diarrhea. In severe infections, there will also be extreme weight loss and worsening of body condition, and death can also occur [7]. Unless there is a heavy infection, the clinical signs of *Trichuris* are rare and consist of minor cecitis and diarrhea with mucus and blood.

Therefore, it is crucial to have adequate tools for the diagnosis of parasitic infections. Routine diagnostics consist of the visualization of parasite eggs in feces, confirming the existence of adult worms inside the host. There are also serological probes such as ELISA, although a positive result is not enough to confirm the parasitism, only previous exposure [23].

Control of Parasites in Captive Animals

Wild animals seem to have a natural resistance to parasitic infections, but when kept in captivity, their sensitivity to parasites appears to be reduced, possibly due to the disruption of their ecosystem [24].

The control of parasites in captive-bred animals is carried out by administering broad-spectrum antiparasitic drugs, normally twice a year, against the stages inside the hosts. For the control of nematodes, benzimidazoles like albendazole or fenbendazole and macrocyclic lactones such as ivermectin are the most utilized families, while praziquantel is used for the control of cestodes. The use of these drugs in wild species involves a series of additional difficulties:

- In a large number of cases, deworming is carried out without a prior coprological examination.
- The antiparasitic drugs used for livestock are often not specific for the target species, so they are underdosed to avoid intoxication problems.
- Animal handling problems can cause most treatments to be administered orally due to the impossibility of giving them parenterally. This oral administration does not ensure an adequate ingestion of antiparasitic drugs, so there will be animals that ingest a higher dose than recommended and others in which the dosage is practically nil.
- One of the main limiting factors regarding the implementation of preventive measures against parasites is the place where these animals are located, which is usually limited and permanent. The effectiveness of any antiparasitic treatment is reduced as a consequence of numerous reinfections when they are continuously located in the same plot.
- The residues produced by the metabolism of pesticides can be toxic to some species of microorganisms that are very useful for soil enrichment, such as some coprophagous beetles [25][26].

For the purpose of limiting the risk of infection from certain parasites, regular monitoring for sanitation and cleaning is necessary to minimize the risk, and the frequent cleaning of animal refuges and facilities, as well as the removal of feces to avoid infectious stages from being reached, are also important [4]. It is noteworthy to state that preventing environmental contamination by the eggs and larvae of parasites represents one of the key steps to stopping the transmission of parasites to wildlife.

Despite proper deworming and good hygiene practices, animals living in captivity will still suffer from diseases caused by parasites. This occurs due to the presence of the animals in the same place for prolonged periods of time, favoring their exposure to infective forms, so that reinfection occurs [15][27].

With all of the above in mind, together with the high resistance presented by the eggs of some helminths and even infective larvae under certain conditions, it appears necessary to adopt an alternative approach for the control of these soil-transmitted parasites [16][23][28][29].

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