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Full Research Article

FURRY HOSTS AND FUNGAL GUESTS: INVESTIGATING DERMATOPHYTE CARRIAGE IN SHELTER AND CLINIC CATS AND DOGS OF NORTHERN PORTUGAL

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Abstract

Dermatophytosis is a widespread fungal infection affecting both animals and humans, commonly known as ringworm. Dermatophytosis results in the breakdown of keratin, leading to skin, hair, and claw lesions, and has an important global prevalence that is often underestimated. While typically self-limiting, dermatophytosis can pose a severe risk due to its contagious nature, particularly in shelters. This study aimed to assess the prevalence of dermatophytes in the fur of dogs and cats in animal shelters and pet clinics, shedding light on the importance of understanding and managing this infectious disease in both animal and human populations.

To better understand the epidemiology of dermatophytes in Portugal, a study was conducted from March to May 2022. The prevalence of dermatophyte isolation in culture was evaluated. A total of 341 animals, 286 (83.9%) dogs and 55 (16.1%) cats were studied, and 45.0% (n=157) of the animals were from shelters, while 54.0% (n=184) were from clinics.

Twenty-eight (8.2%) animals had skin lesions, and of these, four (14.3%) tested positive for dermatophytes. Dermatophytes were isolated from 12/341 studied animals. The prevalence of *Microsporum canis* was 3.2% (confidence interval [CI] 95%: 1.6-5.7%), and the prevalence of *Microsporum audouinii* was 0.3% (CI 95%: 0.0-1.6%). Healthy dogs and cats without clinical signs were found to carry dermatophytes, stressing the potential for these animals to act as subclinical carriers and emphasizing the importance of pet-owner awareness regarding zoonotic risks and the need for ongoing research and surveillance to mitigate the risks associated with fungal infections.

Key Words: cat, dermatophytes, dog, Portugal, prevalence, shelter, zoonosis

INTRODUCTION

Phylogenetic analysis has identified nine accepted genera of dermatophytes: *Arthroderma*, *Ctenomyces*, *Guarromyces*, *Epidermophyton*, *Lophophyton*, *Microsporum*, *Nannizzia*, *Paraphyton*, and *Trichophyton* (de Hoog et al., 2017). Among these, only a select few, including *Lophophyton*, *Microsporum*, *Nannizzia*, and *Trichophyton*, are responsible for dermatophytosis (ringworm) in both humans and animals (Cabañes, 2021), with notable species such as *Microsporum canis*, *Nannizzia gypsea*, and *Trichophyton mentagrophytes* (Moriello et al., 2017).

Dermatophyte species can be categorized into three primary ecological groups based on their natural reservoir: anthropophilic, zoophilic, and geophilic (Mignon & Monod, 2011). Anthropophilic species predominantly colonize humans, while zoophilic species primarily inhabit animals. Geophilic species found in soil are typically non-pathogenic saprophytes (Fratti et al., 2023).

Dermatophytosis, commonly referred to as ringworm, affects both humans and animals, manifesting as skin, hair, and claw lesions due to the breakdown of keratin (Moriello et al., 2017). Despite being one of the most important dermatological diseases globally, its true incidence is often underestimated (Hayette and Sacheli, 2015). Recent years have witnessed a surge in fungal skin conditions, notably dermatophytosis, impacting a growing number of individuals, particularly in hot, humid, and tropical regions, with

the World Health Organization (WHO) estimating it occurs in approximately 25% of the global human population (Keshwania et al., 2023; Urban et al., 2021).

Although typically a self-limiting disease, dermatophytosis, known for its contagious nature, can be prolonged, posing risks to both humans and animals. In veterinary medicine, it is a significant concern (Moreira et al., 2012). Infected dogs and cats, along with other carrier mammals, can transmit the infection to humans and other animals (Chupia et al., 2022; Gordon et al., 2020; Jarjees and Issa, 2022; Moretti et al., 2013; Paryuni et al., 2020) with *M. canis* being the most commonly isolated species, affecting over 90% of cats and 70-80% of dogs (Chermette et al., 2008). *M. canis* finds its primary host in cats. Cats can exhibit various clinical signs if an infection occurs, including alopecia, scales and crust, erythema, follicular plugging, hyperpigmentation, abnormal nail growth, and pruritus (DeBoer & Moriello, 1994).

The transmission of these pathogens hinges on several factors, primarily spore contraction through direct contact with infected pets. It can also occur through contact with contaminated items like blankets or mattress cushions, grooming equipment, gloves, or external pathogens that are present in infected cats (Jarjees and Issa, 2022; Sykes and Outerbridge, 2014). Animal-specific risk factors for dermatophytosis encompass species, breed, young age, poor physical condition, concurrent diseases, physiological stress, inadequate grooming and hygiene, and skin microtrauma (Gordon et al., 2020; Moriello, 2019).

The clinical presentation of dermatophytosis in animals mirrors its variability in humans, often resulting in ring-shaped rashes, kerion, paronychia, claw infections, and round or irregular alopecic lesions with scaling or crusting (Chermette et al., 2008). Animals with skin lesions are more likely to test positive for dermatophytes than those without (Moriello et al., 2017).

Most zoophilic and geophilic organisms that affect human skin, beards, and hair can produce inflammatory dermatophytosis (Degreef, 2008). The gold standard for dermatophytosis detection is dermatophyte test medium (DTM) fungal culture with microscopic identification of fungal macroconidia (DeTar et al., 2019).

Dermatophytosis is an important infection associated with animal shelters, and outbreaks can cause extensive infection, especially among cats, posing health risks to humans. Such outbreaks can also disrupt shelter activities, prompting costly disease control measures and even shelter closures (Mozes et al., 2017). In light of these considerations, this study aimed to determine the prevalence of dermatophytes in the fur of dogs and cats within animal shelters and pet clinics.

MATERIALS AND METHODS

Animal samples

Fur samples from all sheltered (clinically suspect and apparently healthy) dogs (n=286) and cats (n=55) were collected by practicing veterinarians using the technique of brushing with a toothbrush (Mackenzie technique) (Mackenzie, 1963) after taking the general history and health record. During the sampling procedures, a clinical examination of all skin surfaces (especially the ears), the head, and body hair was performed for signs of ringworm infection, such as alopecia, erythema, vesicles or pustules, erosion, scaling, and hyperkeratosis. Before sampling, surfaces were disinfected with 70% ethanol. At room temperature, samples (fur) were sealed in sterile plastic bags. Samples were then subjected to preliminary examination using 10% potassium hydroxide (KOH) solution, but were also cultured. The University of Trás-os-Montes and Alto Douro (UTAD) Committee of Research Ethics waived full ethical approval (Doc6-CE-UTAD-2022).

Fungus isolation methodology

Each sample was inoculated into tubes with Dermatophyte Test Medium (DTM, Liofilchem®, Roseto degli Abruzzi, Italy) and onto Petri dishes with Potato Dextrose Agar (PDA, Liofilchem®, Roseto degli Abruzzi, Italy) and Sabouraud Agar Medium (SDA, Liofilchem®, Roseto degli Abruzzi, Italy). The media were incubated in the dark at room temperature (25–27°C) for four weeks. The plates were checked for growth every 24–48 hours (Robert and Pihet, 2008). Fungal colonies with the macroscopic appearance of a typical dermatophyte were sub-cultured in PDA for isolation and maintenance and were then subjected to lactophenol (cotton-blue) staining for microscopic identification. The fungi were identified by their macro- and microscopic morphological characteristics based on identification keys.

For this study, a dog or a cat was classified as infected if a dermatophyte was isolated and identified from at least one culture.

Data analysis

The prevalence of dermatophytes and the mycobiota biodiversity in the fur of dogs and cats in three shelters and 13 pet clinics was calculated using descriptive and analytical statistics and a confidence interval (CI) of 95%. Chi-squared ($\chi 2$) tests were used to compare demographic variables and infection. Analyses were done with Statistical Package for the Social Sciences (SPSS®, International Business Machines Corporation [IBM], Armonk, New York [NY], United States of America [USA]) 25.0 software for Windows, considering $p < 0.05$ as significant.

RESULTS

In total, 341 dogs and cats were sampled (Table 1), with 286 (83.9%) dogs and 55 (16.1%) cats being studied, and 45.0% (n=157) of samples from shelters and 54.0% (n=184) from clinics. Twenty-eight (8.2%) animals had skin lesions.

All the dermatophyte isolates formed colonies in DTM™ and Potato Dextrose Agar with a velvety surface and yellowish pigmentation on the reverse. Isolates were identified as *M. canis* and *M. audouinii*. The latter was isolated from a male dog from a shelter.

Prevalence of dermatophytes in pets

Dermatophytes were isolated in 12/341 of the studied animals. One isolate was identified as *M. audouinii*, and 11 isolates were diagnosed as *M. canis*. The prevalence of dermatophytes was 3.5% (95% CI: 0.0-0.1%). The prevalence of *M. canis* was 3.2% (95% CI: 1.6–5.7%), and the prevalence of *M. audouinii* was 0.3% (CI 95%: 0.0–1.6%).

Positive samples according to the animal's sex, species, age, origin, and clinical signs examined are presented in Table 1. The prevalence among males (1.3%; 95% CI: 0.2–4.5%) was lower than in females (5.5%; 95% CI: 2.7-9.8%), and the differences were statistically significant (p=0.027) (Table 1).

Table 1. Dermatophyte prevalence in pets, grouped according to sex, species, age, origin, and clinical signs, in Portugal.

Variable	Animals (n)	Positive (n)	Prevalence (%)	95% CI (%)	*p* value
Sex					0.027
Male	158	2	1.3	0.2–4.5	
Female	183	10	5.5	2.7–9.8	
Species					0.959
Dogs	286	10	3.5	1.7–6.3	
Cats	55	2	3.6	0.4–12.5	
Age					0.605
Young	118	5	4.2	1.4–9.6	
Adult	223	7	3.1	1.3–6.4	
Origin					0.164
Shelter	157	7	4.5	1.8–9.0	
Pet clinics	184	5	2.7	0.9–6.2	
Presence of lesions in the skin					0.011
Yes	28	4	14.3	0.0–32.7	
No	313	8	2.6	1.1–5.0	

Dermatophytes were detected in 10/286 dogs and 2/55 cats. The overall prevalence of dermatophyte-positive animals was 3.5% in cats and 3.6% in dogs. Regarding age, the prevalence found in juveniles was 4.2% (95% CI: 1.4–9.6%), and in adults was 3.1% (95% CI: 1.3–6.4%), with these differences not being statistically significant (p=0.605). Regarding origin, the highest value of prevalence (4.5%; 95% CI: 1.8–9.0%) was found in the shelters, and the lowest (2.7%; 95% CI: 0.9–6.2%) in pet clinics (Table 1), although these differences were not statistically significant (p=0.164).

There was a significant difference in the rate of isolation of dermatophytes in the presence of skin lesions (14.3%; 95% CI: 0.0-32.7%) and in the absence of these lesions (2.6%; 95% CI: 1.1–5.0%) in the studied species (p=0.011) (Table 1).

Prevalence of dermatophytes in dogs

Positive samples in dogs according to sex, age, breed, origin, and clinical signs examined are presented in Table 2. The lowest prevalence (0.7%; 95% CI: 0.0–3.9%) was found in the males and the highest (6.1%; 95% CI: 0.0–3.9%) in females. The differences were statistically significant (p=0.008) (Table 2).

Table 2. Dermatophyte prevalence in dogs, grouped according to sex, species, age, origin, and clinical signs, in Portugal.

Variable	Animals (*n*)	Positive (*n*)	Prevalence (%)	95% CI (%)	*p* value
Sex					0.008
Male	139	1	0.7	0.0–3.9	
Female	147	9	6.1		
Age					0.562
Young	90	4	4.3	1.2–10.5	
Adult	196	6	3.1	1.1–6.5	
Breed					0.122
Mongrel	269	8	3.0	1.3–5.8	
Other	17	2	11.8	1.5–36.4	
Origin					0.076
Shelter	122	7	5.7	2.3–11.5	
Pet clinics	164	3	1.8	0.0–5.3	
Presence of lesions in the skin					0.122
Yes	20	2	10.0	1.2–31.7	
No	266	8	3.0	1.3–5.8	
Total	286	10	3.5	1.9–6.3	

Dermatophytes were detected in 4/90 juvenile and 6/196 adult dogs. The prevalence in juveniles (4.3%; 95% CI: 1.2–10.5%) was higher than in adults (3.1%; 95% CI: 1.1–6.5%), but the difference was not statistically significant (p=0.562). Regarding breed, the prevalence of dermatophytes in mongrels was 3.0% (95% CI: 1.3–5.8%), and in other breeds was 11.8% (95% CI: 1.5–36.4%); these differences were not statistically significant (p=0.122). Regarding origin, the highest prevalence (5.7%; 95% CI: 2.3–11.5%) was found in the shelter animals, and the lowest (1.8%; 95% CI: 0.0–5.3%) in animals presented at pet clinics (Table 2), with these differences not being statistically significant (p=0.076).

In dogs, there was no significant difference in the rate of dermatophyte isolation in the presence (10.0%; 95% CI: 1.2–31.7%) and absence (3.0%; 95% CI: 1.3–5.8%) of skin lesions (p=0.122) (Table 2).

Prevalence of dermatophytes in cats

Positive samples in cats according to sex, age, breed, origin, and clinical signs examined are presented in Table 3. The prevalence in males and females was 5.3% (95% CI: 0.1–26.0%) and 2.8% (95% CI: 0.1–14.5%), respectively (p=0.648) (Table 3).

Table 3. Dermatophyte prevalence in cats, grouped according to sex, species, age, origin, and clinical signs, in Portugal (n=55).

Variable	Animals (*n*)	Positive (*n*)	Prevalence	95% CI (%)	*p* value
Sex					0.648
Male	19	1	5.3	0.1–26.0	
Female	36	1	2.8	0.1–14.5	
Age					0.979
Juvenile	28	1	3.6	0.1–18.4	
Adult	27	1	3.7	0.1–19.0	
Breed					0.448
Moggy	14	1	7.1	0.2–33.9	
Other	41	1	2.4	0.1–12.9	
Origin					0.004
Shelter	35	0	0.0	0.0–0.1	
Pet clinics	20	2	0.1	1.2–31.7	
Presence of lesions in the skin					0.004
Yes	8	2	25.0	3.2–65.1	
No	47	0	0.0	0.0–7.6	
Total	55	2	3.6	1.0–12.3	

Table 4. Frequency (n=number, %=percentage of animals) of fungal genera isolated from the fur of dogs and cats in the study (n=341).

Fungal isolate	Dog (n = 286)	Cat (n = 55)	Total (n = 341)	*p* value
Acremonium spp.	13 (4.5%)	2 (3.6%)	15 (4.4%)	0.758
Alternaria spp.	64 (22.4%)	17 (30.9%)	81 (23.8%)	0.184
Aspergillus felis	1 (0.3%)	1 (1.8%)	2 (0.6%)	0.266
Aspergillus fumigatus	2 (0.7%)	1(1.8%)	3 (0.9%)	0.463
Aspergillus nidulans	3 (1.0%)	0 (0.0%)	3 (0.9%)	0.303
Aspergillus niger	13 (4.5%)	4 (7.3%)	17 (5.0%)	0.418
Aspergillus spp.	33 (11.5%)	13 (23.6%)	46 (13.5%)	0.024*
Beauveria spp.	1 (0.3%)	0 (0.0%)	1 (0.3%)	0.553
Bipolaris spp.	2 (0.7%)	0 (0.0%)	2 (0.6%)	0.401
Chaetomium spp.	6 (2.1%)	0 (0.0%)	6 (1.8%)	0,144
Cladophialophora spp.	5 (1.7%)	0 (0.0%)	5 (1.5%)	0.289
Cladosporium spp.	57 (19.9%)	10 (18.2%)	67 (19.6%)	0.763
Curvularia spp.	2 (0.7%)	0 (0.0%)	2 (0.6%)	0.608
Epicoccum spp.	1 (0.3%)	0 (0.0%)	1 (0.3%)	0.554
Fusarium spp.	23 (8.0%)	5 (9.1%)	28 (8.2%)	0.798
Geotricum spp.	2 (0.7%)	0 (0.0%)	2 (0.6%)	0.558
Microsporum audouinii	1 (0.3%)	0 (0.0%)	1 (0.3%)	0.553
Microsporum canis	9 (3.1%)	2 (3.6%)	11 (3.2%)	0.853
Mucor circinelloides	1 (0.3%)	0 (0.0%)	1 (0.3%)	0.553
Mucor spp.	41 (14.3%)	9 (16.4%)	50 (14.7%)	0.701
Neoscytalidium spp.	3 (1.0%)	0 (0.0%)	3 (0.9%)	0.303
Penicillium spp.	73 (25.5%)	25 (45.5%)	98 (28.7%)	0.003*
Rhizomucor spp.	1 (0.3%)	0 (0.0%)	1 (0.3%)	0.553
Scedosporium spp.	4 (1.4%)	1 (1.8%)	5 (1.5%)	0.818
Scopulariopsis spp.	4 (1.4%)	2 (3.6%)	6 (1.8%)	0.296
Trichoderma spp.	42 (14.7%)	3 (5.5%)	45 (13.2%)	0.105
Verticillium spp.	5 (1.7%)	0 (0.0%)	5 (1.5%)	0.183

* $p < 0.05$

Dermatophytes were detected in 1/28 juveniles and 1/27 adults. The prevalence in juveniles (3.6%; 95% CI: 0.1–18.4%) and adults was similar (3.7%; 95% CI: 0.1–19.0%) (p=0.979). Regarding breed, the prevalence found in moggies (domestic shorthair breed) was 7.1% (95% CI: 0.2–33.9%), and in other breeds was 2.4% (95% CI: 0.1–12.9%) (p=0.448). No dermatophytes were found in shelter cats (0.0%; 95% CI: 0.0–0.1%), but the prevalence in cats at pet clinics was 0.1% (95% CI: 1.2–31.7%). The differences were statistically significant (p=0.004).

Regarding clinical signs on the skin of cats, the highest prevalence (25.0%; 95% CI: 3.2–65.1%) was found in the presence of lesions, and the lowest (0.0%; 95% CI: 0.0-7.6%) in the absence of skin lesions (Table 3), with these differences being statistically significant (p=0.004).

Other mycelial fungi were also isolated. Among the 341 dogs and cats investigated, *Penicillium* spp. (28.7%) were the mostly isolated fungi. The most frequent filamentous fungi isolated were *Alternaria* spp. (23.8%), *Cladosporium* spp. (19.6%), *Mucor* spp. (14.7%), *Aspergillus* spp. (13.5%), *Trichoderma* spp. (13.2%), *Fusarium* spp. (8.2%) and *Acremonium* spp. (4.4%) (Table 4).

The occurrence of *Penicillium* spp. was significantly higher in cats (45.5%) than in dogs (25.5%) (p=0.003), but the occurrence of *Aspergillus* spp. was significantly higher in cats (23.6%) than in dogs (11.5%) (p=0.024).

DISCUSSION

The prevalence of dermatophytes in cats varies considerably, depending on factors such as geographical location, season of sampling, and clinical and living conditions (al-Doory et al., 1968). Dermatophytosis is a common problem in animal shelters, with prevalence differing widely depending on the location and population of animals. Because diagnosis is frequently clinical and presumptive, there is a lack of knowledge regarding regional differences in etiology and the different factors that could contribute to this (Moskaluk and VandeWoude, 2022). Dermatophytosis is usually moderate and self-limiting in healthy dogs and cats. Still, it can be challenging to control in a shelter and can develop into an enzootic feature in poorly cared-for, restricted populations (Gordon et al., 2020).

Dermatophytes were isolated from 12/341 collected fur samples. The dermatophyte isolated most frequently was *M. canis*. It accounted for 3.5% (n=10/286) and 3.6% (n=2/55) of the dermatophytes isolated from dogs and cats, respectively. No dermatophytes of the genera *Nannizzia* or *Trichophyton* were isolated. This is consistent with earlier research in which *M. canis* was identified as the most common species in pets, specifically dogs and cats (Bernardo et al., 2005; Bouza-Rapti et al., 2023; Cabañes et al., 1997; Cafarchia et al., 2004; Mancianti et al., 2002; Yamada et al., 2019).

Previous studies in Portugal reported dermatophyte prevalences of 8.4% in dogs and 21.3% to 29.4% in cats (Coelho et al., 2008; Duarte et al., 2010), and 2.9% in pets less than one year old (Cruz et al., 2014). The present study found a very similar dermatophyte prevalence between dogs (3.5%; 10/286) and cats (3.6%; 2/55). This is inconsistent with previous studies that found that the isolation proportion in dogs was lower than in cats (Seker and Dogan, 2011; Sparkes et al., 1993). The prevalence of *M. canis* in younger dogs and cats in our study was consistent with earlier studies (Lewis et al., 1991; Long et al., 2020; Moriello, 2014).

The dermatophyte prevalence found in this study in dogs (3.5%) was lower than that found in other studies. Previous studies found a prevalence ranging between 8.1-24.3% (Hernandez-Bures et al., 2021; Long et al., 2020; Sparkes et al., 1993). This discrepancy might be attributable to various factors, including geographical variations, differences in the studied populations (such as breed, age, and health status), methodology differences in detecting dermatophytes, or changes in environmental conditions that affect the distribution and transmission of dermatophytes.

In this study the anthropophilic species, *M. audouinii*, was isolated from a male shelter dog. The most common cause of *tinea capitis* in children is *M. audouinii*. In the past century, epidemics involving thousands of schoolchildren have been documented in the USA (Samanta, 2015). Few cases of animal infections have been reported in the literature. *M. audouinii* has been isolated from dogs in three cases and from one monkey. The small number of recorded cases suggests that these infections are uncommon (Kaplan and Georg, 1957). There is no strong evidence that animals are involved in the epidemiology of this mycosis. This finding could have resulted from cross-contamination.

In dogs, the lowest prevalence value was found in males and the highest in females. This result does not agree with previously published studies that found higher prevalences in males than in females (Cafarchia et al., 2004; Debnath et al., 2016). In humans, studies found higher prevalences in females than in males (Balakumar et al., 2012; Jarjees and Issa, 2022; Teklebirhan and Bitew, 2015). This difference is probably because females interact with pets more frequently than males, which could include direct interaction between diseased pets and their households (Jarjees and Issa, 2022).

Previous studies have reported an increased risk of *M. canis* infection in cats below one year old (Cafarchia et al., 2004; Lewis et al., 1991). In contrast, the present study found a similar prevalence between juvenile and adult cats. In a study conducted by DeTar et al. (2019) in a feline shelter, the prevalence of *M. canis* was 1.8%, and kittens were eight times more likely to present with dermatophytosis than adults. Furthermore, cats that live in shelters have an increased risk of *M. canis* infection (DeTar et al., 2019). Young animals seem to exhibit a higher susceptibility to dermatophytosis, attributable to several critical factors, such as the immature immune system, the absence of prior immunity, skin microtraumas, often caused by interactions with siblings or the presence of ectoparasites, and the intensive socialization periods involving close

contact with other cats. Moreover, the heightened stress levels associated with shelter life or the stresses associated with transportation can exacerbate cat vulnerability to dermatophytosis (Galuppi et al., 2013; Moriello et al., 2017).

In our study the comparatively low prevalence in cats of *M. canis* infections (3.6%) stands in contrast to findings from similar studies, suggesting a need to explore underlying reasons. For instance, a study in Italy by Proverbio et al. (2014) reported a 5.5% prevalence of dermatophyte infections in stray cats, with *M. canis* being the most frequently identified pathogen. Similarly, research by Duarte et al. (2010) in Portugal found a significantly higher prevalence of 29.4% dermatophytes in stray cats, including species like *M. canis*, *T. mentagrophytes* var. *mentagrophytes*, and *Trichophyton verrucosum*. The range of reported prevalence rates, such as the 6.8% to 10.3% range reported by Verbrugge et al. (2006) for cats with skin lesions, and the documentation of carriers by Chupia et al. (2022), underscores the complexity of dermatophyte transmission and infection rates. The lower dermatophyte prevalence in cats observed in our study could be attributed to several factors, including geographical differences, differences in the cat populations studied (such as the proportion of stray versus domestic cats), and the specific diagnostic methods employed. Additionally, environmental conditions, the effectiveness of local control and prevention measures, and the genetic predisposition of the cat population could also influence dermatophyte prevalence. Our findings, particularly the 25% of positive cats exhibiting skin lesions, align with the understanding that dermatophyte infection can result in both sick and apparently healthy hosts, highlighting the importance of considering both clinical and subclinical infections in managing and preventing dermatophytosis.

In our study, animals with skin lesions were likelier to test positive for dermatophytes than those without clinical signs. These findings are consistent with previous studies (Moriello et al., 2017). Compared to healthy skin, animals and humans with lesions were found to have higher frequencies of dermatophytes, possibly because of flaws in the skin's natural ability to act as a barrier against fungal infection, which enables fungal invasion. The presence of skin wounds, scars, or burns most likely accelerates the infection's clinical course (Paryuni et al., 2020; Vermout et al., 2008). A limited amount of scientific information is available on the isolation of dermatophytes in healthy pets. The observation in our study that eight dogs were carriers of dermatophytes without exhibiting clinical signs suggests a potential for subclinical transmission to humans and other animals. Thus, our study suggests that animals without skin lesions could be carriers of this pathogen to humans and other animals, so humans who are close to and exposed to pets should be more aware of animal diseases, especially skin diseases such as dermatophytosis.

A study conducted on healthy animals from a colony and pet cats in southeast England reported a prevalence rate of 4.3% of dermatophyte infections among the cats (Mancianti et al., 2002). In a study conducted in a Canadian Pacific Northwest animal shelter system, the prevalence of dermatophytosis was 38.5% (Gordon et al., 2020). Another study conducted in a cat shelter in Toronto, Canada, reported a prevalence of

21.2% (Jacobson et al., 2018). The high prevalence rates of dermatophytes in animal shelters can be attributed to several factors, including overcrowding, poor hygiene, and stress.

However, our study seems to be corroborated by the study of Mozes et al. (2017), in which dermatophyte colonization was also uncommon in cats admitted to shelters, even though a significant number of cats were sampled from several shelters. Mozes et al. (2017) suggested that the poor quality of the samples could explain their results. However, the abundance of other fungal species discovered in our study suggests that the sampling was sufficient. Controlling infectious diseases in shelters requires a thorough understanding of the epidemiology of dermatophytosis and other infectious disorders. While potentially time-consuming and expensive, monitoring studies like this can offer crucial information for creating and interpreting infection control measures (Mozes et al., 2017).

The sensitivity of any sample and culture procedure cannot be considered 100% (Moriello et al., 2017). A rapid diagnosis can be made using a polymerase chain reaction (PCR) to detect dermatophyte DNA. A positive result does not always denote an ongoing infection, and results must be interpreted in conjunction with clinical signs because PCR detects both viable and nonviable fungal DNA. Positive PCR or culture results could also point to the presence of spores on the animal's coat rather than an infection in the absence of any clinical signs (Bajwa, 2020; Bouza-Rapti et al., 2023; Moriello et al., 2017; Piri et al., 2018), and it is a challenge to distinguish mechanical carriers from animals with an established infection (Newbury and Moriello, 2014). This distinction is crucial for implementing targeted measures to prevent the spread of dermatophytosis, especially in settings where animals are in close contact with each other and with humans. Therefore, our study advocates for increased vigilance in monitoring both sick and apparently healthy animals. Identifying carriers, regardless of their clinical presentation, is essential for the effective management and control of dermatophyte infections. Early detection and appropriate intervention for these carriers can significantly reduce the risk of transmission, emphasizing the importance of both diagnostic accuracy and a proactive approach to disease management.

Given the rising number of pets being allowed in the bedroom or bed and having close contact with their owners or personal items, along with a lack of awareness about zoonotic risks and how to prevent them, hygiene concerns persist. Merely petting or having pets inside the house can lead to exposure, as physical contact and fur can serve as potential transmission pathways for pathogens, including Alternaria alternata, as demonstrated in the present study. This behavior can put owners, especially those who are young, old, pregnant, or immunocompromised, at risk of contracting fungal, bacterial, or viral infections (do Vale et al., 2020, 2021; Morgado et al., 2022; Zanen et al., 2022). Prevention and control of dermatophytosis are crucial to managing infections in animal shelters. One approach to controlling the spread of dermatophytes is to screen animals for shedding fungus. Screening can be conducted as a response to

clinical signs, as a routine infection control measure, or as a response to an outbreak (Mozes et al., 2017).

Shelters attempt to identify dermatophyte-infected cats at admission, first through exposure history and perceived risk factors, then through accessible point-of-care screening techniques during admission examination, and finally through follow-up diagnostic confirmation (DeTar et al., 2019).

The diversity of mycobiota isolated in this study from the fur of dogs and cats is in line with that found in previous studies in animals, and the high prevalences must be considered, since the isolated genera can cause severe diseases in humans and animals, especially in immunocompromised individuals (Coelho et al., 2003, 2008; Martins, 2022; Meason-Smith et al., 2015). However, non-dermatophytic molds can be recovered as contaminants from glabrous skin, hair, and nails. Several requirements must be met before a non-dermatophytic mold is isolated from a biological sample and is regarded as a causal agent (Coelho et al., 2011).

It is essential to consider the study's limitations. In the animals from the clinics, no recorded information was obtained about antifungal treatment in recent months, which may have contributed to inhibition of fungal growth in culture. The study's ability to draw definitive conclusions about the prevalence and risk factors for dermatophyte infection in cats is limited by its small sample size of 55 cats, including only two positive cases. This limitation impacts the statistical power and accuracy of our findings, indicating the need for further research with larger samples to better understand these aspects.

CONCLUSION

This study sheds light on the prevalence of dermatophytes, particularly the widespread presence of *M. canis*, among dogs and cats in animal shelters and pet clinics. The findings underscore the importance of understanding the epidemiology of dermatophytosis in animal populations, given its potential for transmission to humans and other animals. Notably, even seemingly healthy dogs and cats without clinical signs were found to carry dermatophytes, highlighting the potential for these animals to act as carriers and emphasizing the importance of pet-owner awareness regarding zoonotic risks. The study also emphasizes the need for effective animal shelter screening and infection control measures, where overcrowding and suboptimal hygiene conditions can contribute to the spread of dermatophytes. These findings provide valuable insights into the complex dynamics of dermatophytosis in animal populations, underscoring the necessity for ongoing research and vigilance to mitigate the risks associated with fungal infections.

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Authors' contributions

Conceptualization: PA, HQ, LC and ACC; methodology: PA, HQ, AFV, EP, MM, ASF, LC and ACC; validation: PA, HQ, LC and ACC; formal analysis: PA, HQ, LC and ACC; investigation: PA, HQ, AFV, EP, MM, ASF, LC and ACC; resources: PA, HQ, LC and ACC; data curation: PA and ACC; writing - original draft preparation: PA; writing - review and editing: APL, HQ, LC and ACC; visualization - APL, HQ, LC and ACC; supervision: HQ, LC and ACC; project administration: HQ, LC and ACC; funding acquisition: HQ, LC and ACC. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare no conflicts of interest.

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DLAKAVI DOMAĆINI I GLJIVICE KAO GOSTI: ISPITIVANJE NOSIOCA DERMATOFITA KOD MAČAKA I PASA IZ AZILA I VETERINARSKIH KLINIKA NA SEVERU PORTUGALA

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Kratak sadržaj

Dermatofitoza je rasprostranjena gljivična infekcija životinja i ljudi. Dermatofitoza dovodi do razgradnje keratina, što uzrokuje lezije na koži, dlaci i kandžama i ima važnu globalnu prevalenciju koja se često potcenjuje. Iako je obično samolimitirajuća, dermatofitoza može predstavljati ozbiljan rizik zbog svoje zarazne prirode, posebno u azilima. Ova studija ima za cilj da proceni prevalenciju dermatofita u dlaci pasa i mačaka u azilima za životinje i veterinarskim klinikama, akcentujući važnost razumevanja i upravljanja ovom infektivnom bolešću kako u životinjskim tako i u ljudskim populacijama.

Kako bi se bolje razumela epidemiologija dermatofita u Portugalu, studija je sprovedena od marta do maja 2022. godine. Procenjena je prevalencija izolacije dermatofita u kulturi. Ukupno je ispitano 341 životinja, od kojih je 286 (83,9%) pasa i 55 (16,1%) mačaka, pri čemu je 45,0% (n=157) životinja bilo iz azila, dok je 54,0% (n=184) bilo iz veterinarskih klinika.

Dvadeset osam (8,2%) životinja imalo je lezije na koži, a od njih su četiri (14,3%) testirane pozitivno na dermatofite. Dermatofiti su izolovani kod 12/341 ispitane životinje. Prevalencija *Microsporum canis* bila je 3,2% (interval poverenja [IP] 95%: 1,6-5,7%), dok je prevalencija *Microsporum audouinii* bila 0,3% (IP 95%: 0,0-1,6%). Utvrđeno je da su zdravi psi i mačke bez kliničkih znakova nosioci dermatofite, ističući potencijal ovih životinja da deluju kao subklinički nosioci i naglašavajući važnost svesti vlasnika kućnih ljubimaca o zoonoznim rizicima i potrebi za kontinuiranim istraživanjima i nadzorom kako bi se umanjili rizici povezani sa gljivičnim infekcijama.

Ključne reči: mačka, dermatofiti, pas, Portugal, prevalencija, azil, zoonoza