SEVEN publicações acadêmicas

Tools for control of the african snail (Achatina *fulica*, Bowdich, 1822)

Crossref doi
https://doi.org/10.56238/Connexpemultidisdevolpfut-100

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ABSTRACT
The mollusk Achatina *fulica*, which is popularly known as the African giant snail, is the secondary vector of the helminths Angiostrongylus cantonensis and Angiostrongylus costaricensis, both of which cause human angiostrongyliasis. This species belonging to the class Gastropoda, belongs to the subclass Pulmonata, where terrestrial mollusks such as slugs, snails and snails are inserted. The introduction of this mollusk in Brazil occurred in a disorderly manner culminating in a problem of great environmental impact due to the behavior of agglomeration, direct competition with mollusks of the natural fauna for food and space. These factors may even put the mollusks of the native fauna at risk of extinction. In addition, the fact that the mollusk does not present a food requirement makes it an imminent economic danger, due to the fact that it can devour crops, generating an economic impact. To date, the only known control measures for A. *fulica* are the collection and direct salinization in the mollusk. Thus, another limitation in the control of infestation of this invasive species is the ignorance of a synthetic or natural substance, with effective molluscicide action and also duly legalized by the National Health Surveillance Agency (ANVISA). In this context, it is easy to observe that there is a scarcity of studies aimed at obtaining new substances for the control of terrestrial molluscs. Since most studies of products with molluscicides are especially focused on aquatic molluscs, increasing the relevance of new studies and products, with effective action on A. *fulica*, and with low environmental impact.

Keywords: Control, Agricultural pest, Terrestrial mollusk, African snail, *Achatina fulica*.

1 INTRODUCTION

The mollusk *Achatina fulica,* which is popularly known as the African giant snail, is the secondary vector of the helminths Angiostrongylus cantonensis *and* Angiostrongylus costaricensis, *both of which cause human angiostrongyliasis* (COLLEY, 2010). The mollusk *A. fulica* (Figure 1) belonging to the class Gastropoda (which is considered the largest and most diverse class among the molluscs), belongs to the subclass Pulmonata, where other terrestrial molluscs are inserted. *A. fulica* presents as characteristic the presence of a complete digestive cavity, heart formed, by two atria and two separate ventricles, in addition to the muscular part where it can be perceived in the head the presence of a pair of tentacles and in its extremities are the eyes and the foot part.

It has a mucus composed of *achacin* a viscous glycoprotein substance obtained through the secretion of different glands that have several important functions for the biology of the animal, since it promotes protection of the animal's body against dehydration, its viscosity assists in locomotion, food capture, osmotic regulation and reproduction. Additionally, it can act as a vehicle for the release of pheromones, but the characteristics of this mucus can be directly altered by the physical conditions and the feeding status of the mollusk (MARTINS *et al*., 2003; JEONG *et al*., 2001; SRI ARJANI, 2022).

Figure 1 Mollusc *Achatina fulica*, kept in the laboratory. Source: Own authors.

A. fulica has odoriferous memory, a factor that can facilitate the survival and adaptation of the mollusk to the environment due to the ability to orient itself through the odors of the food it ate and storing this memory over a long period. This is an important mechanism for the survival of the animal, since it can avoid foods that are poorly nutritious or that may cause adverse effects (MARTINS *et al*., 2003; JEONG *et al*., 2001).

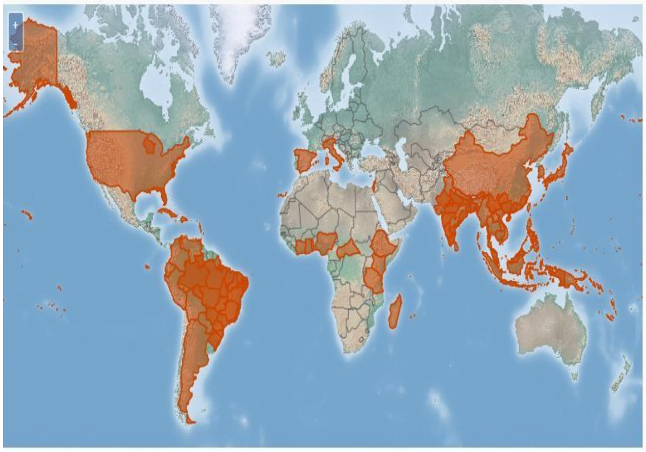
These mollusks can be found on the banks of marshes, vegetable gardens and orchards, abandoned plantations, vacant lots, backyards, gardens among others. They have high adaptation and resistance to abiotic factors such as temperature and humidity, and also have high proliferation in the rainy season (COELHO, 2005; PAIVA, 2006). The snails *A. fulica,* live on average from 3 to 5 years free in the environment (MEAD, 1979), and can reach 9 years in captivity.

The snail *A. fulica* is an original terrestrial mollusc from East-Northeast Africa (PAIVA, 2006). Its distribution has been widely observed in the Kwazulu-Natal regions of South Africa to the northern part of Somalia (SARMA *et al*., 2015). It has become a widespread pest in several regions of the world, being found in countries such as Thailand, China, Australia and Japan in addition to the American continent, being considered one of the largest and worst invasive species (Figure 2) (ZANOL *et al*., 2010).

The mollusk was introduced in Brazil during the 80's, having its introduction initially in the state of Paraná, where at the time there were courses that taught the correct way to carry out the creation and maintenance in the breeding grounds of these mollusks (Fischer *et al*., 2006). It is worth mentioning that to date there are no documents that register authorizations from government agencies for the introduction of these mollusks in the country. The objective of the introduction of mollusks at the time was to obtain a way to replace the escargot *(Helix aspersa*) as a gastronomic delicacy of lower cost (OLIVEIRA *et al*., 2010).

The disorderly introduction of these mollusks culminated in a problem of great environmental impact due to the behavior of agglomeration, direct competition with mollusks of the natural fauna for food and space. These factors may even put the mollusks of the native fauna at risk of extinction. In addition, the fact that the mollusk does not present a food requirement makes it an imminent economic danger, due to the fact that it can voraciously devour crops, generating an economic impact in places that depend on natural fauna (BARROSO, 2003).

Figure 2 Distribution of the mollusc *Achatina fulica* worldwide



Source: https://www.cabi.org/isc/datasheet/2640#toDistributionMaps

According to Fischer and Colley (2010), the National Biodiversity Policy, which describes the regulation of measures to control, manage and eradicate invasive alien species in Brazil, is provided for in Decree 4,339 of August 22, 2002. In addition, the Fauna Law, 5,197 of January 3, 1967 and the Environmental Crimes Law, 9,605, of February 12, 1998 determine the destruction of exotic animals considered harmful to agriculture or public health.

However, the specific prohibition for the creation and commercialization of the mollusc in Brazil was instituted in 2005, with the publication of normative instruction number 73 of IBAMA, which began to consider the mollusc *A. fulica* as a species not belonging to the native fauna, being, therefore, an invasive alien species, harmful to wild species, the environment, agriculture and public health, and authorizing the implementation of control, collection and elimination measures (FISCHER and COLLEY, 2010).

1.1 SITUATION OF *ACHATINA FULICA* IN BRAZIL

The species *A. fulica* has already had its presence confirmed in 25 of the 26 Brazilian states (Figure 3), causing a great impact to the affected communities and economic losses, especially in areas dependent on agriculture because this mollusk does not present food restriction rapidly devouring plantations (THIENGO *et al*., 2013).

The snail *A. fulica* has a preference for wetlands and provided with shelters, necessary to avoid its dryness, causing areas with garbage accumulation, vegetated, with open sewage and in inadequate sanitary conditions to be sought by these organisms. Thus, the preferences of the species added to the precariousness of basic sanitation present in most Brazilian municipalities, makes *A. fulica* easily find suitable habitats to complete its life cycle (**SOUZA *et al.* 2020, SANTOS *et al.* 2022**).

The presence of *A. fulica* throughout the territory can also be seen as a serious public health problem, since this mollusk is a potential host of nematodes that cause human angiostrongylosis (FISCHER *et al*., 2010). In addition to acting as an intermediate host of parasites of domestic and wild animals such as *Aelurostrongylus abstrusus*. (ZANOL *et al*., 2010). The presence of infected animals can be noted in Vila Velha, in Espírito Santo, São Vicente in São Paulo, São Gonçalo, Barra do Pirai and Angra dos Reis in Rio de Janeiro, Joinville and Navegantes in Santa Catarina, Paranaguá in Paraná, Escada in Pernambuco (Thiengo *et al*., 2010) and Belém, in Pará.

In addition, shells of dead organisms, when filled with rainwater, can host populations of *Aedes aegypti* mosquito vector of the diseases dengue, yellow fever, zika and *chikungunya* but the attention on the species is due, above all, to the risk of transmission of diseases to man and other higher vertebrates **(SILVA *et al.* 2021).**

Figure 3. Areas affected by the snail Achatina fulica 2013

Source https://agencia.fiocruz.br/funda%C3%A7%C3%A3o-cria- strat%C3%A9gia-of-snail-control-that-proliferates-with-rapidity.

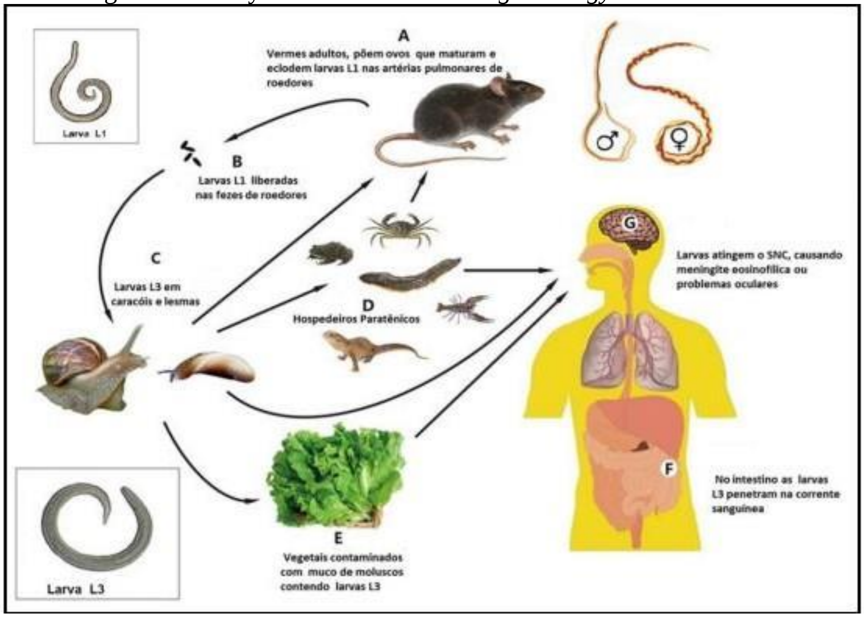
1.2 PARASITES TRANSMITTED BY *ACHATINA FULICA*

The medical and epidemiological interest of the nematode worms of the superfamily *Metastrongyloidae* has been increasing, due to the increased presence of this mollusk acting as an intermediate host of these worms, which gives a character of emerging veterinary and medical importance (WANG *et al*., 2008). The Metastrongilid superfamily consists of approximately 180 different species of nematodes. These are mostly found parasitizing mammals. However, some exceptions are found as occurs with A. *cantonensis and A. costaricensis* which are found parasitizing *A. fulica.* (SPRATT, 2015).

A. cantonensis is the helminth that causes human angiostrongyliasis eosinophilic meningitis in humans in the case of infection through ingestion of the mollusk *A. fulica* contaminated with helminth or food contaminated with L3 larvae of the helminth (TELES and FONTES, 2002). *A. Cantonensis* has its cycle, the presence of two hosts, the mollusks that act as intermediate hosts and rodents (*Rattus rattus*) that act as the definitive host of the worm. Frogs, small lizards and humans are paratenic hosts since they become contaminated through the ingestion of plants, fruits with the presence of the mollusk or even contaminated mollusks (LAI *et al*., 2016).

In the biological cycle *of A. cantonensis*, females lay eggs, which when hatching, release first-stage larvae (L1) into the terminal branches of the rodents' pulmonary arteries. The larvae of the first stage migrate to the pharynx of the rodent, are swallowed and eliminated in the feces. They penetrate or are ingested by an intermediate host (snail or slug). Third-stage (L3) larvae are produced, which are infectious to mammals. When the mollusk is ingested by the definitive host, the larvae of the third stage (L3) migrate to the brain where they develop into young adults. Young parasites return to the venous system and migrate to the pulmonary arteries, where they become sexually mature. Several animals act as paratenic (transport) hosts: after ingesting the infected snails, they carry third-stage larvae that can resume their development when the paratenic host is ingested by a definitive host (CDC, 2015). (Figure 4).

Figure 4. Life cycle of the helminth *Angiostrongylus cantonensis*.

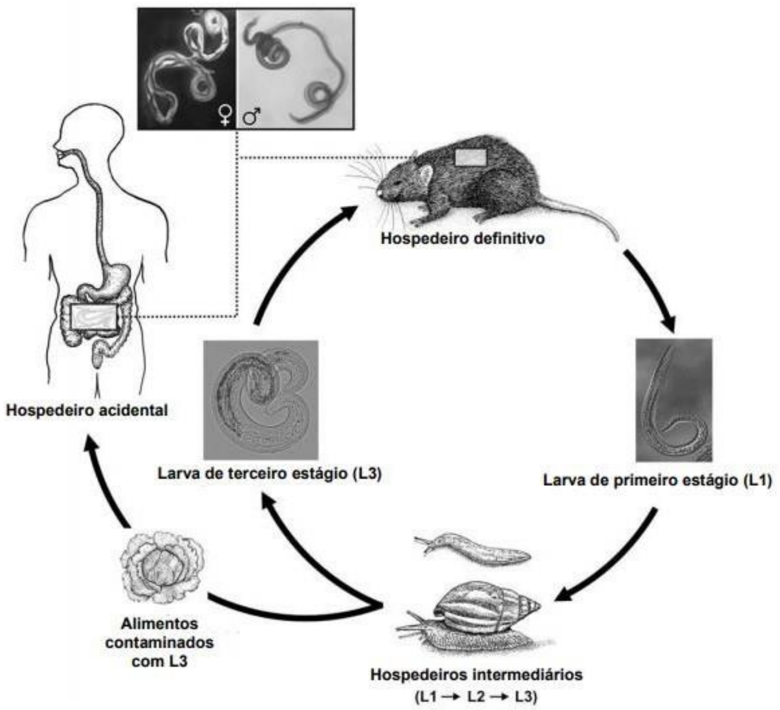


Adapted from (LAI et al (2016)

A. costaricensis is the helminth that causes abdominal angiostrogiliase, one of the forms of human angiostrogiliase. The adult form of these helminths is located in the upper branches of the mesenteric artery of rodents, and it is in this region that females lay their eggs, where after laying the eggs are carried by the bloodstream to the wall of the intestine, where hatching occurs, and the larvae of the L1 form end up being eliminated in the environment along with the feces (ACUNA 2008). These L1 larvae already in the environment, infect the intermediate hosts orally or percutaneously, where they undergo two modifications reaching the L3 form that in turn are eliminated along with the mucus of the snails (ACUNA, 2008) (Figure 5).

Rodents and other vertebrates, on the other hand, become infected through the ingestion of these molluscs, fruits or vegetables contaminated by the larvae in the L3 form, since they are expelled through the release of the mollusk mucus, and when infecting these hosts the larvae migrate through the lymphatic vessels becoming adult worms when they reach the mesenteric arteries (MOTA and LENZI, 2005) (Figure 5).

Figure 5. Life cycle of helminth *Angiostrongylus costaricensis* (Rabello *et al*.; 2011).



1.2.1 Human Angiostrangiliasis

Parasites that are transmitted by the mollusc *A. fulica* cause human angiostrongyliasis in humans, which can present in the forms of eosinophilic meningitis and abdominal angiostrongylase. Abdominal angiostongilliase is caused by the helminth *A. costaricensis.* In Brazil, most of the reported cases occurred in the states of Paraná, Rio Grande do Sul, Santa Catarina and São Paulo and is described as a disease that affects both adults and children (GRAEEF -TEXEIRA, 1991).

This disease is characterized by the presence of an intense inflammatory reaction, which ends up causing the retention of part of the eggs in the tissues, which ends up preventing the release of the larvae. The inflammatory lesion occurs in the cecal ileus part, with tumor and ischemic patterns the clinical manifestations associated with infection in humans are anorexia; nausea; pain; sometimes the presence of a palpable mass in the abdominal quadrant. One of the major problems associated with this disease lies in the lack of specific treatment methods since the death of the parasite within the mesenteric artery can lead to cases of acute arterial thrombosis (GRAEEF – TEXEIRA, 1997).

Infections caused by helminth *A. cantonensis* present in clinical form a picture of eosinophilia meningitis, or parasitic meningitis In parasitic meningitis there is the presence of at least 10% of eosinophils, in relation to the total leukocyte count in the CSF, which defines the picture of eosinophilic meningitis. Helminthic infections, in particular by *Angiostrongylus cantonensis,* the most frequent cause of eosinophilic meningitis (THIENGO, 2007; LIPHAUS *et al*. 2022). In Brazil, cases of this disease have been recorded in states such as Espírito Santo, Pernambuco, Amapá, Pará (GRAEEF –TEXEIRA, 1991, Paiva *et al. 2020, Cunha et al. 2017), where through epidemiological* *studies it was proven direct participation of the mollusc* A. fulica*, in the transmission of this helminth (THIENGO* et al., 2010). The clinical manifestations of this form are similar to those seen in bacterial meningitis (Neck stiffness, fevers, vomiting, severe headache).

Diagnosis is based on the search for larvae in CSF through the western blot technique. At first there is no proven effective treatment, has been used treatment with corticosteroids in order to relieve pain caused by exacerbated inflammatory reaction (WANG, 2008)

1.3 CLAM CONTROL

On the international stage it is considered one of the most dangerous invasive alien species in the world. Due to the high economic and environmental costs attributed to the African giant snail, different control strategies have been adopted. The concept of eradication in the action plan against the African giant snail was replaced by the concept of management, as previously implemented strategies did not obtain results in eradication, thus emerging new strategies that use the combination of alternative control methods (da Silva and Marques, 2017; de la Ossa *et al.,* 2017).

Currently, the most popular control measures for *A. fulica* are collection and salinization (Figure 6). The use of table salt (NaCl) is the most popularly known control measure for *A. fulica*, but its use can harm the chemical properties of the soil (Figure 7). According to Rhoades et al. (2000), salinization affects crops directly, by hindering the absorption of water by plants, causing changes in the physiological processes of plants decreasing or preventing their growth. In addition, another method employed is the use of quicklime by burying the mollusks, instead of using NaCl.

The increase in the concentration of salts present in the soil, causes the osmotic pressure to eventually increase in such a way, that the plants are not able to remove the water and nutrients from it. The increase in this osmotic pressure can cause the plant to lose water to the soil, thus causing an effect known as physiological drought. Nevertheless, as described in Brazil (2005) and Brazil (2006), IBAMA took as its main guidance protocol the use of collection and salinization.

The salt is applied directly on the cephalopodal mass or at the opening of the shell, so that it has direct contact with the mollusk. In general it is indicated that the mollusks, after being collected, are placed in garbage bags, buckets, basins or even in holes dug in the ground. Subsequently, salt or quicklime is applied to all mollusks collected at once. Consequently, the application of salt causes dehydration of the molluscs and their death by the loss of excess water.

In addition, one should be aware of excessive salinization of the soil with coarse salt. In the currently recommended and used form, there is no quantification of the salt concentration (NaCl) that is being used. Additionally, there is no standardized protocol to stipulate the amount of salt that should be used in the control of *A. fulica* (SECRETARIA DE ESTADO DA SAÙDE DE SANTA CATARINA, 2014).

It should be noted that the mollusc *Megalobulimus (Aruá-do-mato)* that is natural to the Brazilian fauna, for presenting morphological similarities to those of the snail *A. fulica*, such as the size and shape of the shell. Element that can end up confusing and eliminating in a wrong way this mollusk, and consequently causing a great impact on the population of a natural mollusk and facilitating the proliferation of *A. fulica*. Since both compete directly for food and the environment (SECRETARIA DE ESTADO DA SAÙDE DE SANTA CATARINA, 2014).

One of the major problems present in the infestation *of A. fulica* is the lack of knowledge of a synthetic or natural substance, with effective molluscicidal action and also duly legalized by the National Health Surveillance Agency (LI *et al*., 2011). In this context, it can be easily noticed that there is a scarcity of studies aimed at obtaining new substances for the control of terrestrial molluscs. Since most studies of products with molluscicides are especially focused on aquatic molluscs, the relevance of new studies and products, with effective action on *A. fulica,* and with low environmental impact (SOUZA *et al*., 2014) increases.

Figure 6. Shell of *Achatina fulica* with salt used for control, being possible to see the mollusk in a liquefied state.

Available in: http://g1.globo.com/ac/acre/noticia/2013/05/invasao-de-caramujos-preocupa-residents-in-rio-branco .html accessed 11/07/2019

Figure 7. Illustrative Photo of Salinized Soil

Source: https:// www.canalrural.com.br/noticias/saiba-como- Recover-and-Avoid-the-Salinization-of-the-Soil

1.3.1 Baits

In many places the mollusc population develops very fast, so that control through collection and salinization ends up becoming unfeasible. As such, many sites have used commercial baits that are primarily used to control slug infestations as an alternative measure to control the A. *fulica mollusk.*

RODA and collaborators in 2018, with work to design a capture strategy to help eradication programs for the African giant snail, *A. fulica*, in South Florida, showed that its application to gastropod programs remains somewhat unexplored. Field studies were conducted to determine the best bait, barrier and trap for use during the eradication program. Immature and adult snails were attracted to the banana and a commercially produced bait (Lesmax). In the results obtained, it was possible to observe that the African snails collected in traps with the commercially produced baits was 85% more effective than with the banana bait.

RODA and Collaborators 2019 researched a new synthetic bait for the management of the invasive African giant snail, *A. fulica*. Synthetic chemical baits that mimic pheromones or food attractants can be essential tools in invasive species eradication programs. However, its uses in programs aimed at controlling or eradicating terrestrial gastropods are largely unexplored. The authors' goal was to find a synthetic attractant that could aid in the eradication or management of the African giant snail (*A. fulica*). They used a reconstructed synthetic mixture that released odors from papaya oil in laboratory and field bioassays, and observed that the reconstructed mixture, applied to cotton wicks with water and canola oil or water and mineral emulsions, attracted more snails than the water and oil emulsion control wicks. The synthetic bait attracted snails from distances of 35 to 105 cm – great distance for gastropods. In addition, this study showed that snails responded quickly to the presence of the attractant. The synthetic bait did not attract pets, bees and other protected non-target species. It is noteworthy that this experiment evaluated only one bait with only attractive function, such bait would not have the purpose of generating death to the animals tested.

Currently, the Ministry of Agriculture, Livestock and Supply (MAPA) is the agency responsible in Brazil for the registration of synthetic substances used in the field. However, the toxicity test is the responsibility of the National Health Surveillance Agency (ANVISA) (ANVISA, 2018). Factor that increases the bureaucracy and cost for the legalization of new assets. Associated with this, currently the lack of selectivity and environmental toxicity are the two main limiting factors to obtain effective substances in the field.

The metaldehyde in most of the baits known and registered by MAPA and tested by ANVISA, for not presenting specificity can lead to great environmental impacts since by the granular appearance, these baits can be easily confused with food, for other animals and natural mollusks of the local fauna.

Another counterpoint of the use of baits is the fact that it is not a cheap methodology, since the size of the terrain, the density of the vegetation and the amount of local mollusks directly impact the amount of baits to be used. In addition, care must be taken that the product does not fall into water sources thus avoiding that they are contaminated (BRAZIL, 2000).

1.4 NATURAL PRODUCTS WITH ACTION ON *Achatina fulica*

Because it has become a pest, the search for control measures of *A. fulica* remains constant, although studies on the action of natural products on terrestrial molluscs are few (SOUZA *et al*., 2014). Some studies show promising results, thus being able to be treated as possible molluscicides, requiring further studies to confirm and improve the results, as in the case of *Capsicum frutescens L* extract. (chili pepper) (JUNIOR, 2018). This extract showed 100% activity at all tested concentrations (2 g/L, 3g/L, 4g/L, 5g/L, 6g/L, 7g/L, 8g/L, 9g/L, 10g/L) in young people aged 30 days. Despite this promising result, more studies are needed to confirm its molluscicidal action and improve the obtaining of extracts.

There are also studies such as the one presented by VIERA and collaborators in 2013, which used the aqueous extract of the leaves of *Baccharis dracunculifolia DC* (broom), *Cyperus rotundus* L. *(Tiririca) and Morus rubra (Amora).* All extracts showed ovicidal action. However, not all had molluscicidal action. The extract of *Agave americana* was tested on another terrestrial mollusc, *Bradybaena similaris*, showing positive results of 100% mortality at concentrations of 1% and 0.5%. The authors stipulated that this action was due to the presence of saponins, and this result was observed after 24 h.

Considering the low number of studies that use natural extracts on terrestrial molluscs, associated with the fact that the use of products are potentially harmful to the environment and human health, we reinforce the need to discover new drugs or compounds to combat the growth of the A. *fulica population.*

2 CONCLUSION

Achatina fulica is considered one of the largest and worst invasive species, this occurs because this species has the facility to adapt easily to adverse environments. This species generates an environmental impact due to its behavior and direct competition with mollusks of natural fauna for food and spaces. These factors may contribute to mollusks of native fauna at risk of extinction. Another impact that this species generated, was in the plantations, causing an economic consequence for the places that depend directly on the plantations.

The African snail has medical importance, as it is the intermediate host of helminths A. *cantonensis and* A. costaricenses*, and may cause abdominal angiostrongyliasis and* meningitis eosinophilia.

To date, the forms of controls known are collection and salinization. However, these measures have some disadvantages. The collection requires time, to collect each mollusk, and when there is an infestation, this measure becomes more difficult and time-consuming, in addition to the necessary care, since it is possible to find contaminated mollusks. Salinization, a measure widely used by the population, can damage the chemical properties of the soil, making the soil infertile.

According to the aforementioned scenario, although some studies corroborate this problem, the lack of control with the species *A. fulica* still becomes insufficient. Therefore, it is necessary to search and further studies for synthetic and/or natural substances, with effective molluscicidal action, legalized by the National Health Surveillance Agency (ANVISA) and with low environmental impact.

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