Endoparasites of Selected Native Non-Domesticated Mammals in the Neotropics (New World Tropics)

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Abstract: In this review, information was summarized on endoparasites found in six non-domesticated neotropical animals. These mammals have the potential to be domesticated. The animals included three rodents, agouti (Dasyprocta leporina), lappe (Agouti paca), and capybara (Hydrochoerus hydrochaeris); a marsupial, manicou (Didelphis marsupialis insularis); and an artiodactyl, the collared peccary (Tayassu tajacu/Peccari tajacu) and a ruminant (the red brocket deer, Mazama americana). While there are many descriptions of the parasites present, the majority of publications failed to note the effect of them on the animals. Most information is available on endoparasites of capybara, while the endoparasites of the red brocket deer were the least reported. The manicou was reported to have had the most number of endoparasites, 44 species of parasites were reported, while there were only 24 endoparasites reported in the lappe. The most common parasites found in these neotropical animals were Paraspidodera uncinata, Strongyloides spp., Eimeria spp., Moniezia benedeni, Trichuris spp., Physoscelis spp., and Giardia spp. A large majority of the studies concluded that these animals were reservoirs for parasites that could affect domesticated livestock. Endoparasites of zoonotic significance were Echinococcus spp., Trichuris spp., Giardia spp., and Cryptosporidium spp.

Keywords: Dasyprocta leporina; Agouti paca; Hydrochoerus hydrochaeris; Didelphis marsupialis insularis; Tayassu tajacu; Peccari tajacu; Mazama americana

1. Introduction

In this review, updates were made on the current knowledge of endoparasites in non-domesticated animals with the potential for domestication. These animals have the potential to be meat protein sources for rural communities. Former reviews on endoparasites in the neotropics summarized the information on cattle (Bos indicus and Bos taurus), sheep (Ovis aries), goats (Capri hircus), horses, (Equus caballi), pigs (Sus surof), and chickens (Gallus domesticus) [1]. Endoparasites mainly found in these domesticated animals were Strongylus vulgaris in horses, Hystrostrongylus rubidis in pigs, Haemonchus contortus in ruminants, and Heterakis gallinarum in chickens. Some endoparasites of ducks (Anas platyrhynchos and Cairina moschata), turkeys (Melaegradis gallopavo), chinchillas (Chinchillas lanigera), guinea pigs (Cavia porcellus), and south american camelds (Lama glama, Lama pacos, Lama gunacoa, and Vicuna vicuna) were Nematodirus spp., Trichostrongylus spp., Giardia duodenalis, Cryptosporidium spp., and Ascaridia gallinarum [2].

Since these six native neotropical animals have potential for domestication [3], it is required to focus on factors which affect animal production. These factors are (i) feeding and nutrition, (ii) reproduction and breeding, (iii) health and disease, (iv) housing and environment, (v) economic and socioeconomic
factors, and (vi) animal behavior and psychology [3,4]. Recently, the agouti, *D. leporina*, has been studied in more detail, with focus on the anatomy of the male and female reproductive system, oestrus cycle in the female (28–31 days) as well as semen analysis using electroejaculation [5–8]. Further anatomical investigations of the digestive system of the agoutis revealed that the majority of the gastrointestinal tract was small intestine in conjunction with a large cecum [9]. The agoutis mainly are frugivorous with the majority of the diet consisting of nuts and fruits, with potentially a preferential particle size [10–13]. Earlier it was found that these animals were rather omnivorous and would consume eggs and chicks [14]. It is clear that there is a need for more investigation on their feeding habits. Several studies have reported on the blood values of captive reared animals, and differences in diets and environments did not affect those values [15]. As such, blood values are a good basis for determination of the health status of neotropical mammals.

The lappe was described as a frugivore, the manicou as an omnivore, the collared peccary as a pseudo-ruminant herbivore, and the red brocket deer was grouped with ruminants [12–19]. The manicou has a gestation period of three weeks [17,18]. Other information on these species is lacking. The objective of this review was to summarize the knowledge of endoparasites found in six native non-domestic neotropical animal species. These neotropical animals are potential sources of meat protein which can be utilized by rural communities.

2. Agouti (*Dasyprocta* spp.)

The earliest work on the gastrointestinal parasites of the agouti, *D. leporina*, was done in the mid 1930s. *Strongyloides agoutii* was described in the feces of the agouti. This parasite has a similar life cycle as the other species of the *Strongyloides* genus [20]. Similar work was done on agoutis found in Trinidad, but the entrails of the animals were analyzed for gastrointestinal parasites. In the early 1950s, the amphistome, *Stichorchis giganteus*; the tapeworm, *Raillietina demerariensis* var. *trinitatae*; and seven roundworms including *Strongyloides agouti*, *Trichuris gracilis* var. *trinitatae*, *Acanthocheilonema spp.*, *Fuellebornema agoutii*, *Pudica pudica*, *Aspidodera binansata* var. *agoutiae*, and *Helminthoxys urichi* were detected in the agouti [21].

In presumed healthy wild agoutis from Trinidad, *Trichuris gracilis* var. *trinitatae* (in cecum and large intestines), *Strongyloides agouti*, *Helminthoxys urichi*, *Eimeria* spp., ascarid-like ova (unidentified species), trematode (unidentified species), and an unidentified cestode were detected [22] and more recently in intensively reared agouti (*D. leporina*), *Strongyloides spp.* was found in 36.9%, *Trichuris* spp. in 4.62%, and *Paraspidodera uncinata* in 15.4% of the agoutis sampled (n = 65). Despite the presence of these parasites, the animals were in good body condition (average body condition score of 3 out of 5) and had no history of gastrointestinal illness [23]. Using fecal floatation techniques, *Trichuris* spp. were found at a concentration of 2.2 × 10^2 eggs/gram, *Strongyloides* spp. at 4.28 × 10^2 eggs/gram, and *Eimeria* spp. at 2.15 × 10^3 oocysts/gram, all with no signs of gastrointestinal illness and a body condition score of 3 out of 5 [24].

In Paraguay, wild agoutis (*D. azarae*) were positive for *Pudica pudica*, *Pudica gonosoma*, *Durettestrongylus baudi*, *Fuellebornema granulosa*, and *Fuellebornema demarsae* [25]. In several studies in Brazil, agouti parasites that were found included *Trichuris* spp. (in cecum), *Eucyathostomum copulatum*, *Helminthoxys urichi* (in cecum and intestines), *Physoclophalus meridionalis* (large intestine) and *Dipetalonema* spp. (body cavity), *Eucyathostomum copulatum* (large intestine), *Heligmostrongylus agouti*, *H. almeidai*, *Heligmostrongylus sedecimradiatus*, *Monodontus aguiari*, *Pudica pudica*, *Pereiraia spp.*, *Physoclophalus meridionalis*, *Trichuris gracilis* (cecum), *Raillietina trinitatae* (small intestine), *Physaloptera toressi*, *P. mediospiralis* (stomach), *Freistronyculus angulac* (stomach), *Vianella trichospicula*, and *Avellaria intermedia* were found [26–35]. The *Eimeria* spp. identified were *E. aguiari*, *E. cotiae*, and *E. paraensis*. The predilection site of these protozoan parasites was the small intestines, but none of the infected animals showed signs of illness and the fecal pellets found were of normal consistency [31]. Reported prevalences were 45.3% (24/53) for protozoan oocysts, 10.8% (7/53) for *Trichuris* spp. eggs, and 18.8% (10/53) for *Strongyloides* spp. [29].
In a zoo in Mephis Tennessee, *Echinococcus oligarthrus* hydatid cysts and *Strongyloides* spp. were found in healthy Brazilian agoutis from Guyana. These animals were treated with ivermectin (0.7 mg subcutaneously, twice daily for 14 days), praziquantel (28.4 mg intramuscularly, twice daily for 30 days), and albendazole (65 mg per os, once a day for 30 days) and some of the subcutaneous cysts were removed surgically [36]. In the studies performed in Argentina, similar parasites as to those mentioned above were found [37].

Other treatments that were reported included fenbendazole (5 mg/kg/day for 5 days) and piperazine citrate (180 mg/kg/day for 5 days), and the efficacy reported with these treatments were poor [38]. Most authors identified various parasites in captive-reared and wild agoutis in the neotropical region; however, only a few made reference to the effect these parasitic organisms had on the animals’ health and body condition. A summary of the endoparasites found in the agouti at different locations and the effects on the animals (host) can be seen in Table 1.

| Parasites Location | Diagnostic Year | Ref. |
|--------------------|-----------------|-----|
| Strongyloides spp. | Trinidad | Necropsy and microscopy 1940 [20] |
| Stichorchis giganteus, Raillietina demerariensis var. trinitatae, Strongyloides agouti, Trichuris gracilis var. trinitatae, Acanthocheilonema trinitate, Echinococcus oligarthrus | Trinidad | Necropsy and microscopy 1951 [21] |
| Pudica pudica, Pudica gonosoma, Durettestrongylus baudi, Fuellebornema granulosa, Fuellebornema demarsae | Paraguay | Necropsy and microscopy 1991 [25] |
| Trichuris spp., Eucyathostomum copulatum, Helminthoxys urichi, Physcephalus meridonatis, Dipeptidella demarsae | Brazil | Necropsy and microscopy 2002 [26] |
| Vianella trichospicula, Azellaria interna | Brazil | Necropsy and microscopy 2006 [28] |
| Protozoan oocysts, Trichuris spp., Strongyloides spp. | Brazil | Copsorscopy 2006 [29] |
| Trichuris gracilis, Helminthoxys urichi, Physaloptera torresi, P. mediospiralis, Raillietina trinitatae | Brazil | Necropsy, fecal flotation and microscopy 2006 [30] |
| E. aguti, E. cotiae, E. paraensis | Brazil | Fecal floatation 2007 [31] |
| Freitastrongylus anglensis | Brazil | Necropsy and microscopy 2007 [32] |
| Strongyloides agouti, Parascioidera uncincta, Helminthoxys urichi, Pudicinae, Trichurus gracilis | Brazil | Necropsy and microscopy 2008 [33] |
| Strongylida, Rhodostoma, Giardia spp., Eimeria spp. | Brazil | Fecal floatation 2008 [34] |
| Echinococcus oligarthrus (hydatid cyst), strongyles, Strongyloides spp. | Guyana | Clinically healthy with no significant findings on bloodwork 2009 [36] |
Table 1. Cont.

| Parasites                                      | Location | Effect on Animal or Pathological Lesion                                    | Diagnostic                         | Year | Ref. |
|------------------------------------------------|----------|---------------------------------------------------------------------------|------------------------------------|------|------|
| Trichuris gracilis var. trinatae, Strongylodes agouti, Helminthoxys urichi, Eimeria spp., ascarid-like ova (unidentified species), trematode (unidentified species), cestode (unidentified species) | Trinidad | Presumed to the healthy animals                                            | Necropsy, fecal floatation and microscopy | 2016 | [22] |
|                                                 |          |                                                                           |                                    |      |      |
| Eucyathostomum copulatum                        | Brazil   | Not recorded                                                              | Necropsy and microscopy            | 2016 | [35] |
|                                                 |          |                                                                           |                                    |      |      |
| Strongyloides spp., Trichuris spp., Paraspodora uncinata | Trinidad | All animals were in good body condition (average score of 3 out of 5) and no history of gastrointestinal illness | Fecal floatation                   | 2017 | [23] |
|                                                 |          |                                                                           |                                    |      |      |
| Trichuris spp. (2.2 × 10^5 eggs/gram), Strongylodes spp. (4.26 × 10^5 eggs/gram), Eimeria spp. (2.15 × 10^3 oocysts/gram) | Trinidad | No signs of gastrointestinal illness and animals having an average body condition score of 3 out of 5 | Fecal floatation (Mc Master)         | 2018 | [24] |

3. Lappe (Agouti paca/Cuniculus paca)

Most of the studies on lappe were from Brazil and the following parasites were found: Heligmostrongylus sedecimradiatus, Longistriata breviscapula, Oswaldonema cruzi, Oswaldonema skrjabini, Paraspodora uncinata, Paraspodora spp., Pereiraia spp., Turgida torresi, Trichuris spp., and Vianella avellari. Physocephalus spp. was found in the stomach, and Strongylodes spp. and Strongylus spp. were found in the small intestine. Heligmostrongylus agouti and Physostomum meridionalis were found in the stomach and Echinococcus vogeli and Calodium hepaticum were found in the liver [26,27,39].

Few studies reported the pathology caused on internal organs by the endoparasites. The liver pathology potentially caused by Echinococcus vogeli and Calodium hepaticum was characterized by fibrosis with a scanty infiltrate of lymphocytes and macrophages [39] and the histopathological lesions of Physostomum spp. in the stomach showed congestion, interstitial hemorrhaging, and mononuclear inflammatory infiltrates [40]. In a breeding farm in Brazil, Eimeria spp., Strongylodes spp., Trichuris spp., and Hymenolepis diminuta were found and managed by anthelmintics and sanitation [41]. Quick lime was also used as an anthelmintic treatment for the larval stages of the parasites in the soil [42].

In a few other countries, the Strongylodes spp. were found [43]. In Costa Rica, Strongylodes spp., Strongylida, Eimeria agouti, Capillaria spp., Ascaroidea, Taenia spp., and Trichuris spp. were found in the gastrointestinal tracts [44]. In Mexico, Strongylodes spp., Strongylida, Trichuris spp., and Eucoccidia were found [45] and in Venezuela, Raillietina demerariensis (a cestode) was found [46].

Echinococcus spp. take a special place in the list of parasites found in the lappe as they are zoonotic. They have been found in Columbia where approximately 47% (44/93) of the lappe were found to be infected [47]. In Bolivia as well as Peru, Echinococcus vogeli was found but there were no reliable prevalence figures available [48–50]. A later study in Peru demonstrated larval cysts of E. vogeli in 12% of the lappe (15/120) [51].

Echinococcosis has been reported as being zoonotic and the agouti (D. leporina) and the lappe (A. paca) are the intermediate hosts of E. vogeli and E. oligarthrus. However, humans become infected via the ingestion of eggs that come from the adult parasites present in dogs [51–56]. All data on endoparasites in the lappe are summarized in Table 2.
Table 2. Endoparasites found in the lappe (*Cuniculus paca*/*Agouti paca*) at different locations.

| Parasites                                      | Location                  | Effect on Animal or Pathological Lesion                                      | Diagnosis                          | Year    | References |
|------------------------------------------------|---------------------------|-------------------------------------------------------------------------------|-------------------------------------|---------|------------|
| Heligmostrongylus sedecimradiatus,             | Brazil                    | Not recorded                                                                  | Necropsy and microscopy             | 1997    | [27]       |
| Longistriata breviscapula, Oswaldenoma crazi, |                           |                                                                               |                                     |---------|------------|
| Oswaldenoma skrjabini, Paraspidodera uncinata,|                           |                                                                               |                                     |---------|------------|
| Paraspidodera spp., Pereiraeia spp., Turgida  |                           |                                                                               |                                     |---------|------------|
| torrei, Trichuris spp., Vianella avellari     |                           |                                                                               |                                     |---------|------------|
| Strongyloides spp., Strongylus spp.,          | Brazil                    | Liver fibrosis with an infiltrate of lymphocytes and macrophages              | Necropsy and microscopy             | 2013    | [39]       |
| Heligmostrongylus agouti, Physcephalus         |                           |                                                                               |                                     |---------|------------|
| meridionalis                                    |                           |                                                                               |                                     |---------|------------|
| Echinococcus vogeli, Calodium hepaticum       | Brazil                    | Congestion, interstitial hemorrhaging, and mononuclear infiltrates             | Necropsy and microscopy             | 2012    | [40]       |
| Physcephalus spp.                              | Brazil (Tocantins)        |                                                                               |                                     |---------|------------|
| Eimeria spp., Strongyloides spp., Trichuris    | Brazil                    | Not recorded                                                                  | Fecal floatation                    | 2018    | [41]       |
| spp., Hymenolepis diminuta                     |                           |                                                                               |                                     |---------|------------|
| Strongyloides spp.                             | Brazil (Sao Luis)         | Not recorded                                                                  | Necropsy and microscopy             | 2018    | [43]       |
| Strongylus spp., Strongylidea, Eimeria agouti,| Costa Rica                | Not recorded                                                                  | Necropsy and microscopy             | 1991    | [44]       |
| Capillaria spp., Ascaroidea, Trichuris spp.,  |                           |                                                                               |                                     |---------|------------|
| Hymanolepis diminuta                           |                           |                                                                               |                                     |---------|------------|
| Strongyloides spp., Strongylida, Trichuris     | Mexico                    | Not recorded                                                                  | Coproscopy                          | 2001    | [45]       |
| spp., Eucoecidia                               |                           |                                                                               |                                     |---------|------------|
| Raillietina demerariensis                      | Venezuela                 | Not recorded                                                                  | Necropsy and microscopy             | 1988    | [46]       |
| Echinococcus spp.                              | Columbia                  | Cysts found in liver and peritoneum                                           | Necropsy and microscopy             | 1979    | [47]       |
| Echinococcus vogeli                            | Bolivia                   | Not recorded                                                                  | Necropsy and microscopy             | 1988, 2013 | [48,49]   |

4. Capybara (*Hydrochoerus hydrochaeris*)

The first reports that were made in Panama on endoparasites was in the 1930s and amphistomate flukes (*Taxorchis schistocotyle*) were detected in a dead animal. However, no lesions were found in the intestinal tract. [57]. Another case report came from the San Diego Zoo, where *Balantidium coli* was associated with mortality as well as mucoid diarrhea. Histological findings of the colon found ulceration and cellular infiltrates that consisted of eosinophils, macrophages, and plasma cells [58]. In Brazil, the death of a capybara was associated with four specimens of trematodes, *Trichostrongylidae*, *Eimeria*, and *Strongyloides* spp. There was multifocal fibrosis with marked thickening of the liver capsule and granulomatous thickening of the bile ducts [59]. *Eimeria ichiloensis* and *Eimeria trinidadensis* have been associated with diarrhoea in the capybara [60].

In Brazil, numerous studies have been conducted on the gastrointestinal parasites of capybaras. *Taxorchis schistocotyle*, *Crurifilaria tuberocauda*, *Eucoecus hydrochoerii*, *Echinocolus hydrochoerii*, *Habronema clarki*, *Hydrochoerisinae anomalobursata*, *Protozoophaga obesa*, *Strongyloides chapini*, *Trichostrongylus axei*, *Vianella hydrochoeri*, *Yatesia hydrochoerii*, *Moneococcus hagmanni*, *M. hydrochoeri*, *M. macrobursatum*, *M. hagmani*, and *H. fuelleborni* have been found in capybaras. *Capillaria hydrochoerii*, *Philophthalmus lachrymosus*, *Hippocrepis hippocrepis*, *Neocotele neocotele*, *Fasciola hepatica*, *Nudacotyle tertius*, *Nudacotyle valdecognatus*, *Taxorchis schistocotyle*, *Eimeria ichiloensis*, *Fasciola hepatica*, *Eimeria spp.*, cestodes, *Trichostrongylidae*, *Capillaria spp.*, *Anoplocephalidae*, *Ascaridae*, and *M. jacobi* have also been found [27,35,61–68].

Three more detailed studies on both juvenile and adult capybaras located the helminths at their predilection sites: *Trichostrongylus axei* (stomach and small intestines), *Vianella hydrochoeri*
(stomach and small intestines), *Strongyloides chapini* (stomach and small intestines), *Yatesia hydrochoeroides* (stomach and small intestines), *Protozoophaga obesa* (pyloric region of the stomach, cecum, colon, and rectum), *Taxorchis schistocotyle* (small and large intestines including cecum), *Hippocrepis hippocrepis* (small intestine, colon, and rectum), *Nudacotyle tertius* and *Monoeocestus hydrochoeroides* (small intestines), *Hydrochoeristrema cabrali* [66,69–71] and *S. chapini* had a higher prevalence in juvenile animals in comparison with adults, while for *Y. hydrochoerus* and *C. hydrochoeroides*, the opposite was recorded [69].

A more epidemiology-based study on 45 samples showed that 5.52% of the samples were positive for *C. parvum* [72], while another study showed that, of the 250 samples tested, 52.4% were positive for *Eimeria trinidadensis*, *Eimeria ichiloensis*, *Eimeria boliviensis*, and *Eimeria araside* [73]. Nine percent of 134 capybaras were found positive for *Fasciola hepatica* [74]. In 31 free ranging capybaras, 58% were positive for *Protozoophaga* spp., 23% for *Vianella* spp., 10% for *Strongyloides* spp., and 10% for *Ancylostomatidae* [75]. In Argentina, about 70% of the capybaras were found positive for endoparasites and infections with multiple parasites and protozoa were higher in young animals and in spring. Parasites found included: *Eimeria* spp., *Blastocystis* spp., *Balantidium coli*, Ascaridia, Trichostrongylidae, *Protozoophaga obesa*, *Strongyloides* spp., *Capillaria hydrochoeroides*, *Monoecocestus hydrochoeroides*, and *Taxorchis schistocotyle* [76]. Other studies in Argentina found *Fasciola hepatica*, *Echinocoleus hydrochoeroides*, and *Taxorchis schistocotyle* [77,78]. In 2019, a new species named *Trichuris cutillasae* was identified in the cecum of capybaras [79].

In Bolivia, in the mid 1990, helminths including *Monoeocestus hagmanni*, *M. hydrochoeri*, *M. macrobursatum*, *Habronema clarki*, *Vianella hydrochoeroides*, *Protozoophaga obesa*, *Taxorchis schistocotyle*, and *Hippocrepis hippocrepis* were found [80], while the protozoa found were *Eimeria trinidadensis*, *E. ichiloensis*, and *E. boliviensis* [81]. A more detailed study in Venezuela found a negative association between the body condition and helminth intensity for *M. macrobursatum* (found in the small intestine), *V. hydrochoeroides* (small intestine), and *H. hippocrepis* (large intestine) [82]. Other parasites found were *Monoeocestus hagmanni* (small intestine), *Protozoophaga obesa* (cecum), *Taxorchis schistocotyle* (cecum), *Hippocrepis hippocrepis*, *Eimeria trinidadensis*, *E. ichiloensis*, and *E. boliviensis* [81,82]. In Columbia, the following protozoan parasites were identified: *Sarcocystis* spp., *Eimeria* spp., *Giardia* spp., *Cycloposthium hydrochaeris*, *C. incurvum*, *C. minutum*, *C. lenticularis*, and *C. compressum* [83].

Stress by feed restriction and physical restraint had a negative effect on growth and body condition and induced a significantly higher coccidia infestation, and a lower helminth burden showing that the living conditions may have an influence on parasitic infestation [84]. Environmental conditions such as season, age, and sex of the animals have also been associated with different parasitic infestations. This shows that the interactions amongst gastrointestinal parasites are complex and further research is needed [85].

Capybaras have been shown to have a wide range of endoparasites, but they appear largely resistant to their effects and show only a few signs of ill health [86]. The capybaras, being the largest rodents on earth, have been given a lot of attention. However, the majority of investigations only noted the presence or absence of endoparasites without making observations on the effects these organisms had on the animals (Table 3).
Table 3. Endoparasites found in the Capybara (*Hydrochoeris hydrochaeris*) at different locations.

| Parasite                        | Location       | Effect on Animal Health or Pathological Lesion                                                                 | Diagnosis              | Year    | Ref. |
|---------------------------------|----------------|---------------------------------------------------------------------------------------------------------------|------------------------|---------|------|
| *Taxorchis schistocotyle*       | Panama         | No lesions were observed in the intestinal tract                                                              | Necropsy and microscopy | 1935    | [57] |
| *Balantidium coli*              | Florida        | Ulceration on colon with infiltration of plasma cells, eosinophils and macrophages                            | Necropsy and histology  | 1961    | [58] |
| *Taxorchis schistocotyle*       | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 2016    | [55] |
| *Cruorifilaria tubercuca*       | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 1997    | [69] |
| *Balantidium coli*              | Brazil         | Ulceration on colon with infiltration of plasma cells, eosinophils and macrophages                            | Necropsy and histology  | 1994    | [69] |
| *Strongyloides chapini*         | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 1995    | [80] |
| *Capillaria hydrochoeri*        | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 2002    | [62] |
| *Trichostrongylus axei*         | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 2004    | [70] |
| *Eimeria trinidadensis*         | Bolivia and Venezuela | Not recorded                                                                                               | Necropsy and microscopy | 2005    | [81] |
| *Protozoophaga obesa*           | Bolivia        | Not recorded                                                                                                 | Necropsy and microscopy | 2013    | [78] |
| *Eimeria spp.*                  | Belgium        | Not recorded                                                                                                 | Necropsy and microscopy | 2014    | [75] |
| *Capillaria hydrochoeri*        | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 2015    | [83] |
| *Hippocrepis hippocrepis*       | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 2015    | [66] |
| *Capillaria hydrochoeri*        | Brazil         | Not recorded                                                                                                 | Necropsy and microscopy | 2016    | [71] |
| *Trichuris cutillae*            | Argentina      | Not recorded                                                                                                 | Molecular and Morphological techniques | 2019    | [79] |
5. Manicou (Didelphis marsupialis insularis/Didelphis marsupialis)

The earliest data on endoparasites of the manicou (D. marsupialis insularis) were recorded in the early 1950s in Trinidad. In the large intestine, Aspidodera raillieti, Sublura trinitatis, Trichuris reesali, Trichuris minuta Trichuris urchi, Cruzia cameroni, Longistriata didelphis, and Viannaia hamata were identified. In the small intestine, Fuellebornema agouti, Delicata spp., Camerostrongylus didelphis, and Capillaria spp. were recorded. Physaloptera turgida and Spirocera cylicola (later found to be Didelphonema longispiculata [87]) were found in the stomach and small intestine. While, Helminthoxys urchi was found in the stomach [88]. The trematodes Achillurabainia recondita and Rhopalias coronatus were found in the intestines and Metadelphis evandroi was found in the bile duct [89].

In the US (Alabama and Georgia), Isospora boughtoni and Isospora spp. oocysts, Brachylaima virginianum, and Cruzia americana were found in the intestines of opossum (D. marsupialis) [90]. Physaloptera turgida was found in the stomach and ulcers penetrations from the glandular mucosa to the submucosal level [91]. In the lung, Capillaria aerophila and metastrongyloid nematodes which resembled Perostrongylus and Didelphostrongylus hayesi were found [91,92]. The lungs infested with Perostrongylus showed a diffuse interstitial pneumonia pattern [91].

In Brazil, two hundred and twenty-four D. marsupialis were examined and fifteen animals were found with Besnoitia spp. in cystic leasions in the muscles and viscera [93]. Other parasites detected in Brazil were Capillaria spp. (palate), Eucoleus fluminensis (mouth), Trichuris minuta (large intestine), Heterostrongylus spp. (lungs), Mammomonogamus laryngeus (nostrils), and Aspidodera raillieti (large intestine). Aspidodera spp., Cruzia tentaculata, Turgida turgida (stomach), Thelazia iheringi, Dipetalonema spp. (liver cysts, peritoneum, skin), Litomosoides spp. (skin), Lagochilascaris turgida, Viannaia hamata, and Sarcocystis neurona [26,27]. S. neurona caused neurological diseases in different animal species and is also zoonotic [94]. Similar endoparasites that were found in D. marsupialis in Brazil were also found in Peru [95].

In Costa Rica, the coccidian, Eimeria marmosopos, was found [96], and this coccidial species was located in the epithelial cell of the small intestines and caused cellular necrosis [97]. Recently in Mexico, the gall bladder was found to be the site of infection for Amphimerus caudatelestitis and Philandrophilus magnacirrus. In the intestines, Rhopalias coronatus, R. macracanthus, Thaumasioscole didelphidis, Viannaia viannai, Travassostrongylus spp., and Onicola luehei were found and the cecum was the predilection site for Cruzia tentaculata and Trichuris didelphis. Turgida turgida was found in the stomach and Capillaria spp. was found in the lungs [98]. Aspidodera spp. and C. tentaculata were found in the small intestines of D. marsupialis in Pocone, Brazil [35] (Table 4).
Table 4. Endoparasites found in the Manicou (*Didelphis marsupialis insularis/D. marsupialis*) at different locations.

| Parasite                                                                 | Location                        | Effect on Animal Health or Pathological Lesion | Diagnosis                        | Year   | Ref.   |
|--------------------------------------------------------------------------|---------------------------------|-----------------------------------------------|-----------------------------------|--------|--------|
| *Aspidodera raillieti*, *Sublura trinitatis*, *Trichuris resali*, *Trichuris minuta* *Trichuris urichi*, *Cruzia cameroni*, *Longistriata didelphis*, *Viannaia hamata*, *Fuellebornema agouti*, *Delicata spp.*, *Camostronmglyus didelphis*, *Capillaria spp.*, *Phyaloptera turgida*, *Spirocerca cylindae*, *Helminthoxys urichi* | Trinidad                        | Not recorded                                  | Necropsy and microscopy            | 1951   | [88]   |
| *Didelphonemena longispiculata* (syn. *Spirocerca cylindae*)              | Trinidad                        | Not recorded                                  | Necropsy and microscopy            | 1953   | [87]   |
| *Achillarabainia recondita*, *Rhopaliias coronatus*, *Metadelphis evandroi* | Trinidad                        | Not recorded                                  | Necropsy and microscopy            | 1958   | [89]   |
| *Isospora boughtoni*, *Isospora spp.*                                   | Alabama                         | Not recorded                                  | Sedimentation techniques           | 1969   | [90]   |
| *Phyaloptera turgida*, *Brachyglainea virginianum*, *Cruzia americana*, *Capillaria aerophila*, *Peronstrongylus spp.* | Georgia                         | Weak, emaciated, circling and uncoordinated | Necropsy and microscopy            | 1975   | [91]   |
| *Didelphostrongylus hayesi*                                              | Georgia                         | Not recorded                                  | Necropsy and microscopy            | 1976   | [92]   |
| *Besnoitia spp.*                                                         | Brazil                          | Not recorded                                  | Necropsy and Histology             | 1983   | [93]   |
| *Aspidodera raillieti*, *Cruzia tentaculata*, *Lagochilascaris turgida*, *Viannaia hamata* | Brazil                          | Not recorded                                  | Microscopy                         | 1997   | [27]   |
| *Capillaria spp.*, *Eucoleus fluminensis*, *Trichuris minuta*, *Heterostronmglyus spp.*, *Mammamonomogamus larvaeous*, *Aspidodera raillieti*, *Aspidodera spp.*, *Cruzia tentaculata*, *Turgida turgida*, *Thelazia iheringi*, *Dipetalonem*a spp., *Litomosoides spp.* | Brazil                          | Not recorded                                  | Necropsy and Microscopy             | 2002   | [26]   |
| *Eimeria marmosus*                                                      | Costa Rica                      | Not recorded                                  | Fecal floatation and microscopy    | 2015   | [96]   |
| *E. marmosopos (1 x 10^5 oocyst/gram)*                                  | Costa Rica                      | Necrosis of cells of the small intestine      | Histology                          | 2015   | [97]   |
| *Amphimerus caudaletestis*, *Philandrophila magnacirrus*, *Rhopaliias coronatus*, *R. macracanthus*, *Thaumasioculex didelphidi*, *Viannaia viennai*, *Travaomstrongylus spp.*, *Onicola lueheii*, *Cruzia tentaculata*, *Trichuris didelphids*, *Turgida turgida*, *Capillaria spp.* | Mexico                          | Not recorded                                  | Necropsy and Microscopy             | 2015   | [98]   |
| *Aspidodera spp.*, *Cruzia tentaculata*                                 | Brazil                          | Not recorded                                  | Necropsy and microscopy            | 2016   | [35]   |
6. Collared Peccary (Pecari tajacu/Tayassu tajacu)

The earliest study on parasites in peccaries was done in the 1930s in Texas and Monezia benedeni and Parostertagia heterospiculum was found in the small intestine [99]. In the stomach, Physocephalus sexalatus was found and in the oesophagus, Parabronema spp. [99,100]. Much later and in the same region, Eimeria chaparralensis, Eimeria dicotylensis, Eimeria pecari, Eimeria spp., Klossia spp., Balantidium spp., Dirofilaria acutiuscula, Gongylonema baylisi, Gongylonema pulchrum, Physocephalus sexalatus, Parabronema pecariae (Stomach), Parostertagia heterospiculum, Physocephalus spp., Texicospirura turki, Moniezia benedeni, and Fascioloides magna were found [101–105], while another study failed to recover endoparasites [106] In Brazil, in the late 1930s, Gonglyonema baylisi was found in the oesophagus [107] and later on Texicospiruria turki, Parabronema pecariae, Physocephalus sexalatus, Gongylonema spp., and Gongylonema baylisi detected in the stomach. Monodontus semicircularis and Moniezia benedeni in the small intestine; Eucyathostomum dentatum, Trichuris spp., and Balantidium coli in the large intestine; and Dirofilaria acutiuscula, Molineus semicircularis, Nematodirus molina, and Oesophagostomumdentatum [27,108,109]. In Peru, eggs of Ascaris spp., ancylostomatids, spirurids, Paragonimus spp., Giardia spp., Cryptosporidium spp., Balantidium spp., and Eimeria spp. were identified in the fecal samples [110,111]. It should be noted that Cryptosporidium spp. and Giardia spp. are of zoonotic importance (Table 5).

In Surinam, Toxocara alienata were found but was not associated with poor body condition [112]. In Mexico, Globocephalus urosubulatus, Parabronema pecariae, Parostertagia spp., Texicospiruria turki, and Paramphistomum spp. were detected in the stomach and Oesophagostomum spp. Strongyloides spp., Eimeria spp., Isospora spp., Oesophagostomum spp., and Moniezia benedeni inhabited the intestines [113,114]. In Panama, Entamoeba coli, Entamoeba spp., Cryptosporidium spp., Endolimax nana, and Strongyloides spp. were detected [115]. In Bolivia, Texicospiruria turki, Monodontus angularis, Eucyathostomum spp., Stichorchis giganteus, Moniezia benedeni, Ascaris spp., and Eimeria spp. were detected [116]. In the work done in mid 1980s by Hellgren et al. [117] on collared peccaries with signs of respiratory distress and coughing, Ascaris suum was found in the bile duct and the same parasite was found in South America [117–119].
Table 5. Endoparasites found in the collared peccary (*Tayassu tajacu*) at different locations.

| Parasite                                   | Location                        | Effect on Animal Health or Pathological Lesion | Diagnostics                  | Year   | Ref.  |
|--------------------------------------------|---------------------------------|-----------------------------------------------|------------------------------|--------|-------|
| *Monezia bendeni*                          | Texas                            | Not recorded                                  | Necropsy                     | 1931   | [99]  |
| *Physocephalus sexalatus*, *Moniezia bendeni*, *Parostertagia heterospiculum* | Texas                            | Not recorded                                  | Necropsy                     | 1933   | [100] |
| *Texicospirura turki*                      | Texas and New Mexico             | Not recorded                                  | Necropsy                     | 1966   | [110] |
| *Balantidium spp.*, *Dirofilaria acutiuscula*, *Gongylonema baylisi*, *Parabronema pecariae*, *Parostertagia heterospiculum*, *Physocephalus spp.*, *Texicospirura turki*, *Moniezia benedeni*, *Fascioloides magna* | Texas                            | Not recorded                                  | Necropsy                     | 1970   | [101] |
| *Gongylonema pulchrum*, *Parabronema pecariae*, *Texicospirura turki*, *Physocephalus sexalatus* and *Moniezia benedeni* | Texas                            | No evidence of disease or loss of body condition | Necropsy | 1985 | [102] |
| *Eimeria chaparralensis*, *Eimeria dicotyleosis*, *Eimeria pecari*, *Eimeria spp.*, *Klossia spp.* | Texas                            | Not recorded                                  | Fecal floatation             | 1984   | [103] |
| *Ascaris suum*                             | Texas                            | Respiratory distress and coughing             | Necropsy                     | 1984   | [117] |
| *Parabronema pecariae*, *Trichostrongylus columbiformis* | Mexico                           | Not recorded                                  | Necropsy                     | 1968   | [105] |
| *Globcephalus urosubulatus*, *Parabronema pecariae*, *Parostertagia spp.*, *Texicospirura turki*, *Paramphistomum spp.*, *Oesophagostomum spp.*, *Moniezia benedeni* | Mexico                           | Not recorded                                  | Fecal floatation, sedimentation and necropsy | 2008 | [113] |
| *Gongylonema baylisi*                      | Brazil                           | Not recorded                                  | Necropsy                     | 1937   | [107] |
| *Dirofilaria acutiuscula*, *Eucathostomum dentatum*, *Gongylonema baylisi*, *Molineus semicircularis*, *Nematodirus molina*, *Oesophagostomum dentatum* | Brazil                           | Not recorded                                  | Necropsy                     | 1997   | [27]  |
| *Parabronema pecariae*                     | Brazil                           | Not recorded                                  | Necropsy                     | 2000   | [109] |
| *Strongyloides spp.*, *Eimeria spp.*, *Isospora spp.*, *Oesophagostomum spp.* | Brazil                           | Not recorded                                  | Fecal centrifugation floatation and Mc Master Technique | 2014 | [114] |
| *Texicospiruria turki*, *Monodontus angularis*, *Eucathostomum spp.*, *Stichorchis giganteus*, *Moniezia benedeni*, *Ascaris spp.*, *Eimeria spp.* | Bolivia                          | Not recorded                                  | Fecal floatation and sedimentation | 2014 | [116] |
| *Entamoeba coli*, *Entamoeba spp.*, *Cryptosporidium spp.*, *Endolimax nana*, *Strongyloides spp.* | Panama                           | Not recorded                                  | Fecal centrifugation floatation | 2010   | [115] |
| *Ascaris spp.*, ancylostomatids, spirurid, *Paragonimus spp.* | Peru                             | Not recorded                                  | Fecal floatational and sedimentation | 2008   | [110] |
| *Texicospiruria turki*, *Parabronema pecariae*, *Physocephalus sexalatus* and *Gongylonema spp.*, *Monodontus semicircularis*, *Moniezia benedeni*, *Eucathostomum dentatum*, *Trichuris spp.*, *Balantidium coli* | Central Amazon                   | Not recorded                                  | Necropsy                     | 1986   | [108] |
| *Toxocara alienate*                        | Surinam                          | Not recorded                                  | Necropsy                     | 1982   | [112] |
| *Giardia spp.*, *Cryptosporidium spp.*, *Balantidium spp.*, *Eimeria spp.* | Brazil                           | Not recorded                                  | Fecal floatation              | 2010   | [111] |
7. Red Brocket Deer (Mazama americana)

In Trinidad, in the 1930s, *Mazama simplicicornis* was found to have the following parasites; *Mazamanema longibursatum*, *Ierestrongylus filiformis*, *Mazamastrongylus trinitatis*, *Paramphistomum cotylophorum*, *Moniezia benedeni*, *Setaria bidentata*, *Eucyathostomum longibursatum*, *Strongyloides papillosus*, and *Nematodirus urichi*. Setaria bidentate was found in the omentum, and *Eucyathostomum longibursatum* and an oxyurid-type worm was found in the large intestine [120–122]. In Brazil, parasites found in *Mazama americana* were *Dictyocaulus* spp., *Eucyathostomum* spp., *Eucyathostomum longibursatum*, *Setaria bidentata*, *Seteria* spp., *Haemonchus contortus*, *Haemonchus similis*, *Trichostrongylus axei*, *Trichostrongylus colubriformis*, *Physocephalus sexulatus*, *P. lassencei*, *Pygarginema verrucosa*, *Paramphistomum* spp., *Eimeria* spp., and *Cooperia punctata* [27,61,123,124] (Table 6). Lux Hoppe et al. [125] found *Trichostrongylus axei*, *Haemonchus contortus*, *H. similis*, *Physocephalus lassancei*, and *Pygarginema verrucosa* in the abomasum. *Capillaria bovis*, *Bunostomum phlebotomum*, and *Cooperia punctata* inhabited the small intestine.

Table 6. Endoparasites found in the Red Brocket deer (*Mazama americana*) at different locations.

| Parasites Location | Effect on Animal Health or Pathological Lesion | Diagnostic | Year | Ref. |
|--------------------|-----------------------------------------------|------------|------|------|
| *Mazzamanema longibursatum, Ierestrengylus filiformis, Mazamastrongylus trinitatis, Nematodirus urichi* | Trinidad | Not recorded | Necropsy | 1935 | [120] |
| *Eucyathostomum longibursatum, Setaria bidentata, Oxyurid* | Trinidad | Not recorded | Necropsy | 1936 | [121] |
| *Paramphistomum cotylophorum, Moniezia benedeni, Setaria bidentata, Eucyathostomum longibursatum, Nematodirus urichi, Mazamastrongylus trinitatis, Strongyloides papillosus* | Trinidad | Not recorded | Necropsy | 1936 | [122] |
| *Dictyocaulus spp., Eucyathostomum spp.* | Brazil | Not recorded | Necropsy | 1997 | [27] |
| *Trichostrongylus axei, Trichostrongylus colubriformis, Cooperia punctata* | Brazil | Not recorded | Fecal floatation and sedimentation | 2000 | [123] |
| *Paramphistomum spp., Eimeria spp.* | Brazil | Not recorded | Fecal floatation and sedimentation | 2007 | [124] |
| *Trichostrongylus axei, Haemonchus contortus, H. similis, Physocephalus lassancei, Pygarginema verrucosa, Capillaria bovis, Bunostomum phlebotomum, Cooperia punctata* | Brazil | Not recorded | Necropsy | 2010 | [125] |
| *Cooperia punctata, Eucyathostomum spp.* | Brazil | Not recorded | Necropsy | 2017 | [61] |
| *Haemonchus contortus, H. similis, Physocephalus sexulatus, P. lassencei, Setaria bidentata, Trichostrongylus axei, T. colubriformis, Pygarginema verrucosa* | Brazil | Not recorded | Necropsy | 2008 | [115] |
| *Paramphistomum cervi* | Mexico | Not recorded | Necropsy | 2008 | [115] |
| *Eimeria spp.* and *Trichuris spp., Strongyloides spp.* | Mexico | Not recorded | Fecal floatation and Necropsy | 2014 | [116] |
| *Taeinea hydatigena* | Peru | Not recorded | Necropsy | 2015 | [126] |

In Mexico, *Paramphistomum cervi* was found in the rumen and abomasum as well as *Eimeria spp.*, *Trichuris spp.*, *Strongyloides spp.*, and *Mammomonogamus spp.* [115,116] (Table 6). In Peru, the cysticercus of *Taenia hydatigena* was found in the omentum of *M. americana* as an intermediate host, while the definitive hosts were identified as carnivores [126]. A summary of endoparasites found in specific neo-tropical host species was provided (Table 7). Endoparasites that were common to different animal (host) was also listed (Table 7).
| Neotropical Animals Species (Hosts) | Total No. of Internal Parasites Reported | Endoparasites Found in the Six Selected Host Species | Similar Endoparasites Found in Various Neotropical Animal Host Species |
|-----------------------------------|----------------------------------------|-----------------------------------------------------|---------------------------------------------------------------------|
| **Manicou (D. marsupialis insularis)** | 44                                      | Strongyloides spp., Stichorchis giganteus, Raillietina demarariensis var. trinitatiae, Strongyloides agouti, Trichuris gracilis var. trinitatiae, Trichuris spp., Acanthocheilonema spp., Fuellebornema agouti, Pudica pudica, Aspidodera binanusa var. agouti, Helminthcoxys urichi, Paraspisadora uncinata, Pudica gonomoma, Durestemrongylus laudi, Fuellebornema granulosa, Fuellebornema demarasia, Encystophostrongylus copulatum, Physophorus meridionalis, Physophalus torresi, Physophalus mediostralis, Diaptenema spp., Vianella trichospicula, Avellaria intermedia, Eimeria agouti, Eimeria coteia, Eimeria parasense, Eimeria spp., Giardia spp., Echinococcus oligarthrus, Freitastrongylus angulatus. | Strongyloides spp., Giardia spp., Eimeria spp. (agouti, lappe, capybara, and collared peccary) |
| **Agouti (D. leporina)** | 6                                      | Helminthcoxys urichi, Physophorus meridionalis, Eimeria agouti, Raillietina demarariensis, Eimeria spp., (agouti and lappe) | |
| **Lappe (A. paca)** | 24                                     | Helminthcoxys urichi, Helminthcoxys agouti, Longistriata breviscapula, Osuvaldoema cruzi, Osuvaldoema skrjabini, Paraspisadora uncinata, Paraspisadora spp., Pereiraia spp., Turgida torresi, Trichuris spp., Vianella avellari, Strongyloides spp., Strongyloides spp., Physophalus meridionalis, Echinococcus vogeli, Coladum hepaticum, Physophalus spp., Eimeria spp., Hymenolepis diminuta, Eimeria agouti, Capillaria spp., Tienia spp., Raillietina demarariensis, Echinococcus spp. | Trichostongylus columbianus, Strongyloides spp., Eimeria spp., Physophalus sexulatus, Trichuris spp., Moniezia benedeni, Paramphistomum spp. (capybara and red brocket deer) |
| **Capybara (H. hydrochaeris)** | 42                                     | Trichostongylus columbianus, Strongyloides spp., Eimeria spp., Physophalus sexulatus, Trichuris spp., Moniezia benedeni, Paramphistomum spp. (capybara and red brocket deer) | |
| **Manicou (D. marsupialis insularis)** | 44                                      | Trichostongylus columbianus, Strongyloides spp., Eimeria spp., Physophalus sexulatus, Trichuris spp., Moniezia benedeni, Paramphistomum spp. (capybara and red brocket deer) | |

Table 7. Endoparasites found in selected non-domesticated neotropical animals.
### Table 7. Cont.

| Neotropical Animals Species (Hosts) | Total No. of Internal Parasites Reported | Endoparasites Found in the Six Selected Host Species | Similar Endoparasites Found in Various Neotropical Animal Host Species |
|-------------------------------------|------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------|
| Collared peccary (T. tajacu)       | 39                                       | *Moniezia benedeni, Physocephalus sexalatus, Physcocephalus spp., Parostertagia heteropiculum, Texicospirura turki, Balantidium coli, Diroflaria acutiscula, Gongylonema baylisi, Gongylonema pulchrum, Parabronema pecarina, Fascioloides magna, Eimeria chapareleniensis, Eimeria dicotylensis, Eimeria pecari, Eimeria spp., Isospora spp., Klossia spp., Ascaris suum, Ascaris spp., Trichostrongylus columbiformis, Globocephalus urosubulatus, Paramphistomum spp., Oesophagostomum spp., Oesophagostomum dentatum, Nematodirus molinae, Eucyathostomum dentatum, Eucyathostomum spp., Stichorchis giganteus, Molineus semicircularis, Strongyloides spp., Paragonimus spp., Monodontus angularis, Entamoeba coli, Entamoeba spp., Cryptosporidium spp., Endolimax nana, Trichuris spp., Toxocara alienata, Giardia spp.* | *Trichuri spp., Strongyloides spp., Eimeria spp., Giardia spp., Stichorchis giganteus (agouti and collared peccary)* |
| Red Brocket deer (M. americana)    | 30                                       | *Mazamanema longibursatum, Ierstrongyulus filiformis, Mazamastrongylus trinitatis, Nematodirus urichi, Eucyathostomum longisubulatum, Eucyathostomum spp., Setaria bidentata, Setaria spp., Paramphistomum cyglrophorum, Paramphistomum cervi, Paramphistomum spp., Moniezia benedeni, Strongyloides papillosus, Strongyloides spp., Dictyocaulus spp., Haemonchus contortus, Haemonchus similis, Trichostrongylus axei, Trichostrongylus columbiformis, Cooperia punctata, Eimeria spp., Physcocephalus lassancei, Physcocephalus sexalatus, Pygargonema verrucosa, Capillaria bovis, Bunostomum phlebotomum, Trichuris spp., Taenia spp.*, *Mammomonogamus spp.* | *Trichuri spp., Strongyloides spp., Eimeria spp. (agouti and red brocket deer)* |

*Trichuri spp., Strongyloides spp., Eimeria spp. (lappe and red brocket deer)*
8. Conclusions

Most endoparasites were detected (clinical or subclinical) in the agouti, while for the red brocket deer (*Mazama americana*) few endoparasites were found (Table 7). This was in relation to the number of studies performed on these animals. A large majority of the authors viewed these neotropical non-domesticated animals as parasitic reservoirs that could affect domesticated introduced livestock species. The endoparasites of zoonotic significance found in the non-domesticated neotropical animals were *Echinococcus* spp., *Trichuris* spp., *Giardia* spp., and *Cryptosporidium* spp. There were a few reports of parasites showing negative effects on neotropical non-domesticated animals. Further studies on the effect of parasitism on these six neotropical species should elucidate their importance as pathogens, and their effect on the growth and performance of animals. Furthermore, the relation between the infestation grade and clinical manifestation should be determined.

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