Original Article

Serum Trace Elements and Oxidant/Antioxidant Status in Persian Cats With Dermatophytosis Compared to Other Dermatological Disorders

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ABSTRACT

Background: Despite the high prevalence of dermatophytosis in cats, little is known about the impact of this disease on the antioxidant status and trace elements in these animals.

Objectives: This study aimed to investigate the concentration of serum trace elements (copper, iron, zinc, and selenium) and oxidant/antioxidant status (malondialdehyde, total antioxidant capacity (TAC), and thiol group) in Persian cats with dermatophytosis compared to healthy controls and other dermatological disorders.

Methods: Three groups of cats were selected: Cats with dermatophytosis (n=13), cats with other dermatological conditions (n=6), and clinically and dermatologically healthy cats (n=6). All 25 cats were subjected to clinical and dermatological examinations, including direct microscopic examination and fungal cultures. Additionally, possible contamination with feline immunodeficiency virus (FIV) and feline leukemia virus (FeLV) were tested.

Results: *Microsporum canis* was the only dermatophyte species isolated from the affected cats, and only two cats were infected with the FIV: One in the dermatophytosis group and one in the other skin disease group. For trace elements, we did not detect any differences between cats with dermatophytosis and healthy cats. However, copper levels were higher in other skin disease groups than healthy controls ($P<0.05$). Cats with dermatophytosis and other skin diseases revealed a decrease in TAC compared to healthy controls ($P<0.01$).

Conclusion: The present study found variations in the oxidative indices in cats with dermatophytosis and other skin disorders. This result supports the hypothesis that improving antioxidant status through dietary supplementation may be beneficial in preventing and resolving skin diseases in cats.

Keywords: Oxidative stress, Dermatophytosis, Cat, Trace elements, Dermatological disorders

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Introduction

Dermatophytosis, a fungal infection of keratinized skin structures resulting in various skin lesions, alopecia, and pruritus, is a significant health concern in animals and humans (Moriello & Coyner, 2021; Shokri & Khosravi, 2016). Small animals are primarily affected by *Microsporum. canis*, *Microsporum. gypseum*, and *Trichophyton* species, with cats being the most susceptible species and *M. canis* being the most prevalent (Moriello, 2019; Abastabar et al., 2019). *M. canis* is also considered to be a frequent agent of tinea capitis, tinea corporis, and tinea manum in humans (Shokri & Khosravi, 2016; Moriello, 2019; Abastabar et al., 2019; Ansari et al., 2016).

Several factors predispose animals to infection, including age, genetic susceptibility of certain breeds (particularly Persian cats), housing conditions, host immunity status (immunosuppressive diseases, such as feline immunodeficiency virus [FIV] or feline leukemia virus [FeLV] infection in cats, and immunosuppressive drugs), and nutritional status (Al-Qudah et al., 2010; Beigh et al., 2014; Moriello et al., 2017; Nikbakht; 2022; Ramezanpour Eshkevari; 2024). Due to its zoonotic status, pleomorphic clinical signs, and infectious and contagious nature, dermatophytosis is a crucial issue in veterinary medicine (Moriello et al., 2017). The skin plays a crucial role in preventing the penetration of fungal pathogens, but it is also vulnerable to oxidative damage (Khan et al., 2022). Various defense mechanisms include non-enzymatic and enzymatic compounds in the skin that act as powerful antioxidants or oxidant-degrading systems (Portugal et al., 2007). During oxidative stress, the skin's defenses become overloaded, causing various skin disorders, such as erythema, edema, wrinkles, hypersensitivity, and keratinization (Trouba et al., 2002). Dermatophytes can trigger the production of reactive oxygen species (ROS), either directly or indirectly. Following dermatophyte infection, ROS are produced by immune cells, such as neutrophils and macrophages, to help eliminate fungal infections (Pathakumar et al., 2020; Linnerz & Hall, 2020). Different enzymatic systems, such as the nicotinamide adenine dinucleotide phosphate (NADPH) oxidase system, mitochondrial respiratory chain, and lipoxygenase pathway, can generate ROS in immune cells. These systems generate a variety of ROS, including hydroxyl radicals, hydrogen peroxide, and superoxide anions (Brieger et al., 2012). Furthermore, oxidative stress can activate the transcription factor of nuclear factor kappa B (NF-kB), which regulates gene expression in inflammation and immune responses (Celestrino et al., 2021). Nuclear factor kappa B (NF-kB) activation can further increase ROS production by immune cells, leading to a positive feedback loop that amplifies the immune response and oxidative stress (Linnerz & Hall, 2020). In addition to immune cells, dermatophytes produce ROS as part of their metabolic processes. Fungal cell walls contain enzymes, such as NADPH oxidase and lipoxygenase, which can produce ROS while breaking down nutrients. The ROS produced by dermatophytes can damage host tissues and contribute to the pathogenesis of infection (Hogan & Wheeler, 2014). Trace minerals, such as iron, copper, zinc, and selenium, are essential for proper immune function and skin health. These micronutrients are components and cofactors of endogenous antioxidants. Cytoplasmic superoxide dismutase (SOD) contains copper and zinc metals as cofactors, glutathione peroxidase contains selenium, and catalase contains iron (Sloup et al., 2017). Iron and zinc play crucial roles in immune cell development, differentiation, and function (Maggini et al., 2007; Gombart et al., 2020; Seyednejad et al., 2023). Selenium is a crucial trace element frequently used as an antioxidant to protect the skin against ROS (Zhu et al., 2015). Selenium also plays a role in immune regulation by affecting the proliferation and function of immune cells, such as T lymphocytes and natural killer cells (Avery & Hoffmann, 2018). Copper regulates wound healing, melanin production, and defense against oxidative stress in animals (Park, 2015). Selenium deficiency has been associated with skin disorders, including impaired wound healing and increased vulnerability to UV-induced skin damage (lv et al., 2020). Similarly, zinc deficiency has been associated with a range of dermatological issues, including cutaneous lesions, impaired wound healing, and heightened vulnerability to infections (Nosewicz et al., 2022). Previous studies have indicated that some animals, such as dogs and calves with skin disorders, have altered trace element concentrations and compromised antioxidant defenses (Al-Qudah et al., 2010; Beigh et al., 2014; Beigh SA, et al., 2016).

Despite the high prevalence of dermatophytosis in cats, little is known about its impact on antioxidant status and trace elements in these animals. The present study aimed to investigate the concentration of serum trace elements (copper, iron, zinc, and selenium) and oxidant/antioxidant status (malondialdehyde [MDA], total antioxidant capacity [TAC], and thiol group) in Persian cats with dermatophytosis compared to healthy controls and other dermatological disorders.

Additionally, the researchers checked the cats for "FIV" and "FeLV" infections to minimize the potential effect of these immunosuppressive diseases on the incidence of dermatophytosis.

Materials and Methods

Animal selection

A total of 25 cats enrolled in this study were admitted for clinical and dermatological examinations at the Ferdowsi University of Mashhad (FUM) Vet Hospital from September 2017 to February 2019. Only Persian cats were included in this clinical study to minimize possible breed differences. Cats diagnosed with dermatophytosis based on clinical signs and a positive Wood's lamp followed by a positive mycological culture and microscopic identification of the fungus were included in this study only when the presence of other probable dermatological diseases or other problems were ruled out. Following the analysis of the dermatologic data collected, 25 privately owned Persian cats were divided into three groups as follows:

1. Healthy control group: Six adult healthy cats (four males and two females), age group 6-84 months (Mean±SD; 38.5±32.6). These cats were presented to the hospital for routine checkups and vaccinations. Healthy control cats had no history of ear or skin diseases and were negative for dermatophytes.

2. Cats with dermatophytosis: Thirteen cats with dermatophytosis (four males and seven females, two undetermined) with an age group of 1-17 months (Mean±SD; 7.5±6 months) were selected.

3. Cats with other dermatologic conditions: The study included six cats (one male and five females) with various skin problems but dermatophyte-negative with an age group of 12-126 months (Mean±SD; 46.5±42 months).

The diseased cats had a history of dermatological problems for at least 4–5 weeks before presentation. All cats included in the study were medication-free for at least 30 days before collecting blood samples and had lived exclusively in domestic environments.

Dermatological examination

The techniques evaluated for the dermatologic diagnostics evaluation of cats were skin scrapings, trichograms, tape strips, Wood's lamp and direct sampling for fungal culture, direct examination of the exudates from pustules or draining tracts, bacteriological tests, and skin biopsies. To gather debris, skin-scraping samples were collected with sharp or dull scalpel blades. The debris was examined under a microscope at low magnification. For the trichogram study, an area of 1 cm was plucked with forceps in the direction of hair growth and placed in a drop of mineral oil on a slide. In the present study, flea and/or food allergies presented as a concurrent problem in some cats, and others could not be ruled out owing to owner compliance issues.

Mycological examination

All cats with suspected dermatophytosis skin lesions were closely examined, including observation and palpation of the skin for any primary and/or secondary skin lesions. Hair samples were collected based on clinical signs and Wood's lamp examination. Hair sampling was chosen according to clinical signs and was either done using the toothbrush technique when lesions were generalized or by using a hair pluck at the margins of localized lesions (Moriello et al., 2017). All samples were examined for fungal elements under a light microscope at 40 x magnification using 20% potassium hydroxide / dimethyl sulfoxide (Merck Co., Darmstadt, Germany). All samples were inoculated onto Mycosel agar (Merck Co., Darmstadt, Germany). The plates were incubated at 27 °C and examined daily for four weeks. Dermatophyte isolates were identified by colony morphology and microscopic examination with a lactophenol cotton blue preparation.

Collection of blood and serum samples

Blood samples were obtained from each cat by jugular or cephalic venipuncture. Five mL of blood without anticoagulant was centrifuged at 1800 g for 10 minutes. The serum was collected and stored at −20 °C until analysis.

FeLV infection and FIV examination

All cats selected for this study were tested for FIV and FeLV using ELISA (SensPERT FIV/FeLV Rapid Test; VetAll Laboratories), which detects the presence of FeLV p27-antigen (sensitivity, 98.6%; specificity, 98.2%) and FIV antibodies (sensitivity, 93.5%; specificity, 100%).

Measurement of serum trace elements

Serum levels of copper, iron, zinc, and selenium were measured using commercial kits (Pars Azmoon, Iran, for iron; Giesse Diagnostics, Italy, for zinc; EliTech

Diagnostics, France, for copper) using an autoanalyzer (Biotecnica, Targa 3000, Rome, Italy). Selenium concentration was determined using atomic absorption spectrophotometry (Perkin Elmer 3030, USA). Control serum (Randox control sera, Antrim, UK) was used to control measurement accuracy.

Measurement of oxidant/antioxidants

MDA

The concentration of MDA in the serum was determined as TBA reactive substances, according to Placer et al. (1966). This method depends on forming a colored complex between MDA and TBA. Briefly, 0.2 ml of serum was added to 1.3 mL of 0.2 mol/L tris, 0.16 mol/L KCl buffer (pH 7.4). TBA (1.5 mL) was added, and the mixture was heated in a boiling water bath for 10 minutes. After cooling, 3 mL of pyridine–butanol (3:1, v/v) and 1 mL of 1 mol/L NaOH were added. Absorbance was measured at 548 nm against distilled water as a blank. The nmol of MDA per mL of serum was calculated using 1.56 ± 10^5 as the extinction coefficient.

Thiol groups

Total thiol groups in serum samples were measured using a spectrophotometric assay with 2,2-dithiobisnitrobenzoic acid (DTNB or Ellman's reagent) (Hu, 1994). After adding Tris buffer to the serum sample, the absorbance was measured at 412 nm (A1). Then DTNB was added, and the absorbance at 412 nm was measured (A2). The concentration of total thiol groups was calculated and expressed as mmol/L.

TAC

The TAC of the serum sample was measured using the ferric-reducing ability of plasma (FRAP) assay (Boligon et al., (2014), which depends on the reduction of ferric tripyridyltriazine (Fe(III)-TPTZ) complex to ferrous Fe(II) (TPTZ) by a reductant at low pH. Fe (II)-TPTZ had an intense blue color and could be monitored at 593 nm. The FRAP values were determined by extrapolation from the standard curve and were expressed in mmol/L.

Statistical analysis

All the statistical analysis was performed using SPSS software, version 26. Values of the measured parameters were expressed as Mean±SD. After testing the data for normal distribution, differences between groups were determined using a one-way analysis of variance. Significance was considered at $P<0.05$. The Bonferroni test was used to compare the groups.

Results

Demographic characteristics

The study participants included Persian cats living exclusively in domestic environments and fed mostly commercial dry food. Table 1 summarizes the sex and age of the 25 cats studied.

Dermatological manifestations

Of the 13 dermatophyte-positive cases, all were positive for fungal elements by direct microscopic examination and culture-positive. According to the culture results, *M. canis* was the only dermatophyte species isolated from the cats. *M. canis* produces a yellow-greenish fluorescence in hair and small ectothrix spores. The colonies are white to buff in color with a characteristic yellow-to-orange-brown reverse. Macroaleuriospores are numerous, spindle-shaped, with thick walls and 6–15 cells; microaleuriospores are rare, small, clavate to elongate, and single-celled (Carter, 1990).

In the present study, 77% of dermatophytosis-positive cats had dermatological manifestations, which included one or more irregular or annular areas of alopecia, scaling, crusting, erythema, ringworm lesions, diffused dermatitis, 'stud tail' and conjunctivitis. All 13 dermatophyte-positive cats tested positive for wood infection.

The affected regions based on the fungal culture results were as follows: Head and neck, 41% (9/13); limbs, 27% (6/13); dorsal midline and tail, 18% (4/13); and abdomen, 14% (3/13). The areas around the eyes, mouth, nose, and ears were involved on the head. The forelimbs were affected more often (5 out of 6 affected limbs) than the hindlimbs. Overall, most infected cats revealed a generalized distribution pattern of the disease.

Among the six cats with different skin conditions (dermatophyte-negative cats), feline acne (2/6), food hypersensitivity (1/6), moderate facial and otic pruritus due to otodectic mange (2/6), and traumatic alopecia (1/6).

Trace elements

The serum copper level was higher in cats with other skin diseases (2.31±0.7 ppm) than in healthy controls (1.48±0.7 ppm) ($P<0.05$). No differences were detected in the serum trace elements between the dermatophytosis-affected cats and the healthy control group (Table 2).

Table 1. Sex and age of all 25 studied cats

Parameters		No./Mean±SD		
		Dermatophytosis Group	Other Skin Diseases Group	Control Group
Sex	Male	4	1	4
	Female	7	7	2
Age (m)		7.5±6	46.5±42	38.5±32.6

Oxidant/antioxidant parameters

A significant decrease in TAC (measured using the FRAP assay) was detected in cats with dermatophytosis (120.31±33.7) and other skin diseases (94.54±37.8) in comparison with healthy cats (187.06±47) (P<0.01) (Table 3).

Discussion

Dermatophytosis is a crucial skin disease in small animals and is highly prevalent in Persian cats. It is a zoonotic disease with a public health impact, causing skin infections that can be contagious, chronic, and significantly affect the quality of life of affected individuals (Shokri & Khosravi, 2016; Moriello, 2019; Gordon et al., 2020; Khodadadi et al., 2021). Among immunocompetent hosts, dermatophytosis is a self-limiting skin disease that occurs within weeks to months (Moriello & Coyner, 2021). A crucial step towards preventing this disease and improving treatment is identifying the factors influencing its occurrence.

Previous studies identified *M. canis* as the predominant dermatophyte isolate in affected cats (Moriello, 2019; Katiraee et al., 2021; Cafarchia et al., 2013; Lavari et al., 2022). Our results are consistent with previous studies, in which *M. canis* was the only fungal species identified in cats with dermatophytosis.

Table 2. Serum trace minerals profile in cats affected with dermatophytosis, other skin diseases, and healthy control

Parameters	Mean±SD		
	Dermatophytosis Group	Other Skin Diseases Group	Control Group
Copper (ppm)	1.26±0.38[a]	2.31±0.7[b]	1.48±0.7[a]
Zinc (ppm)	0.92±0.4	1.4±0.6	1.39±0.9
Iron (ppm)	15.34±11.8	14.46±9.5	18.93±12.5
Selenium (ppm)	0.38±0.1	0.44±0.1	0.39±0.1

[a, b]Significantly differences at P<0.05.

Table 3. Oxidative stress parameters in cats affected with dermatophytosis, other skin diseases, and healthy control

Parameters	Mean±SD		
	Dermatophytosis Group	Other Skin Diseases Group	Control Group
FRAP (mmol/L)	120.31±33.7[a]	94.54±37.8[a]	187.06±47[b]
MDA (mmol/L)	0.8±0.1	0.75±0.1	0.88±0.1
Total thiol groups (mmol/L)	1.44±0.6	1.13±0.5	1.48±0.7

Abbreviations: FRAP: Ferric reducing ability of plasma; MDAL: Malondialdehyde.

[a, b]Significantly differences at P<0.01.

Dermatophytes have been shown to possess multiple enzymatic properties that can vary according to the fungal strain. Keratinase secreted from *M. canis* may be associated with increased inflammation and pruritus (Dahl, 1994). This inflammatory reaction can produce extreme amounts of reactive oxidants, which can cause oxidative stress (Beigh et al., 2014). Trace elements have been reported to be required for the activity of several enzymes, including antioxidant enzymes (Chow, 2019). Although the trace element status and antioxidant imbalance in feline dermatophytosis have not been studied, similar studies have investigated a variety of infectious and inflammatory skin disorders in other animals, including canine dermatophytosis (Beigh et al., 2014; Ural et al., 2009; Nafie et al., 2021), sarcoptic mange (Beigh et al., 2016), demodicosis (Dimri et al., 2008), and bovine dermatophytosis (Al-Qudah et al., 2010; Nisbet et al., 2006; Pasa & Kiral, 2009).

The excessive production of free radicals, inadequate antioxidants, or a combination of both causes oxidative stress. It contributes to the pathogenesis of various infectious, inflammatory, and degenerative diseases, including skin disorders (Al-Qudah et al., 2010; Beigh et al., 2014; Beigh et al., 2016; Dimri et al., 2008; Saleh et al., 2011). Our study indicated that cats with skin diseases, including dermatophytosis, were found in a state of significant oxidative stress, as indicated by reduced TAC compared with healthy controls. The observed decrease in TAC in cats with dermatophytosis and other skin disorders might be related to the overconsumption of antioxidants during infestation. Due to this insufficient antioxidant capacity, excess free radicals can damage cellular compounds, such as lipids, proteins, and DNA (Halliwell, 1999).

Previous studies conducted on dogs and calves have also found alterations in the oxidant/antioxidant balance in animals with dermatophytosis (Al-Qudah et al., 2010; Beigh et al., 2014) and in diabetic rats (Shahsavari et al., 2023). In 2014, Beigh et al. reported a decrease in SOD and catalase activities and an increase in MDA levels in dermatophytosis-affected dogs. However, the results of this study did not show a relationship between reduced glutathione and MDA levels and dermatophytosis in cats. Several authors have demonstrated an exhausted antioxidant system in dogs with other skin diseases, including sarcoptic mange (Beigh et al., 2016) and demodicosis (Dimri et al., 2008). However, their possible role in feline skin diseases has not yet been studied.

Trace minerals are essential components in living organisms. They are now recognized as essential for health and play a vital role in antioxidant defense (Evans & Halliwell, 2001). Deficits in trace elements may lead to cat dermatophytosis by suppressing their immune system and lowering the activity of antioxidant enzymes containing copper, zinc, iron, and selenium as cofactors. Many studies have shown the relationship between micronutrient level and pathogenicity of infectious and inflammatory skin diseases in dogs and calves (Al-Qudah et al., 2010; Beigh et al., 2014; Beigh et al., 2016; Dimri et al., 2008; Nisbet et al., 2006). In 2014, Beigh et al. observed lower copper and zinc concentrations and higher iron levels in dogs with dermatophytosis. In 2010, researchers studied the trace elements copper, zinc, and selenium in calves (Beigh et al., 2014). Al-Qudah et al. (2010) found that the levels of these elements in the blood of calves with dermatophytosis were lower than those in healthy controls. Dogs with demodicosis also indicated reduced zinc and copper concentrations (Dimri et al., 2008). However, two other studies did not show a relationship between dogs' zinc and copper concentrations and dermatophytosis (Ural et al., 2009; Nafie et al., 2021). Similarly, no differences were detected in serum trace elements between the dermatophytosis-affected cats and the healthy control group in the present study.

According to the results of this study, serum copper levels were higher in cats with other skin diseases than in healthy controls ($P<0.05$). Both copper and zinc are cofactors of the SOD enzyme (Evans & Halliwell, 2001), and studies have shown that zinc and copper concentrations correlate with SOD activity in both dermatophytosis and healthy dogs (Beigh, 2014; Nafie, et al., 2021). Therefore, increased serum copper levels in feline dermatoses may result from a probable increase in SOD activity.

Conclusion

The present study found variations in the oxidative indices in cats with dermatophytosis and other skin disorders. This result supports the hypothesis that improving antioxidant status through dietary supplementation may be beneficial in preventing and resolving skin diseases in cats. Nevertheless, in the current study, trace minerals and oxidative stress indices in the skin were not investigated and can be analyzed in further research. Future therapeutic trials are required to determine the role of minerals and antioxidants in treating dermatophytosis.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Ferdowsi University of Mashhad (FUM), Mashhad, Iran. This study used only non-experimental animals (including owned or unowned animals). It followed internationally recognized high standards (best practices) of individual veterinary clinical patient care.

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Authors' contributions

Conceptualization and supervision: Javad khoshnegah and Mohammad Heidarpour; Methodology: Javad Khoshnegah and Samaneh Eidi; Data collection: Javad Khoshnegah, and Bahareh Ahmadi; Data analysis: Mohammad Heidapour; Investigation and writing: Bahareh Ahmadi and Javad Khoshnegah; Funding acquisition and resources: Javad Khoshnegah.

Conflict of interest

The authors declared no conflict of interest.

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مقاله پژوهشی

ارزیابی ارتباط استرس اکسیداتیو و عناصر کمیاب در گربه‌های دچار درماتوفیتوز و سایر بیماری‌های پوستی

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چکیده

زمینه مطالعه: علی‌رغم شیوع بسیار درماتوفیتوز در گربه‌ها، اطلاعات کمی درخصوص اثر این بیماری بر مقادیر آنتی‌اکسیدانی و عناصر کمیاب در گربه‌های مبتلا وجود دارد.

هدف: مطالعه حاضر با هدف بررسی غلظت عناصر کمیاب سرم (مس، آهن، روی و سلنیوم) و شاخص‌های اکسیدانی/آنتی‌اکسیدانی (مالون‌دی‌آلدئید، ظرفیت تام آنتی‌اکسیدانی و گروه تیول) در گربه‌های پرشین مبتلا به درماتوفیتوز و مقایسه آن‌ها با گربه‌های مبتلا به سایر بیماری‌های پوستی و نیز گربه‌های سالم صورت گرفت.

روش کار: بدین منظور سه گروه از گربه‌ها انتخاب شدند: ۱۳ گربه مبتلا به درماتوفیتوز، ۶ گربه مبتلا به سایر بیماری‌های پوستی و ۶ گربه سالم. پس از معاینه فیزیکی همه گربه‌ها، ارزیابی جامع درماتولوژیک و نمونه‌گیری برای آزمایش مستقیم میکروسکوپی و کشت قارچ صورت گرفت. همچنین احتمال آلودگی همه گربه‌ها با ویروس‌های FIV و FeLV بررسی شد.

نتایج: در گروه گربه‌های دچار درماتوفیتوز، تنها گونه درماتوفیت جداشده، میکروسپوروم کنیس بود. در میان کل گربه‌های موردمطالعه، تنها دو گربه (یکی از گربه‌های دچار درماتوفیتوز و یکی از گربه‌های مبتلا به سایر بیماری‌های پوست و مو)، FIV مثبت بودند. هیچ‌گونه تفاوتی در مقادیر سرمی عناصر کمیاب بین گربه‌های مبتلا به درماتوفیتوز و گربه‌های سالم وجود نداشت. بااین‌حال، مقدار سرمی مس در گروه گربه‌های مبتلا به سایر بیماری‌های پوستی در مقایسه با گروه سالم بالاتر بود ($P<0/05$). گربه‌های دچار درماتوفیتوز و گربه‌های مبتلا به سایر بیماری‌های پوستی در قیاس با گربه‌های سالم، دارای کاهش ظرفیت آنتی‌اکسیدانی کل بودند ($P<0/01$).

نتیجه‌گیری نهایی: مطالعه حاضر تغییراتی را در شاخص‌های اکسیداتیو در گربه‌های مبتلا به درماتوفیتوز و سایر اختلالات پوستی نشان داد. این یافته‌ها از این فرضیه حمایت می‌کند که بهبود وضعیت آنتی‌اکسیدانی با افزودن مکمل‌های غذایی به رژیم غذایی گربه‌ها، ممکن است در پیشگیری و رفع بیماری‌های پوستی آن‌ها مفید باشد.

کلیدواژه‌ها: استرس اکسیداتیو، درماتوفیتوز، گربه، عناصر کمیاب، اختلالات درماتولوژیک

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