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Review Article

Habronemiasis: Biology, Signs, and Diagnosis, and Treatment and Prevention of the Nematodes and Vector Flies

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ABSTRACT

Habronemiasis is a parasitic disease of horses and other equids which is caused by the invasion of *Draschia megastoma*, *Habronema majus*, and H. *muscae* nematodes and is transmitted by house flies, face flies, and stable flies. The adult nematodes live in the horse's stomach, laying eggs, which pass out in the horse's feces. The carrier flies lay eggs in the horse's manure, which becomes infested with larvae while the flies feed in the manure. The nematode larvae molt while in the fly larvae and develop into infective L3 larvae by the time the adult flies emerge from their pupal stage. The infective larvae are then transmitted to the horse when flies feed on secretions or discharges from hosts' eyes, nostrils, mouths, wounds, and other openings. The L3 larvae are ingested by the horse and are then able to complete their lifecycle. The most common aberrant forms (conjunctival and cutaneous habronemiasis) are associated with the nematode larvae being deposited in these areas, not completing its life cycle, with resultant signs probably associated with local hypersensitivity. This article details the biology of nematode parasites, diagnosis and treatment of this condition, and methods of prevention and control of the transmitting flies.

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1. Introduction

Habronemiasis (also called summer sores, granular dermatitis, jack sores, bursati, and other terms) is a complex parasitic disease of donkeys, horses, mules, zebras, and dogs and is most commonly encountered in temperate, subtropical, and tropical regions [1-8]. This disease is caused by the invasion of *raschia megastoma, Habronema majus (H. microstoma),* and *H. muscae* nematodes. The pathogenic nematode larvae are transmitted by flies (house flies, face flies, and stable flies) while feeding on preexisting wounds or on moist mucus of the equid's anatomy, including genitalia, eyes, nostrils, lips, and prepuce [9-11]. The most common aberrant forms (conjunctival and cutaneous habronemiasis) are associated with the nematode larva being deposited in these areas and not completing its life cycle, with resultant signs probably associated with local hypersensitivity. Typical signs include nonhealing skin lesions, ulceration of moist areas, intense itching, and formation of exuberant granulomatous tissues [8]. In the gastric form, nematode larvae are deposited near the mouth, are swallowed, and are able to mature into adults and produce eggs in the stomach of equids. The eggs are later excreted through the equid's feces. This condition has a worldwide distribution [6,12-18]. It was most commonly encountered in North America prior to the widespread use of macrocyclic lactone dewormer agents; however, recent anecdotal reports of this condition appear to be increasing in the United States (R. Bigbie, personal communication 2012; J. Schumacher, personal communication, 2012; R. Hanson, personal communication, 2012).

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This review discusses the life cycle of the parasite and its intermediate hosts. We also discuss clinical signs, treatment, and prevention of habronemiasis.

2. Life Cycles of *Habronema* and *Draschia* spp

The distribution of these nematode parasites is worldwide. They can complete their life cycle only in equines (the primary host) and flies (the intermediate host). Adult *H. muscae*, *H. majus*, and *D. megastoma* are usually found within the stomachs of equines, earning the name stomach worms, and only rarely in the cecum or colon. Adult worms produce eggs mostly in the stomach of the primary host. Eggs move through the alimentary tract and are excreted through feces. Eggs are thin-walled and embryonated (40-50 um × 10-12 um) and hatch quickly after they are excreted. However, larvae may occasionally emerge while the eggs are in transit through the gastrointestinal tract (Fig. 1). The larvae are ingested by fly maggots (larval stage) that inhabit feces. The larvae molt twice within the fly maggots and develop into infective L3 larvae by the time the adult flies emerge from their pupal stage. The infective larvae are transmitted to primary hosts when flies are attracted to and feed on secretions or discharges from hosts' eyes, nostrils, mouths, vulvae, teats, wounds, and other openings. The development is weather/temperature dependent but may be as soon as 7-8 days. The stomach worm larvae migrate to the fly's mouth parts, and the infective L3-stage larvae "escape" while the adult fly is feeding, usually near the mouth, lips, or wounds of primary hosts (horse). The L3 larvae that are ingested by the horse are then able to complete their lifecycle [1-3]. The larvae develop to adults in the stomach in approximately 2 months. Larvae that do not complete the migration to the stomach may cause granulomatous lesions in the skin, eye, and, rarely, viscera.

When larvae are deposited in or near a wound or the eyes, cutaneous or ocular habronemiasis may result. In this case the L3 is unable to mature to an adult nematode, and the life cycle is not completed. Continued migration of L3 larvae results in a local inflammatory condition. Cutaneous habronemiasis can be very pruritic and may lead to self-mutilation with resultant tissue necrosis and calcification of the third-stage larvae. This condition is poorly understood but may be associated with hypersensitivity to the L3 stages, particularly when adults are living in the stomach; there may be a genetic susceptibility, as some horses are affected yearly [1].

3. Intermediate Hosts (*Musca* and *Stomoxys* spp)

Three fly species most commonly associated with habronemiasis are *Musca domestica* (house fly), *M. autumnalis* (face fly), and *Stomoxys calcitrans* (stable fly) [1-3,12,14,19,20]. Other flies implicated as potential intermediate hosts include *Fannia* spp, *Haematobia irritans*, *M. autumnalis*, *Musca humilis*, *M. insoria*, *M. terrareginae*, *M. hilli, Pseudopyrellia* spp, and *Sarcophaga misera* [12-14,19,20]. The house fly occurs on all continents except Antarctica, in rural, suburban, and urban environments and in tropical to temperate regions [10,11,21]. The face fly is native to Europe and central Asia and was introduced and spread across North America after World War II, with the southern extreme at approximately 34°N and the northern limit at approximately 53°N [22,23]. The stable fly is a worldwide pest of livestock and other mammals and is found throughout North America. Comprehensive review of the veterinary effects and control of muscid flies on livestock are found elsewhere in the literature [22-24]. Additional reviews that concentrate on selected species such as the house fly and the stable fly are also available [22,24,25].

The three fly species have different morphological and behavioral characteristics. Mouthparts vary among species. The house and face flies are nonbiting nuisance flies that feed on hosts' eye secretions, nasal discharges, and blood and purulent discharges from wound and dung fluids. They possess spongy mouth parts and ingest only liquid food. The stable fly is a biting fly with "stiletto"- or "bayonet"-like mouthparts for piercing host skin (Fig. 2). Stable flies are both nuisance and blood-sucking flies. Their painful bite can cause horses to stamp and kick. In large numbers, the stable fly can cause significant blood loss and skin irritation [10,11]. The eyes of the females are more widely spaced

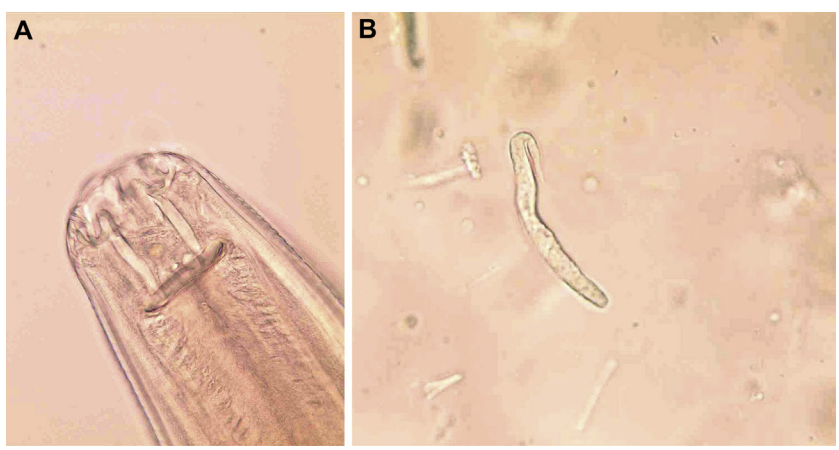

Fig. 1. (**A**) Anterior end of *H. muscae*. *Habronema* sp is distinguishable by its cylindrical mouth cavity. (**B**) *H. muscae* larva. Many larvae hatch from eggs and are passed as such in feces but occasionally are found surrounded by a thin, almost unapparent egg shell. Original×40.

Fig. 2. An adult stable fly, *Stomoxys calcitrans*, on an aloe vera leaf. Note the distinctive "stiletto" or "bayonet" like mouthparts for piercing host skin. The stable fly is slightly smaller than either the house or face fly. (Courtesy of Wikimedia Commons).

than those of the male. The house fly is a dull gray fly, approximately 6-9 mm in length, with four distinct narrow black stripes on the thorax (Fig. 3). The abdomen of the house fly is a pale color with yellowish sides and underside. The face fly resembles the house fly and is 6-10 mm long, but its female has a characteristic yellow patch on the ventrolateral aspect of the first visible abdominal segment

Fig. 3. The house fly, *Muscae domestica*, is a dull gray fly, approximately 6-9 mm in length, with four distinct narrow black stripes on the thorax. This fly's abdomen is a pale color with yellowish sides and underside. (Courtesy of Wikimedia Commons).

Fig. 4. The face fly, *Muscae autumnalis*, closely resembles the house fly, is 6-10 mm long, and is seen around the horse's eyes, mouth, and nostrils. (Courtesy of Wikimedia Commons).

(Fig. 4). The male has a distinct black longitudinal band along the midline and bright yellow lateral abdomen. The face fly behavior may also differentiate it from other flies as it is attracted to the eyes, mouth, and nose of horses (and cattle). The stable fly also resembles the housefly but is smaller (4-7 mm) than either the house or the face fly, with a distinct "checkerboard" of dark spots on its dorsal abdomen [10,11].

These flies undergo a complete metamorphosis with distinct egg, larva (maggot), pupa, and adult stages. The female flies lay individual eggs or groups of eggs in wet decaying organic substrates upon which the larvae feed and develop. Breeding sites for the house and stable fly are most commonly livestock manure, poultry litter, fermenting vegetables, kitchen waste, wet and/or manure sod or straw bedding, garbage, and poorly composted manure [23]. The face fly requires fresh horse or cattle manure to develop [22]. Round bales and animal waste appear to be the most common winter feeding and developmental sites for the stable fly [26]. As with other forms of hay feeding practices, much hay will be mixed with feces around the feeding site; however, round bale feeding usually has more waste associated with it. With respect to the transmission of *Habronemia*, horse manure is the most significant fly breeding site. Horse manure alone may be too dry for the stable fly, but when left in stalls and soaked with water and/or urine or when deposited in around wet areas, horse manure can be a good breeding ground [10,11].

The three fly species have similar life cycles but possess some biological differences. House flies and stable flies breed year round in tropical and subtropical regions but undergo hibernation in temperate regions [23]. Larvae, and rarely pupae, overwinter within or beneath livestock manure. House flies can complete their life cycle in 10-42 days, and adult flies have a life span of 2 weeks to 3 months, depending on temperature and food supply. Without food, they may survive only 2-3 days. Feedstuffs are required prior to copulation, with oviposition occurring between 4 days and 3 weeks postcopulation. Adult house flies normally have a flight range of 0.8-3.2 km but may fly up to 32.2 miles (~30 km) under certain conditions. Stable flies may complete their life cycle in 3-9 weeks, and adult flies

have a life span of 4-6 weeks. The stable fly can travel 1.5 km in a 48-hour period but may travel much farther [27]. The stable fly is a blood feeder and may feed throughout the day; however, its peak feeding activity is in early morning and late afternoon [28]. Stable flies feed more frequently near barns, shady structures, or shade trees and tend to bite/feed on the lower parts of the horse's legs and ventral abdomen. At night, the inactive adults can usually be found in buildings (support beams, ceilings, and so forth) and outside (grass, shrubs, trees), particularly (in the case of stable flies) in areas that may be protected from the wind [29]. Face flies have 3-6 generations in northern localities, whereas 7-12 generations are possible in southern localities [22]. In autumn, unmated adult flies enter diapause and overwinter in structures where livestock is kept by aggregating in wall voids or attics. Their breeding season begins in spring and ends in fall. Once breeding begins, generations overlap and develop toward a stable age distribution. Peak abundance has been reported in summer. Unlike house flies, face fly larvae breed exclusively in fresh livestock dung pats; face fly adults tend to feed on facial blood secretions and do not like to feed in darkened barns or shady locations.

The house fly is commonly found in hot summer months; the face fly and stable fly are usually seen from mid to spring to summer and possibly into early fall. A recent study conducted on central Florida horse farms showed significant stable fly trap captures in March and April [30]. Under optimal conditions, the stable fly can develop from egg to adult in as few as 12 days but will average 20-25 days, whereas the face fly's life cycle will take from 12-16 days.

Large, well-fed females produce more eggs, particularly between ambient temperatures of 25°C and 30°C. The eggs ($\approx$1 mm long) will hatch, if maintained at warm temperatures, as cream-colored to white larvae in approximately 1 day in warmer weather. As they near maturity, the maggots can respond to light and can crawl up to 0.3m to a cool, dry area in order to develop into the pupal stage. The "legless" larvae of the house fly complete their development to a pupa in 4-15 days at optimal temperatures (35°C-38° C) but may require 14-30 days at 12°C-17°C, and 11-21days for the stable fly [10,11,31].

The pupa is encased in the final larval skin, is approximately 8 mm long for the house fly and 6-7 mm for the stable fly, and may be black, brown, red, or yellow in color. The adult fly escapes or emerges from the pupal case in 2-6 days at optimal temperatures (32°C-37°C) for the house fly and 6-26 days for the stable fly but may take longer at cooler temperatures [10,11].

4. Clinical Signs and Diagnosis

H. majus and *H. muscae* cause little or no pathologic changes in the equine stomach. However, large numbers may cause ulcerative and/or catarrhal gastritis. *D. megastoma* may produce very large "tumor-like" granulomatous masses (up to 10 cm in diameter) that contain adult worms and necrotic material. These *Draschia* lesions can, on rare occasion, interfere with the function of the pylorus and result in stomach perforation [1-3,32].

Cutaneous habronemiasis presents as proliferative granulation tissue. Cutaneous sarcoids, squamous cell carcinoma, mast cell tumors, and fungal or bacterial granulomas should be considered as differential diagnoses (Fig. 5). Lesions of ocular habronemiasis may resemble foreign bodies, neoplasia, onchocerciasis, and/or phycomycosis/botryomycosis. Ocular habronemiasis results from larvae in the eyeball, eyelid, conjunctiva of the medial canthus, and/or on third eyelid. Occasionally the tarsal glands are enlarged due to granuloma formation.

The most common sites for cutaneous habronemiasis are limbs, prepuce, external genitalia, and ventral abdomen [1-3] (Fig. 6). Pruritus may accompany either the cutaneous or ocular form of habronemiasis. Pruritus is evident when horses scratch and/or chew at the skin lesions. Lesions are usually reddish-brown, with occasional ulceration. They often are "greasy," serosanguineous, and contain yellow calcified "rice grain-like" material. Habronemiasis has a seasonal distribution, with occurrences predominately in the spring and summer and coinciding with fly activity. The condition usually regresses during the winter months [1-3]. A retrospective study in North America (63 horses) indicated that there was no sex predilection, that the parasite affected horses generally 7.3 years of age, and that Arabians and gray horses were overrepresented Thoroughbreds were underrepresented [2]. Affected equids may become reinfected in the same or subsequent years. Lesions from cutaneous habronemiasis may spontaneously resolve during cool weather or with reduced activity of the fly intermediate host.

Microscopic evaluation of cytologic aspirates, scrapings, or biopsies from cutaneous lesions will usually reveal eosinophils admixed with other inflammatory cells. Recovery of larvae from a biopsy or scraping of the lesions could confirm a diagnosis [1-3,6,9]. The presence of fly eggs or larvae in feces would be supportive of a diagnosis of gastric habronemiasis. A seminested PCR assay has been developed to detect *Habronema* sp DNA for both the gastric and cutaneous forms of habronemiasis [20,33,34]. However, at the time of this writing, the test is not widely available. Habronemiasis can be mistakenly diagnosed in cases of the more potentially dangerous condition pythiosis [17]. Habronemiasis and pythiosis may be differentiated by the seminested PCR test for habronemiasis, a species specific probe for pythiosis and/or histopathology of lesion biopsy samples [17,20,33-35].

5. Treatment and Prevention

5.1. Habronemiasis

The routine use of macrocyclic lactones (ivermectin or moxidectin) should remove the adults from the stomach [1-4,23]. Topical, systemic application of corticosteroids may be indicated for some lesions to reduce the inflammation-associated tissue proliferation. Mixtures of glucocorticosteroids and dimethyl sulfoxide (DMSO) have also been used topically to treat these *Habronema* lesions[1,2,5]. Surgical debulking of dense fibrous or calcified tissue by curettage and/or cryotherapy will aid in the response to other therapies such as topical or systemic

Fig. 5. Diagnosis of Habronema of the urethra in a 16-year-old, Quarter Horse gelding. This horse was referred to the Veterinary Medical Teaching Hospital at Auburn University for a possible squamous cell carcinoma of the urethra. The horse lived at a boarding stable in east central Georgia during the summer of 2012 and had a history of routine deworming with both ivermectin and moxidectin, each once to twice yearly. (Courtesy of Reid Hanson, DVM, Dept. of Clinical Sciences, College of Veterinary Medicine, Auburn University, AL).

Fig. 6. Habronema lesion on the prepuce of a 12-year-old, Quarter Horse gelding from central Georgia during the spring of 2012. This horse was referred to the Veterinary Medical Teaching Hospital at Auburn University for a chronic granulomatous mass of the prepuce. A diagnosis of habronemiasis was confirmed by histological evaluation of a biopsy of this lesion. The horse had a history of routine deworming with both ivermectin and moxidectin, each at least once yearly. (Courtesy of Reid Hanson, DVM, Dept. of Clinical Sciences, College of Veterinary Medicine, Auburn University, AL).

glucocorticosteroids [1,2,6,36,37] (Fig. 7A, B). When cryotherapy is used, double freeze-thaw cycles of the lesion(s) will be required. Debulking third-eyelid infestations produced granulomas prior to the use of topical or systemic corticosteroid therapy is required of most lesions larger than 1-2 cm in diameter [2,3,5]. Macrocyclic lactones (e.g., ivermectin, moxidectin) applied directly on or in the lesion may yield better results than corticosteroid use alone. Fly control is essential if nontreated horses are present [2-5].

5.2. Preventive Fly Control

Flies that serve as intermediate hosts for stomach worms require breeding material, moisture, and warmth in order to complete their life cycles. Elimination of breeding environment will limit their survival [10,11]. Proper waste management or, where possible, elimination of the breeding habitats is the most effective method of fly control. Sanitation is the "backbone" of any integrated fly control program. Paddocks, corrals, holding facilities, alleys, stalls, and other areas should be designed or modified to include plans for rapid and efficient removal of manure, excess feedstuffs, wet straw, and other materials. Feeders (both for hay and concentrates) should be designed to minimize waste and maximize quick and easy removal of all potential fly breeding materials. Removal of manure and other fly breeding materials twice weekly, avoidance of straw as a stall bedding material, prompt removal of spilled feedstuffs, use of tightly closed garbage containers, regular cleaning all garbage cans or dumpsters, and placement of garbage/manure holding sites or containers as far as practical from the stable or horse facilities are all critical points in reducing fly breeding sites. When round bales of hay are fed to horses, special attention should be given to regularly moving or cleaning the feeding area or covering previous feeding areas with 5.1-10.2 cm of dirt [10,11].

The addition of sodium bisulfate to stalls (1.1-4.5 kg daily or ~2.5-5 lbs/100 sq ft of stall space) may also be of value in decreasing fly numbers [38,39]. Application of bismuth sodium can also reduce odor associated with ammonia [39]. The need to keep areas drier may require modifying paddock or stall drainage and/or adjusting watering systems. Stored manure and other waste should be kept as dry as possible, unless proper lagoon storage is used. Manure and other waste can be disposed of by proper composting, by being thinly spread over pastures in a manner that allows drying, or by being hauled away, buried, or stored in lagoons or liquid manure pits. Compost piles should be properly managed to maximize heat production and/or covered with a fly barrier material such as plastic. If manure is spread over pastures used for horse grazing, the potential exists to magnify internal parasite infections on the farm. Thus, cropland, hay fields, and non-horse grazing areas should be used, when possible, for spreading manure. If liquid storage systems are used, adding water to insure liquid consistency and agitating the mixture in a manner to prevent floating or drying areas for fly breeding will be required [11]. Careful planning and attention should be given to minimize the accumulation of any "filth" and wet organic material near where horses live.

Flies may seek resting or "harborage" sites around shade structures or vegetation in shady areas. Mowing or removing plants in these areas may reduce fly activity. Fly

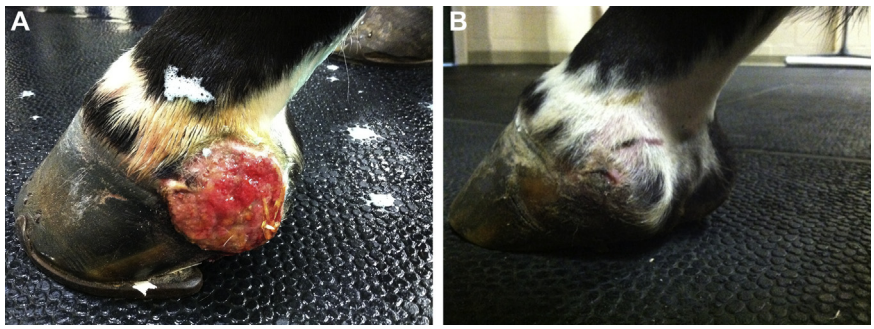

Fig. 7. (**A**) Cutaneous habronema lesion on the lateral heel bulb of the left front hoof of a 3-year-old Warm Blood mare from west central Alabama in early summer of 2012. This horse had a history of a nonhealing laceration for approximately 2 months. Upon presentation, the lesion appeared to have small "sulfur like" granules. A biopsy and subsequent histologic evaluation confirmed a diagnosis of habronemiasis. This horse had a history of being dewormed using an ivermectin product, orally, twice a year. (Courtesy of Reid Hanson, DVM, Dept. of Clinical Sciences, College of Veterinary Medicine, Auburn University, AL). (**B**) After the lesion was surgically debulked and treated topically with a mixture of DMSO-moxidectin-dexamethasone for 6 weeks. The lesion has improved. (Courtesy of Reid Hanson DVM, Dept. of Clinical Sciences, College of Veterinary Medicine, Auburn University, AL).

traps or baits may be of value in reducing numbers of adult house flies and, to a lesser extent, face flies but are of limited use for stable flies. Fly traps that use both insecticide baits and pheromones or sugar lures appear to be the most beneficial for house flies. Fly traps placed both inside and outside near entrances and alleys and near trees and where animals sleep may be of some use around stables. Horse housing fly traps with odor-causing baits (molasses, fruit, meat, sugar, and/or pheromones) or near white surfaces may be beneficial as fly attractants. Ultraviolet light traps placed near barn/stable entrances and 1-2 m from the floor can work well when they are the only visible light. Sticky resin fly paper or "ribbons" may be effective in reducing infestations in confined areas such as stalls but have little effect outdoors. Sticky fly strips or fly paper is most effective when placed in areas of low air flow. Strips hung or placed at 0.25 cm inch of fly strip for every 28.32 m^2 of barn floor is optimal for the control of house flies. Insecticidal baits should be kept away from domestic animals and children [11,31]. All fly traps should be cleaned 1-2 times per week.

Some parasitic wasps (*Hymenoptera, Muscidifurax, Pteromalidae, Spalangia*) may prove useful as biological control agents in fly control programs for house and stable flies [40,41]. These species of wasps lay their eggs in fly pupa; wasp larvae then feed on and kill the fly larvae. The wasp lifespan ranges from 15-30 days. Periodic release of the parasitoid wasps in the late winter and spring can reduce early season buildup of fly numbers. The use of parasitoids can aid in the success of an integrated fly control program but can be labor intensive. The animal caretaker responsible for parasitoid release should be familiar with proper handling of wasps and should understand that insecticide application or feces removal may impact wasp survival. Caretakers should also be aware of manufacturers' information to maximize the success of biologic fly control.

Stabling horses during peak fly activity may also be of benefit if barns or stalls have fans and/or are equipped with fly-proof screens. Individual fly nets (e.g., face, ear) can also help in fly control [10]. Repellents have some value if applied to lower limbs, ears, and legs, particularly if they are used with face or ear nets. Covering wounds with fly repellants may also be an effective management tool.

Insecticides may be needed to complete a well-planned fly control program. Effective use of insecticides will suppress adult fly populations initially, but is a poor substitute for manure/waste/straw disposal; therefore, insecticides should not be the primary focus of a fly control program. Application of insecticides to horses has minimal long-term fly control value. Insecticide sprays can, however, produce immediate relief for heavily infested animals. Sprays or whips applied to the abdomen and legs of horses can help reduce stable fly bites and can be very effective in reducing face fly feeding when applied around the eyes, nose, and mouth. Strips or collars designed for horses may also be useful for face fly control. Space sprays or foggers or other forms of ultralow volume treatment will have best efficacy in small, confined areas and are numerous. Sprays should be applied only under low-wind conditions and with equipment that produces particle sizes based on the manufacturer's recommendations. As fogging or misting will usually have little or no residual effect, such practices will need to be repeated daily to be effective [11].

The most common approved insecticides are pyrethrins and pyrethroids (cypermethrin, fenvalerate, permethrin, resmethrin, etc). Pyrethroids are synthetic analogs of the natural pyrethrins (pyrethrum). Pyrethrins are natural extracts from the flower of the chrysanthemum plant (*Chrysanthemum cinerariaefolium*), whereas pyrethroids, via chemical modification, have greater efficacy and are less susceptible to biodegradation. Piperonyl butoxide is a synergist and is added to many commercial pyrethroid products. Piperonyl butoxide suppresses the insect's ability to detoxify the pyrethroid, thus enhancing efficacy. Pyrethroids are included in residual sprays, fogs, and whips and possess both knockdown and repellent properties. Although organophosphates (coumaphos, dichlorvos, malathion, and others) and synthetic organochlorines (methoxychlor) may be approved for use on horses, they are used less frequently and are rapidly being replaced by pyrethroids. Pyrethroids are not without risk, however, and

have been associated with decreased semen quality in some farm and laboratory animals [42]. Pyrethroids may disrupt the conversion of testosterone to dihydrotestosterone, thus potentially altering the male's spermiogram [43,44]. Although studies supporting altered stallion fertility associated with pyrethroids are lacking at the date of this writing, caution should be exercised when using them for fly control on breeding stallions.

Application of residual insecticides to resting areas such as ceiling beams and cracks or crevices of buildings (western and southern sides), where accumulations of regurgitated fluid or fecal material from flies are observed, tends to be more effective than spraying the animals. The need for pesticide application can be assessed by randomly placing 7.6-cm × 12.7-cm white index cards on fly-resting areas for 7 days. Pesticide application is indicated when an average of 100 spots/card is observed. The use of residual insecticide for flies not only kills flies at the time of application but may be effective for up to 2-6 weeks. Keep in mind that such practices may reduce the population of beneficial insects. Resistance tends to develop to a class of insecticide rather than to an individual chemical [10,11]. Permethrin resistance by the house fly and the stable fly has been documented [45,46]. Alternating synthetic pyrethroids, such as permethrin, with organophosphates, when available, will yield better long-term results. Spraying should begin in the early spring and should be repeated as necessary [10,11]. Whenever insecticides are used, label recommendations should be followed without modification.

Larvicides are useful in killing or reducing fly larvae when applied directly to manure piles or when used as feed through chemicals. Some products (Insect Growth Regulators [IGRs]) interfere with growth and development of fly maggots. Other insecticides kill the larvae directly when applied to or concentrated in feces. Spraying the manure piles with insecticide may be a very effective tool but can have adverse effects on the beneficial insects that are useful in both fly control and normal manure breakdown and recycling. If feed through chemicals are used, all horses in the area should be treated or the results will be less than optimal. The two most commonly used IGRs are diflubenzuron (Equitrol II and Simplifly [Farnam Companies, Inc, Phoenix, Arizona, USA]) and cyromazine (Solitude [Zoetis, Inc, Kalamazoo, MI]). Both agents inhibit the development of chitin and the insect cuticle and are efficacious for house and stable fly larvae. Diflubenzuron appears to be safe and effective in horses when administered orally in feed (0.12-0.20 mg/kg daily) for the control of house and stable flies [47]. Low level resistance of house fly larvae to diflubenzuron and cyromazine has been reported in some parts of the world, but these products remain effective in controlling house flies in North America when used according to label recommendations [45,48,49]. Although the organophosphate tetrachlorvinphos (Rabon, Equitrol), a cholinesterase inhibitor, appears to be safe in horses if fed at recommended concentrations [50,51], caution should be used when it is fed to debilitated, aged, breeding, pregnant, or nursing animals. Tetrachlorvinphos has good efficacy against house, face, and stable fly larvae. These products can be administered to horses individually, added to feed, or fed as an individual supplements. Some insecticides applied to manure or bedding can have harmful effects on parasitoid wasps and other beneficial insects. Feed through products are most useful when included as a component of an integrated fly control program [10,11,31].

6. Conclusions

Habronemiasis is a parasitic condition in horses that results from a complex association between the horse, the nematode stomach worms (*H. majus* and *H. muscae* and *D. megastoma*), and their intermediate hosts, the house fly, face fly, and stable fly (*M. domestica*, *M. autumnalis*, and *S. calcitrans*, respectively). The condition is less common than it was prior to the introduction of macrocyclic lactone endectocide in the early to mid 1980s. Primary gastritis associated with the adult worms is a rare condition. Cutaneous and ocular habronemiasis are observed more commonly and result when flies feed near an open wound or the eyes and the L3 stage of invades the tissue. Infestation results in granulomatous and exudative lesions with characteristic white to yellow granules. Diagnosis is based on clinical signs, cytology, and/or biopsy analysis. Individual lesions are treated with topical and systemic corticosteroids. This should be combined with use of macrocyclic lactones to kill the adult worms. Prevention is best accomplished by periodic treatment to eliminate adult worms and control of the intermediate host. Fly control should also include proper management of manure and other organic wastes in order to reduce fly breeding sites. Other ancillary fly control measures include the use of fly traps and baits, parasitoid wasps, and control of larvae l in manure by direct insecticide application and/or feed through larvacides. Judicious use of residual fly sprays to animals or to premises should be included in the prevention strategy.

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