Chapter

Fungi and Oomycetes–Allies in Eliminating Environmental Pathogens

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Abstract

Fungi and oomycetes are the subjects of numerous current research studies. These are natural agents that can control parasitic populations, and arthropod populations with a role in the transmission of various diseases but can also eliminate various pollutants that are found in the external environment. Therefore, their conservation and exploitation are a global necessity, due to the benefits they confer on the quality of life of animals, but also of humans. Science must be aimed at finding a balance between the different constituents of the ecosystem and establishing coexistence relationships that are beneficial to all. Thus, research should be directed at investigating the potential actions of fungi and oomycetes against the various agents with which they coexist naturally in the external environment. This chapter provides information regarding the mechanism of action of these natural constituents and updates information on the species of fungi and oomycetes that have been studied so far. Thus, readers can have a base in this field and can further exploit what they have discovered to continue to improve the welfare of animals, addressing an ecological and healthy vision.

Keywords: ecological action, fungi, oomycetes, cleaning

1. Introduction

Plants and animals coexist in a certain balance within the ecosystem, together with fungi, oomycetes, bacteria, viruses, and parasites.

Currently, about 75.000 species of fungi have been described, many of which are still unclassified [1]. Also, in the category of fungi, oomycetes have been included in the past. Detailed studies have highlighted their morphological and functional differences, the oomycetes being now included in the phylum *Oomycota* [2]. Both fungi and oomycetes are found in various symbiotic relationships and can be saprophytes or parasites [3]. These relationships can be exploited in creating ideal habitats for animals.

Many bacteria, viruses, and single-celled parasites can be carried by arthropods (insects, mites) or other vectors (amoebas) and can be sources of infection, causing many diseases in animals. Fungi and oomycetes can use different mechanisms by which they can eliminate these vectors. They can also be involved in the detoxification of the environment from numerous pollutants and can be considered important agents in the biocontrol of some animal parasites. In removing amoebae, fungi use hyphae that function as “sticky extensions” that capture “prey” or can parasitize internally, causing amoebae death by sporulation [4]. Sprayed in the form of a solution on the body of insects, more precisely on the body of mosquitoes, the fungi attach themselves through the conidia to their cuticle. Then begins the germination and dispersal of spores in the hemocoel. At this level, the evolutionary cycle of fungi continues with the multiplication of hyphae, which gradually kill the host by colonizing the trachea and producing toxins, after which the fungi leave their body [5, 6]. In eliminating the larval forms of some insects, the fungi also through the conidia block the siphon region and thus determine the death by asphyxiation of the hosts [6]. The same mechanisms have been reported in the elimination of evolutionary stages of ticks. An important role in the fixation and adhesion of conidia at the cuticular level is played by hydrophobins and adhesins, as proteins, but also lipase and esterase, as enzymes [7–9].

Certain pollutants, such as pesticides, can be battered by various fungi through numerous chemical processes (deoxygenation, hydroxylation, esterification, or dehydrogenation) [10]. Certain heavy metals in the environment can be inactivated by organic acids and siderophores (metabolites) of fungi [11]. Enzymes also play an important role in bioremediation, among them can be mentioned: cellulase, lipase, protease, peroxidase, amylase, chitinase, catalase, laccase, xylanase, etc. [12].

In the management of parasitic populations, especially nematode populations found in animals, fungi use complex mechanisms to eliminate these pathogens. The first stage is the recognition between the fungus and the nematode. Fungi adhere to the body of nematodes through lecithin that binds to carbohydrate receptors located in the cuticle of the parasite [13, 14]. Adhesion is facilitated by fungal spores and protein fibrils that form nematode-trapping traps. The fibrils are arranged in a network or perpendicular to the external surface of the nematodes, after which they easily penetrate their body. The penetration step involves the release of hydrolytic enzymes and the application of progressive pressure on the parasite’s cuticle [15]. After complete penetration of the cuticle, the formation and multiplication of hyphae begin. Gradually the fungi digest the nematodes internally. Nutrients are captured in the hyphae in lipid droplets or are fixed and carried by lecithin [16]. The same steps are observed in the case of oomycetes. They adhere to the surface of parasite eggs or larvae, through hyphae, after which they penetrate the egg wall or larval cuticle, releasing various enzymes (various exoglycosidases, kinases, endo-β-1,3-glucanases, and cellulases). Gradually, they digest and destroy the internal contents through hyphae and zoospores that form continuously [17].

Another method of removing nematodes is using adhesive nets, hyphae, or knobs forming constricting rings together. Through the movements and body heat, the nematodes trigger the complete tightening of the rings around them and the exteriorization of a penetrating tube where the internal multiplication of the hyphae begins [18]. Certain fungi can spread to the surface of the body of nematodes or larvae, including the wall of nematode eggs. Gradually the sporulation takes place internally, having an ovicidal, larvicidal, or adulticidal effect [19, 20]. An ovicidal effect can be exerted by fungi also through hyphae, more precisely through oppressors, secondary metabolites, and the toxins they contain [19]. The same toxins can cause paralysis of adult nematodes [19].

The following subchapters contain information related to fungal species, but also oomycetes that can be used successfully in the elimination of various animal pathogens.

2. Elimination of vectors involved in the transmission of various diseases to animals

2.1 Amoebae

Amoebae are protozoa that can live freely in very different environments or can be parasitic, surviving in different hosts. Free amoebae are present in the external environment in soil, water, and air, but are also used in various medical fields, such as dialysis centers and dentistry [21]. Parasitic amoebae (*Entamoeba* spp. and *Balantidium* spp.) are found in animals' intestines [22].

In veterinary medicine, only four classes of free amoebae have pathogenic potential: *Acanthamoeba*, *Naegleria*, *Balamuthia,* and *Sappinia* [23]. Each class determines certain clinical manifestations of amoebiasis. *Acanthamoeba* enters the animal body by respiration or skin and through the circulation reaches the central nervous system, causing amoebic granulomatous encephalitis (GAE) [21, 24, 25]. The evolution of the disease is slow, and long-lasting [26]. Certain species of the genus *Balamuthia* (*Balamuthia mandrillaris*) cause similar lesions, respectively: granulomatous *Balamuthia encephalitis* (BAE) [27]. The route of infection is predominantly cutaneous [28]. *Sappiniae* amoebic encephalitis (SAE) is caused by two species, *Sappinia diploidea* and *Sappinia pedata* [29]. From the *Naegleria* class, *Naegleria fowleri* is important. It is found in water and can be accidentally inhaled by animals while swimming [30]. The location is also in the brain, but the migration route is a nerve (olfactory nerve pathway) [18]. The characteristic lesion caused by this class of amoebas is meningoencephalitis, which develops with diffuse cerebral edema [30].

An important role in the circulation of certain pathogens has the amoebas of the *Acanthamoeba* class. Among the pathogens are bacteria (*Listeria monocytogenes*, *Pseudomonas aeruginosa*, *Rickettsia*-like, *Salmonella enterica*, *S. thyphimurium*, *Yersinia enterocolitica*, *Campylobacter jejuni*, *M. avium*, *M. bovis*, *Bacillus anthracis*, *Escherichia coli* O157, *Helicobacter pylori*, *Chlamydia pneumoniae*, *Coxiella burnetii*, *Francisella tularensis*) [31–42], fungi (*Cryptosporidium parvum*, *Cryptococcus neoformans*) [43–45] and a limited number of viruses (*Adenoviridae*) [46].

Numerous researchers aim to use amoebophagous fungi in the elimination of vectors and in the prevention of many diseases that can be transmitted to animals. They can act as parasites or predators. Among the fungi with the role of parasites, which invade and multiply inside the amoebae, are found *C. neoformans*, *Blastomyces dermatitidis*, *Sporothrix schenckii*, *Histoplasma capsulatum*, *Aspergillus* spp., *Penicillium* spp. and *Fusarium* spp. [23, 43, 47–50]. There are species of fungi that multiply in the nucleus (*Nucleophaga* sp.) [51] or others that multiply in the cytoplasm of amoebas (*Sphaerita*, *Pseudosphaerita*) [4]. Species such as *Paramicrosporidium* can cause degeneration and changes in the nuclear and plasma membranes of amoebae [52, 53]. Amoeba trophozoites can be parasitized by *Cochlonema* species [54–57] or can be captured by hyphae of fungi, such as *Stylopage* [58] and *Acaulopage* [59, 60]. Mycotoxins produced by fungi also have a role in the degeneration and decomposition of trophozoite or cyst forms of amoebae [61]. Thus, ameobophagous fungi can be used in the elimination of pathogens carried by amoebae, by applying and cultivating them in soils and waters.

2.2 Insects

Globally, insects can be found in many habitats [62]. They have an important role in all terrestrial ecosystems, intervening in soil fertilization by circulating nutrients and seeds, but also in plant pollination. Thus, they are essential for maintaining optimal qualities in the development of agriculture [63]. Another role with a major impact on the quality of life of animals is the fact that insects are a nutritional basis for them [64]. The larval and adult stages are the most frequently consumed by animals.

In veterinary medicine, the role of insects is very important. Like amoebae, they can transmit various diseases from one animal to another. *Diptera*, insects, flies, and mosquitoes have a major impact on animal health. Culicoids can carry viruses such as BTV (bluetongue virus), AHSV (African horse sickness virus), EHDV (Epizootic hemorrhagic disease virus), and Akabane virus [65]. Newcastle disease [66], certain bacterial agents (*E. coli*, *Salmonella*, *Shigella* spp., *S. aureus*, *Campylobacter*) and parasites (*E. vermicularis*, *S. stercoralis*, *T. canis*, *Trichomona*s, *Diphyllobothrium*, *Taenia*, *Dipylidium*, *Entamoeba histolytica*, *Giardia lamblia*) can be mechanically carried by flies, especially the domestic fly [67–69]. Mosquitoes, in turn, can carry many pathogens, such as West Nile virus, Rift Valley fever virus, Wesselsbron virus, Middelburg virus, Israel Turkey encephalitis virus, Usutu virus, Batai virus, Sindbis virus, Japanese encephalitis virus, St. Louis encephalitis virus, Eastern equine encephalitis virus, Western equine encephalitis virus, Venezuelan equine encephalitis virus, Tembusu virus, *Wuchereria bancrofti*, *Plasmodium relictum* (avian malaria), *T. corvi* (avian trypanosomiasis), *Chandlerella quiscali* (avian filarial worms), *Dirofilaria repens* and *Dirofilaria immitis* [70–79].

The use of pyrethroids as insecticides is the most widely used method of control. However, recent research aims to apply fungi, in various forms, as an ecological method of controlling insect populations [80]. Ansari et al. [81] used the conidia of several species of fungi against culicid adults. The species chosen were *Metarhizium anisopliae* V275, *Isaria fumosorosea* PFR 97, *Isaria fumosorosea* CLO 55, *Beauveria bassiana* BG and *Lecanicillium longisporum*. Conidia were applied in the form of dry conidia and wet conidia, the first variant being the most effective, causing the death of all individuals after 5 days. The most virulent strain of the fungus was *Metarhizium anisopliae* V275 [81]. The same fungus was effective against larval forms of culicids, houseflies, horn flies, and mosquitoes [82–86]. Other authors have reported a larvicidal potential of *Culicinomyces clavisporus* against culicids [87]. Fly larvae, mosquitoes, and culicids have also been eliminated by *Beauveria bassiana*, with many studies reporting this [83–86]. This fungus has led to the death of culicid larvae of the species *Culex tarsalis*, *Culex pipiens*, *Anopheles albimanus*, *Ochlerotatus sierrensis*, *Ochlerotatus nigromaculis,* and *Aedes aegypti* [88]. Ong'wen et al. [89] tested the simultaneous action of dragonfly nymphs *Pantala favescens* and *B. bassiana* spores against *Anopheles gambiae* mosquitoes. They observed that the larvae exposed to the action of nymphs (predatory role) were much more vulnerable, in the adult stage, to the action of *B. bassiana* spores [89]. Ishii et al. [90] demonstrated the adulticidal action of *B. bassiana* conidia against *An. stephensi* mosquitoes. Seven days after exposure, the insect's body was completely invaded by hyphae [90]. Oomycetes *Lagenidium giganteum*, *Aphanomyces laevis*, *Couchia* spp., *Crypticola* spp., *Leptolegnia caudata* and *Pythium* spp. can kill mosquito larvae through mycelium and oospores [91, 92].

2.3 Ticks

Ticks are parasitic mites, which require, for the complete development and completion of the biological cycle, a blood-feed on the vertebrates involved. The tick population is extremely numerous in the warm season, being an important agent for transmitting contagious diseases to animals, but also humans. They can carry bacteria (*Borrelia*, *Ehrlichia*, *Anaplasma*, *Coxiella*, *Brucella*, *Francisella tulacobacteria*, *Rickettsia* spp.) [93–95], piroplasmas (*Babesia*, *Theileria*), but also protozoa (*Cytauxzoon*, *Hepatozoon*) [76].

Biological control of ticks can be achieved by using entomopathogenic fungi. Currently, many fungi are known with a high potential to eliminate various evolutionary forms of ticks. Among them are: *Beauveria bassiana*, *Beauveria brognardi*, *Metarhizium anisopliae*, *Metarhizium robertsii*, *Metarhizium brunneum*, *Fusarium* sp., *Aspergillus fumigatus*, *Aspergillus ochraceus*, *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus parasiticus*, *Isaria fumosorosea*, *Scopulariopsis brevicaulis*, *Paecilomyces lilacinus*, *Paecilomyces farinosus*, *Paecilomyces fumosoroseus*, *Penicillium insectivorum*, *Conidiobolus coronatus*, *Trichothecium roseum*, *Verticillium aranearum*, *Verticillium lecanii*, *Isaria fumosorosea*, *Isaria farinose*, *Curvularia lunata*, *Rhizopus thailandensis*, and *Rhizopus arrhizus* [96–114].

Depending on the evolutionary stage, the action of certain fungi is different. Eggs are the most sensitive and nymphs are the most resistant [115, 116]. A high ovicidal action against *Boophilus microplus* eggs were observed in *Verticillium lecanii* (strains LBV-2 and LBV-1) and lower in *Beauveria bassiana* [117]. A decrease in hatching capacity and indirectly the number of larvae formed have been reported by some authors regarding the action of *I. fumosorosea* [112]. The same effect was indicated for *Isaria farinosa* and *Purpureocillium lilacinum* [112]. *Metarhizium anisopliae* Ma-z4 has larvicidal action on the same species of ticks mentioned above [118]. In the case of adult females of *B. microplus*, the isolates E9 and AM of *Metarhizium anisopliae*, applied to the body of animals through spores in a concentration of 7.5×10^8 conidia/ml, determined high mortality and negatively influenced the number of eggs laid by females [119]. A pronounced acaricidal effect on adult females of *Dermanyssus gallinae* was noted in *B. bassiana* CD1123 conidia, applied at a concentration of 10^9/ml [120]. An ovicidal, larvicidal, and adulticidal effect against *Argas reflexus* ticks has been reported in V245, 685, and 715C of *Metarhizium anisopliae*, the first strain being the most pathogenic [121]. High mortality, observed starting one week after application, was also recorded in females of *Rhipicephalus annulatus* exposed to the action of *Metarhizium anisopliae* [122].

Varroa destructor mites are important in veterinary medicine as a consequence of the devastating effects induced in bee populations. Honey is an intense natural product used in various diseases in animals. It helps to heal wounds [123, 124], to treat gastric ulcers, and can be used as an adjunct in the treatment of diabetes, certain bacterial or parasitic infections, and in stopping the growth of tumors [125]. So, protecting bees is undoubtedly fundamental. The scientific research has brought favorable results regarding the use of the following fungi against *V. destructor* mites: *Beauveria bassiana*, *Hirsutella* spp., *Metarhizium* spp., *Paecilomyces* spp., *Tolypocladium* spp., *Verticillium lecanii*, *Clonostachys rosea* and *Lecanicillium lecanii* [126–133].

3. Environmental detoxification

Currently, our planet is going through continuous degradation due to the numerous pollutants accumulated in soils, waters, and air. Many of them are difficult to decompose. The current trend in research concerns the concept of bioremediation. It refers to the use of certain microbes in various habitats to metabolize various pollutants [134, 135]. Fungi have been intensively studied, their potential to cleanse the planet being recognized by many researchers. Detoxified soils are more fertile, ensuring rapid growth of plants, their nutritional qualities being better preserved. Indirectly, fungi provide animals with adequate food. The same is true of detoxifying water and air: it improves the quality of life of animals.

3.1 Heavy metals in the soil

Animals exposed for a long time to the action of heavy metals have developed developmental problems, spermatogenesis, neurological, renal, and liver problems [136]. Their carcinogenic potential has also been reported [137].

The action of fungi on heavy metals in the soil (Pb, Cd, Cu, Zn, Cr, Ni, Ag) is mediated by external temperature, but also by pH, the whole detoxification process being explained by the phenomena of bioabsorption, bioconcentration, and biotransformation [138]. Among the effective fungi are *Beauveria bassiana*, *Aspergillus* sp., *Fusarium* sp., *Penicillium chrysogenum*, *Rhizopus* sp., and *Absidia* [139–143].

3.2 Pesticides in wastewater

Wastewater is subject to filtration and treatment, as it can be an important source of pesticides, with harmful effects on the environment and animals. Currently, certain fungi capable of eliminating these pollutants have been identified. Hultberg and Bodin [144] used experimentally a combination of *Chlorella vulgaris* (algae) and *Aspergillus niger* and observed a significant reduction in the concentration of pesticides present in water. Piazides based on triazines, dicarboximides, and organophosphates can be successfully degraded by *Verticillium* sp. (H5) and *Metacordyceps* sp. (H12) [145].

Certain residual insecticides, such as endosulfan, can be deteriorated by *Penicillium chrysogenum*, *Bacillus subtilis*, *Aspergillus terreus*, *Aspergillus flavus*, *Aspergillus niger*, *Fusarium ventricosum,* and *Cladosporium oxysporum* [146–148]. Mohammed and Badawy [149] indicate the use of *A. terreus* YESM3 in the elimination of the insecticide imidacloprid.

3.3 Various pollutants from soil, water, and air

Xenobiotic compounds are chemicals that enter the animal body in numerous ways (digestive, respiratory, parenteral) and are various. Reproductive problems (infertility, abortion) have been reported in animals following exposure [150]. Many plant constituents, various pesticides, medicinal products, feed additives, or industrial chemicals, are considered xenobiotics [151]. They have been successfully degraded by species of white-rot fungi (*Pleurotus* spp., *Agaricus bisporus*, *Bjerkandera adusta*, *Phanerochaete chrysosporium*, *Irpex lacteus*, *Lentinula edodes*, *Trametes versicolor*) [152].

Polycyclic aromatic hydrocarbons are found in the form of aerosol particles and can enter the body through the respiratory tract. Prolonged exposure to these constituents has devastating effects on the body. They can adversely affect the endocrine, reproductive, immune, and nervous systems. It also has a carcinogenic and teratogenic action [153]. *Polyporus* sp. S133, *Hypocrea,* and *Fusarium* can decompose polycyclic aromatic hydrocarbons [10]. Recent studies show that the *Pythium aphanidermatum* oomycete intensifies the action of *Mycobacterium gilvum* VM552 and *Pseudomonas putida* G7 against the pollutants mentioned [154].

4. Biocontrol of animal parasitosis

Parasites are pathogens that can survive in the body of animals for long periods, significantly affecting their quality of life. Depending on the class they belong to (Protozoa, Trematodes, Cestodes, Nematodes), they can be diagnosed in different age categories of the hosts [155]. There are many ways to infest animals, with a major impact on the digestive tract. In this way, the hosts can ingest from the external environment eggs or larvae of parasites. Adult forms usually survive in various animal organs. In stopping the evolutionary cycle of parasites, the veterinarian must take several preventive measures. These are undoubtedly necessary, due to the zoonotic potential of certain parasites. To eliminate and kill the adult forms, but also certain larval stages of the parasites, it is well known that various medicinal substances with the antiparasitic role are used. Of the four parasitic classes, nematodes are the most developed, and the main classes of drugs used against them are benzimidazoles, nicotinic receptor agonists, and macrocyclic lactones (avermectins, milbemycins) [156]. Cestodes are sensitive to isoquinolines (praziquantel) and trematodes to thiabendazole (benzimidazole) [157]. We mention only the helminths because they are pentiful in the animal population and the intermediate evolutionary forms resist the most in the external environment. One aspect that must be taken into account when administering the anthelmintics mentioned above is the one related to their use in farm animals. The possibility of eliminating them through milk (ruminants) must be known and indirectly, their remanence in certain secondary products must be mentioned. Macrocyclic lactones also have a long residue in the body of animals [158]. Analyzing this desideratum we can consider the elimination and the complete degradation of parasitic elements from the external environment as the main stage in stopping the biological cycle of parasites. This stage was a basis for current research in the field of biomedical sciences. Disinfectants have been tested and analyzed in numerous studies. Among those discovered so far as having a potential effect on the intermediate elements of nematodes, are those based on alcohols (ethanol, propanol), pentapotassium, and quaternary ammonium compounds [159, 160]. Alcohol-based disinfectants and more can have a corrosive effect if applied to different surfaces and instruments. Also, not enough details are known about the effect they can have on the skin of animals. Here we refer to those kept in paddocks or cages. Considering these aspects, the current research investigates the application of some fungi or oomycetes in the control of the evolutionary cycle of parasites, being an ecological and environmentally friendly method.

Ruminants are frequently parasitized with trichostrongyls. Of these, *Haemonchus* sp. is very important due to the severe anemias, but also to the elaborate clinical symptoms that it can give. Many studies have reported the nematicidal action of some *Pleurotus* species against larval forms (L1, L3, L4), but also of adult *Haemonchus* sp. [161]. This action is due to chemical compounds contained in hyphae (fatty acids, alkaloids, quinones, peptides, polyphenols, and terpenoids) [162]. Vieira et al. [163] associated two fungi (*Pochonia chlamydosporia* VC4 isolate and *Arthrobotrys cladodes* var. macroides CG719 isolate) against the larvae of *Haemonchus* sp. but also of *Cooperia* sp. and *Oesophagostomum* sp. The results were promising, the two fungi potentiating each other's action [163]. Besides the larvicidal action, *P. chlamydosporia* also has an ovicidal action against some helminth eggs [164]. Other researchers have observed that *A. cladodes* used alone against the larvae of *Haemonchus* sp. resulted in high mortality, between 68.7% and 81.73% [165–167]. Silva et al. [168] do not recommend the associations between the following fungi, in combating the larval forms of *Haemonchus* sp.: *Duddingtonia flagrans*, *Clonostachys rosea*, *Arthrobotrys musiformis,* and *Trichoderma esau*. Other authors propose the use of the following fungi, frequently isolated from the external environment, in the control of gastro-intestinal helminthiases of small ruminants: *Arthrobotrys oligospora*, *Candelabrella musiformis*, *Arundo conoides*, *Andropogon dactyloides*, *Trichoderma*, *Beauveria*, *Clonostachys* and *Lecanicillium* [169]. Cai et al. [170] investigated the action of two species of *Arthrobotrys* (*Arthrobotrys musiformis* and *Arthrobotrys robusta*) against the larval forms of trichostrongyls from sheep and goats. The percentages obtained were remarkable, between 97.71% and 99.98% [170]. Similar results regarding the larvicidal action of *Arthrobotrys musiformis* (90.4%) were reported by Silva et al. [171] and much lower percentages of 50% were obtained by Acevedo-Ramírez et al. [172]. The same authors observed a reduction in the number of *Haemonchus* sp. larvae, over 60% in the case of *Trichoderma esau* and *Clonostachys rosea* and 85.7% in the case of *Duddingtonia flagrans* [171]. A larval reduction of over 90% was identified by Chandrawathani et al. after administering *in vivo* to small ruminants *D. flagrans* at a dose of 1×10^6 spores/animal/day for 6 days [173].

Other researchers have investigated the action of fungi (*Arthrobotrys* sp. E1; *A. cladodes* CG719; *A. conoides* I40; *A. musiformis* A1, A2, A3; *A. oligospora* C1, C2; *A. robusta* B1, I31; *Duddingtonia flagrans* CG722, CG768; *Monacrosporium appendiculatum* CGI; *Methanocorpusculum sinense* SF53, SF139; *M. thaumasium* NF34A; *Nematoctonus robustus* D1) on infesting larvae of *Strongyloides papillosus* isolated from cattle. The results were satisfactory, causing a larval reduction between 65.4 and 100% [174]. *D. flagrans* can destroy *Strongyloides* larvae in 2 weeks, and *V. chlamidosporium* (PTCC 5179) in 3 weeks, as reported by Zarrin et al. [175]. The same authors indicate the use of *F. solani* (PTCC 5284) and *T. harzianum* (IBRC-M 30059) in the control of strongyloidiasis in domestic animals [175].

In horses, Araujo et al. [176] investigated the larvicidal action of 3 fungi (*Duddingtonia flagrans* AC001, *Monacrosporium thaumasium* NF34, *Arthrobotrys robusta* I-31) against *Strongyloides westeri*. The results showed a reduction in the larval population between 67.9% and 80.4% [176]. Also in horses, effective against the larvae of *Strongylus equinus*, it is *Arthrobotrys oligospora* [177]. *P. chlamydosporia* is a fungus used in numerous researches against several species of parasites, against which it has shown significant negative effects. Among the species of parasites that have proved sensitive to its action, are found: *Ascaridia galli* [178, 179], *Heterakis gallinarum* [178, 179], *Oxyuris equi* [180], *Ascaris suum* [181], and *Toxocara canis* [182].

A satisfactory larvicidal potential against the gastrointestinal nematode *Ancylostoma caninum*, found in canids, had the fungus *Arthrobotrys oligospora* [177] and the oomycete *Pythium oligandrum* [183]. The same oomycete has an ovicidal action against *Toxocara canis* and *Toxocara cati* eggs, found in dogs and cats [17]. Other authors recommend the use of *Paecilomyces lilacinus*, *Trichoderma virens,* and *Fusarium pallidoroseum* in the biocontrol of ascariasis in dogs [184–186].

Biocontrol in animal trematodes is still at the beginning of the research, until now the ovicidal effect of *Paecilomyces lilacinus* and *P. variety* against *Fasciola gigantica* [187], but also *P. chlamydosporia* against *Fasciola hepatica* eggs [188] are known.

5. Conclusions

Fungi and oomycetes are important agents in the control of animal diseases, which can seriously alter their health. Through the actions they present (insecticide, amoebicide, antiparasitic - ovicidal, larvicidal, nematicidal, and anti-pollution) according to those deduced from the scientific literature, they are key elements in ensuring the welfare of animals and improving their quality of life.

Conflict of interest

There are no conflicts of interest to declare.

Notes/Thanks/Other declarations

Thanks go to Banat's University of Agricultural Sciences and Veterinary Medicine "'King Michael I of Romania", for helping the author with the costs of publishing this book chapter.

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