Assessment of oxidative stress, trace elements, serum biochemistry, and hormones levels in weaned calves with dermatophytosis

K. Sezer1*, B. Hanedan2, M. Ozcelik3, A. Kirbas4

1Burdur Mehmet Akif Ersoy University, Faculty of Veterinary Medicine, Department of Internal Medicine, Burdur, Turkey
2Ataturk University, Faculty of Veterinary Medicine, Department of Internal Medicine, Erzurum, Turkey
3Fırat University, Vocational School of Health Services, Elazığ, Turkey
4Bozok University, Faculty of Veterinary Medicine, Department of Internal Medicine, Yozgat, Turkey

ABSTRACT: In this study, it was aimed to evaluate oxidative stress, serum biochemistry, trace elements, minerals, and testosterone and thyroid hormone levels in weaned calves with dermatophytosis. A total of 28 weaned Holstein calves were used in the study, including 6-8 months old, 14 with dermatophytosis (7 males, 7 females) and 14 healthy (7 males, 7 females). The animals were grouped as the diseased and healthy animals, 14 animals in each group as well as the male diseased and the male healthy animals were grouped as 7 animals in each group for the comparison of testosterone levels. The blood analyses were performed using ELISA kits and biochemistry automatic analyzer. There was a significant difference between the diseased and healthy groups for NO (nitric oxide) (P<0.05), TOS (total oxidative stress) (P<0.001), TAC (total antioxidant capacity) (P<0.01). However, in comparison of the diseased and healthy groups, serum biochemistry with the exception of glucose and triglyceride, trace elements except for manganese, minerals, and thyroid hormone levels were not statistically different (P>0.05). In comparison of the diseased and healthy animals for testosterone levels, it was not determined any difference (P>0.05). The present study revealed that dermatophytosis could affect oxidant status in calves with dermatophytosis, and that TOC (total oxidant capacity) and NO as oxidative stress marker might be increased for fungicidal effect in the diseased animals with dermatophytosis.

Keywords: Calves with dermatophytosis, oxidative stress, trace elements, serum biochemistry, hormones.
INTRODUCTION

Dermatophytosis commonly occurs in humans and animals and is an infectious disease characterized by keratinization in stratum corneum layer of skin and hair loss. This zoonotic disease is of economic importance because of difficult control, contagious, and high cost of treatment (Chermette et al., 2008; Radostits et al., 2007). Dermatophytosis is caused by Trichophyton, Microsporum and Epidermophyton species in domestic animals (Deacon, 1988; Kahn and Line, 2010; Radostits et al., 2007). It is reported that T. verrucosum generally causes the disease in cattle (Al-Qudah, et al., 2010; Papini et al., 2009). Factors such as keratinase enzyme, hemolytic activity, humidity, pH, fatty acids of the skin, amino acids, hormones, individual resistance and immune response have important roles in the development of disease (Hashemi and Sarasgani, 2004; Pal and Dave, 2013; Radostits et al., 2007; Schaufuss and Steller, 2003; Xavier et al., 2008).

In calves, dermatophytosis is characterized by non-pruritic lesions around the eye, ear, and dorsum, and sometimes also develops in the generalized form (Kahn and Line, 2010). There are characteristic lesions with scaling patches of hair loss, and gray-white crust formation, but sometimes these lesions have thick crusts with suppuration (Kahn and Line, 2010).

In cattle, deficiency of minerals and trace elements causes growth retardation, immune system deficiency and dermatological lesions (Kahn and Line, 2010; Radostits et al., 2007). Zinc and selenium play roles in numerous metabolic reactions in the body (Shafiei Neek et al., 2011). Zinc deficiency may lead to the development of dermatophytosis, chronic infection and expansion of lesion area (Szczerpanik and Wilkolek, 2004).

In recent years, the effect of reactive oxygen species (ROS) on the body defense system has become important in farm animals (Castillo et al., 2003). Reactive oxygen species are produced as by-products due to cellular metabolism in low concentrations for numerous physiological processes including activation of transcription factors, cell immunity, and cellular defense against microorganisms (Miller et al., 1993; Zhang et al., 2016). Reactive oxygen species are increased during diseases and pathological changes in the organism and oxidative stress occurs because of deficiency of antioxidants and increase of oxidants (Lykkesfeldt and Svendsen, 2007; Roth, 1997). In bovine animals oxidative stress has been reported in various diseases caused by pneumonia, enteritis, sepsis, mastitis (Atakisi et al., 2010; Erkilic et al., 2016; Lykkesfeldt and Svendsen, 2007; Schott et al., 2014). In recent years, oxidative status has been investigated to enlighten the pathogenesis of dermatophytosis in animals and humans (Beigh et al., 2014; Karapetlivan et al., 2007; Kurutas and Ozturk, 2016).

In humans, pathogenic fungi and yeasts are reported to be affected by steroids, and this has become special area of interest in clinical research (Brasch, 1997; Clemons et al., 1988). An in vitro study has demonstrated that the growth of T. rubrum and E. floccosum is suppressed by androgenic hormones but T. mentagrophytes and M. canis is least responsive to most hormones (Brasch and Flader, 1996). In addition, testosterone levels in patients with dermatophytosis caused by E. floccosum decreased compared to healthy subjects but testosterone levels were not different between the patients with T. rubrum and healthy subjects (Brasch and Flader, 1996). However, to the best knowledge of authors, the role of androgenic hormones is not known in male calves with dermatophytosis.

Deficiency of minerals and trace elements leads to immune system deficiency, dermatological lesions and dermatophytosis. In addition, oxidative status has been shown in the pathogenesis of infectious diseases and the role of androgenic hormones is not known in male calves with dermatophytosis. In this study, it was aimed to evaluate oxidative stress, serum biochemistry, trace elements, minerals and testosterone and thyroid hormone levels in calves with dermatophytosis.

MATERIALS AND METHODS

Animals

This study was carried out on total 28 weaned Holstein calves, 6-8 month old, 14 with dermatophytosis (7 males and 7 females) and 14 healthy weaned calves (7 males and 7 females). Each group consisted of 14 weaned calves. Group I was the female and male diseased calves; Group II was the female and male healthy calves. All calves in the study were from one farm and all animals were kept under similar management conditions and were not kept overcrowded (including 96 calves in herd). All calves were healthy at weaning and throughout the study period except for dermatophytosis. Clinical examinations were performed by the same clinician (KS) and took skin scraping and hair samples randomly from the 14 calves of 45 calves with suspected dermatophytosis.

Microbiological analysis
Skin scrapings and hair samples (in calves showed skin lesions) were in part processed for microscopy by use of 10-20% potassium hydroxide (KOH) and after 30 min examined under 400X magnification of the light microscope. Rest of the samples was seeded on the Sabouraud Dextrose agar (SDA, OXOID) supplemented with chloramphenicol (0.05 mg/mL), and plates were incubated at 25°C and 37°C for a period of 1-4 weeks and examined on a daily basis as noted by studies (Larone, 1995; Quinn et al., 1999). The isolated fungal colonies were stained with lactophenol blue. The macro- and microscopic characteristics of isolates were detected as *Trichophyton* sp. (Larone, 1995; Robert et al., 2008).

**Blood sampling**

Blood samples were obtained from the calves by venipuncture of *vena jugularis* to vacutainer tubes. The blood samples were centrifuged at 3,000 rpm for 10 min and the serum samples were allocated to Eppendorf tubes and stored at -20 °C until analyses.

**Total antioxidant capacity (TAC) analysis**

Determination of TAC levels was performed using a novel automated colorimetric measurement method (Erel, 2004). The assay has finest quality precision values, lower than 3%. The results were indicated as mmolTrolox Equivalents/L for serum.

**Total oxidant capacity (TOC) analysis**

Determination of TOC levels was performed using a novel automated measurement method (Erel, 2005). The results were indicated as mmol H$_2$O$_2$ Equivalents/L for serum.

**Plasma total nitric oxide (NO) analysis**

The plasma total NO level measurement was performed by colorimetric method using NO detection kit (Enzo Life Science).

**Serum biochemistry analyses**

Serum alkaline phosphatase (ALP), aspartate aminotransferase (AST), gamma glutamyl transferase (GGT), total protein, albumin, glucose, urea, creatinine, total bilirubin, triglyceride (TG), total cholesterol, low density lipoprotein cholesterol (LDL-C), calcium (Ca), magnesium (Mg), retinol and β-carotene levels were determined by colorimetric method by a biochemistry auto analyzer using commercial test kits (Beckman Coulter, AU5800, USA).

**Serum trace elements analyses**

The serum copper (Cu), zinc (Zn), iron (Fe) were measured by flame atomic absorption (flame-AA) spectroscopy (Perkin Elmer AAS 800). Selenium (Se) was measured by hydride system atomic absorption (hydride-AA) spectroscopy. Manganese (Mn) levels were measured using atomic absorption spectrometer-graphite furnace system (graphite furnace-AAS).

**Hormone analyses**

Testosterone hormone, thyroid stimulating hormone (TSH), free triiodothyronine (fT3), and free thyroxin (fT4) levels were analyzed by chemiluminescence method (Beckman Coulter DXI 800, USA).

**Statistical analysis**

The comparison of the data between the diseased group and the healthy group was performed (SPSS, Version 11.5 Microsoft, Chicago, IL, USA) by using independent samples t test and Mann-Whitney U tests in 95% confidence interval. The significance degree between two groups was determined to be P<0.05. Data were expressed as mean ± standard error of the mean (SEM) and as median (minimum - maximum).

**RESULTS**

Oxidative stress markers such as TOC, TAC and NO levels in the weaned calves with dermatophytosis and in the healthy calves are given in Table 1. Total NO, TOC levels in calves with dermatophytosis were significantly increased compared to the healthy calves. TAC levels were significantly decreased in calves with dermatophytosis compared to the healthy calves.

The levels of trace elements and minerals are given in Table 2. The levels of these parameters except for manganese were not significantly different between the diseased and healthy calves. However, manganese levels were significantly lower than those of the healthy calves. Other elements (Cu, Se, Zn, Fe, Ca, Mg) were not found to be statistically important.

The levels of serum biochemistry parameters and hormones such as testosterone, TSH, fT$_3$, and fT$_4$ are given in Table 3. The levels of these parameters were not significantly different between the diseased and the healthy calves. The serum glucose and TG levels were significantly increased in the diseased animals over those in the healthy animals.
Table 1. Levels of total oxidant capacity, total antioxidant capacity and nitric oxide in calves with dermatophytosis and in the healthy calves

| Parameter                      | Group I (n=14)          | Group II (n=14)         |
|--------------------------------|-------------------------|-------------------------|
| Total NO (µmol/L)              | 70.09±3.40<sup>a</sup>  | 50.96±3.54<sup>b</sup>  |
| TAC (mmol Trolox Equiv./L)     | 2.13 (1.78-2.61)<sup>a</sup> | 2.86 (2.11-3.12)<sup>b</sup> |
| TOC (µmol H₂O₂ Equiv./L)       | 4.41±0.07<sup>a</sup>   | 3.54±0.09<sup>b</sup>   |

Group I: Calves with dermatophytosis; Group II: Healthy calves; NO: Nitric oxide; TAC: Total antioxidant capacity; TOC: Total oxidant capacity. The total NO, and TOC values were given as mean ± SEM for each group including 14 weaned calves, and the TAC values were given as median (minimum - maximum) for each group including 14 weaned calves.

Means with different superscripts in the same row are significantly different (P<0.05).

Table 2. Levels of trace elements (Cu, Zn, Se, Fe, and Mn) and minerals (Ca and Mg) in calves with dermatophytosis and in the healthy calves

| Parameter | Group I (n=14)          | Group II (n=14)         |
|-----------|-------------------------|-------------------------|
| Cu (ppm)  | 0.43±0.02               | 0.45±0.01               |
| Zn (ppm)  | 0.77±0.06               | 0.71±0.04               |
| Se (ppb)  | 13.77±1.31              | 15.70±0.88              |
| Fe (ppm)  | 0.50±0.03               | 0.48±0.02               |
| Ca (mg/dL)| 9.5 (6.46-15.15)        | 9.15 (3.41-9.68)        |
| Mg (mg/dL)| 4.39±0.17               | 4.19±0.20               |
| Mn (ppm)  | 1.88±0.13<sup>a</sup>   | 3.05±0.17<sup>b</sup>   |

Group I: Calves with dermatophytosis; Group II: Healthy calves. The Cu, Zn, Se, Fe, Mg and Mn values were given as mean ± SEM for each group including 14 weaned calves, and the Ca values were given as median (minimum - maximum) for each group including 14 weaned calves.

Means with different superscripts in the same row are significantly different (P<0.05).

Table 3. Levels of serum biochemistry, and thyroid hormones in calves with dermatophytosis and in the healthy calves

| Parameter                      | Group I (n=14)          | Group II (n=14)         |
|--------------------------------|-------------------------|-------------------------|
| Triglyceride (mg/dL)           | 27.71±2.88<sup>a</sup>  | 19.00±1.99<sup>b</sup>  |
| Total cholesterol (mg/dL)      | 82.28±5.74              | 74.84±4.33              |
| LDL-C (mg/dL)                  | 38.07±3.21              | 35.46±2.53              |
| Urea (mg/dL)                   | 14.28±1.08              | 15.53±1.35              |
| Creatinine (mg/dL)             | 0.7 (0.6-0.9)           | 0.8 (0.6-0.9)           |
| Total bilirubin (mg/dL)        | 0.18±0.005              | 0.19±0.008              |
| Glucose (mg/dL)                | 70.64±2.76<sup>a</sup>  | 62.84±3.46<sup>b</sup>  |
| Total protein (g/dL)           | 6.65 (6.30-8.60)        | 6.70 (4.50-8.10)        |
| Albumin (g/dL)                 | 2.80±0.07               | 2.81±0.10               |
| AST (U/L)                      | 87±4.59                 | 94.46±5.46              |
| GGT (U/L)                      | 18.85±0.98              | 17.07±1.04              |
| ALP (U/L)                      | 133.50 (89-222)         | 102.0 (50-222)          |
| Retinol (mg/dL)                | 26.19 (17.56-41.04)     | 23.34 (16.64-37.50)     |
| β-carotene (mg/dL)             | 12.77±1.18              | 12.85±1.45              |
| TSH U/l/mL                     | 0.18 (0.0-9.0)          | 0.14 (0.0-2.05)         |
| Free triiodothyronine (FT<sub>3</sub>) (pg/mL) | 2.78 (2.39-4.07)    | 3.19 (1.66-3.88)        |
| Free thyroxin (FT<sub>4</sub>) (ng/dL) | 0.79±0.04          | 0.83±0.05               |

Group I: Calves with dermatophytosis; Group II: Healthy calves. The triglyceride, total cholesterol, LDL-C, urea, total bilirubin, glucose, albumin, AST, GGT, β-carotene, and free thyroxin values were given as mean ± SEM for each group including 14 weaned calves. The creatinine, total protein, ALP, retinol, TSH, and free triiodothyronine values were given as median (minimum - maximum) for each group including 14 weaned calves.

Means with different superscripts in the same row are significantly different (P<0.05).
DISCUSSION

Zoophilic dermatophytes induced infections are acute or chronic and highly inflammatory. Keratinocytes, after infected with a zoophilic dermatophyte, express pro-inflammatory genes and secrete cytokines to contribute recruitment of inflammatory cells in the skin, tissue remodeling and wound healing (Martinez-Rossi et al., 2017). Experimental dermatophyte infection in mice has showed that dermal inflammation and histopathologically macrophages, dendritic cells, neutrophils are present. Inflammation also results in cytokine over expression such as transforming growth factor-β, interleukin-1β, and IL-6 (Cambier et al., 2014). The pathogens are cleared in the body by ROS produced by phagocyte cells (Mittal et al., 2014). In addition, during inflammation, macrophages and neutrophils produce NO for microbiocidal effect (Mizokami et al., 2016). Comply with these studies, in the present study, significant increase in TOC and NO levels was found in calves with dermatophytosis compared to the healthy calves. This suggested that TOC and NO as oxidative stress marker might be increased for fungicidal effect in the groups with dermatophytosis.

Oxidative stress as revealed by high MDA levels and lower SOD and catalase levels has been reported in dogs with dermatophytosis (Beigh et al., 2014). Similarly, in calves with dermatophytosis, oxidative stress through high MDA and NO, and low antioxidant GSH has been reported (Karapehlivan et al., 2007). In addition, significant oxidative/nitrosative stress revealed by increased MDA, NO and 3-NT levels have been demonstrated in patients with pityriasis versicolor (Kurutas and Ozturk, 2016). Similarly, in the present study, oxidative stress was found in calves with dermatophytosis via increased TOC and NO, and decreased TAC levels. This study suggested that oxidative stress might mediate the fungicidal activity in calves with dermatophytosis.

Trace elements such as Cu, Zn, Se, Mn and Fe have cofactor roles in antioxidant enzymes. Several studies have demonstrated that trace elements have important roles in antioxidant enzymes expression and activities. For example, a selenium, zinc, copper, iron, and manganese deficient diet has been demonstrated to cause a significant decrease in GSH-Px, Cu,Zn-SOD, catalase and GSH-Px, and Mn-SOD activities (Gong and Xiao, 2018; Malecki and Greger, 1996; Prohaszka and Brokate, 2001; Toyoda et al., 1989). The deficiencies of trace elements may be caused by dietary imbalances or diseases. In calves with dermatophytosis, trace elements such as whole blood Se, serum Zn, and Cu levels have been significantly decreased in line with significant reduction in antioxidant defense systems including GSH-Px activities and glutathione levels by attributing to possible dermatophyte consumption (Al-Qudah et al., 2010). In other studies, significant decrease in serum zinc levels without changes in blood leukocytes levels (Nisbet et al., 2006), significant decrease in serum Mn and Zn levels and increase in Cu levels in bovine dermatophytosis (Paksoy et al., 2013), and significant decrease in serum Fe in cattle with dermatophytosis (Yildirim et al., 2010) have been reported. In contrast to the results of those studies, in the present study, serum Cu, Zn, Se, Fe levels were not different statistically in the group with dermatophytosis compared to the healthy control group. The serum Mn levels were significantly decreased in calves with dermatophytosis than in the healthy calves in line with the result of Paksoy et al. (2013). The serum Ca and Mg minerals between the group with dermatophytosis and the healthy group were not different statistically. This study did not found any significant difference except Mn in serum trace elements and serum minerals between the diseased group and the healthy group. Similarly, the serum Zn and Cu levels were not statistically different between young cattle with dermatophytosis and the healthy young cattle (Aslan et al., 2010). In addition, a recent study in patients with tinea pedis has revealed that zinc and selenium levels are significantly lower on the lesion site than those on the healthy site, but Cu levels are significantly higher on the lesion site than those on the healthy site. In addition, positive correlation between the lesional area Cu and the lesional area 8-iso-PGF_2α (lipid peroxidation product) has been demonstrated (Miraloglu et al., 2016). It is thought that evaluating oxidant status and trace ele-

---

### Table 4. Serum testosterone levels in the calves with dermatophytosis and in the healthy calves

| Parameter       | Group I (n=7) | Group II (n=7) |
|-----------------|--------------|---------------|
| Testosterone (ng/dL) | 1.64 ± 0.24  | 3.66±0.96     |

Group I: Calves with dermatophytosis; Group II: Healthy calves. The testosterone values were given as mean ± SEM for each group including 7 male weaned calves.
ments on the lesional site can provide better knowledge in elucidating the dermatophytosis pathogenesis.

Significant decrease in the serum Zn and vitamin A levels has been reported in calves with dermatophytosis (Pasa and Kiral, 2009). Several studies have reported that the levels of vitamin A may be changed in infection conditions (Bendich, 1993; Chew, 1987; Or et al., 2002). Zinc has the effects on vitamin A metabolism such as absorption, transport and utilization through protein synthesis, and Zn-dependent dehydrogenase enzyme (Christian and West, 1998). These studies have determined the important association between zinc and vitamin A. In the present study, contrary to the findings of Pasa and Kiral (2009), retinol and β-carotene levels were also in normal ranges in line with normal serum Zn levels in calves with dermatophytosis.

In addition, the present study found no statistical difference in the serum biochemical parameters such as triglyceride, total cholesterol, LDL, urea, creatinine, total bilirubin, glucose, total protein, albumin, TSH, fT3, fT4, AST, GGT, ALP in calves with dermatophytosis compared to healthy calves. This revealed that the calves with dermatophytosis may have normal organ functions. However, in a study (Atakisi et al., 2006) evaluated serum adenosine deaminase and liver function tests in dermatophytic cattle, increased adenosine deaminase, GGT, ALT, AST, and LDH levels have been found and it was thought to be associated with possible liver damage due to the toxic metabolic products of the fungi.

Androgenic hormones can affect fungal growth in male patients with dermatophytosis (Hashemi and Sarasgani, 2004). Serum testosterone levels have been reported to significantly decrease in patients with dermatophytosis caused by E. floccosum (Hashemi and Sarasgani, 2004). In contrast to E. floccosum, T. mentagrophytes and M. canis are less susceptible to the androgenic hormones (Brasch and Flader, 1996). In the present study, testosterone levels were not significantly different between male calves with dermatophytosis and the healthy male calves but the male calves with dermatophytosis had non-significant reduction of testosterone levels compared to the male healthy calves.

CONCLUSIONS
The present study revealed that dermatophytosis might affect oxidant status in calves with dermatophytosis and TOC and NO as oxidative stress marker might be increased for fungicidal effect in the groups with dermatophytosis. In addition, serum biochemistry parameters including thyroid and testosterone hormones with the exception of glucose and triglyceride, trace elements except for Mn and minerals were found to be in normal ranges. However, future studies with larger sample sizes are needed to be conducted for changes in testosterone levels.

CONFLICT OF INTEREST
The authors declare no conflict of interest.
REFERENCES

Al-Qudah KM, Gharaibeh AA, Al-Shyayb MM (2010) Trace minerals status and antioxidant enzymes activities in calves with dermatophytosis. Biol Trace Elem Res 136(1):40-47. doi:10.1007/s12011-009-8525-4

Aslan O, Aksoy A, Iça T (2010) Serum concentrations of zinc, copper, manganese in young cattle with dermatophytosis. J Fae Vet Med Univ Erciyes 7(1):29-33.

Atakisi E, Karapehlivan M, Atakişi O, Kontaş T, Maralş Ş. (2006) A new automated colorimetric method for measuring total antioxidant capacity in cow milk. Res Vet Sci89(1):10-13.

Beigh SA, Soodan JS, Singh R, Khan AM, Dar MA (2014) Evaluation of trace elements, oxidant/antioxidant status, vitamin C and beta-carotene in cows with dermatophytosis. Mycoses 57(6):358-365. doi:10.1111/myc.12163

Bendhi A (1993) Physiological role of antioxidants in the immune system. J Dairy Sci 76(9):2789-2794.

Brasch J (1997) Hormones, fungi and skin. Mycoses 40:11.

Brasch, J, Flader S (1996) Human androgenic steroids affect growth of dermatophytes in vitro. Mycoses 39(9-10):387-392.

Cambier L, Weatherspoon A, Defaweux V , Bagut ET, Heinen MP, Antoine Bendich A (1993) Physiological role of antioxidants in the immune system. USA: Merck Co., Inc. Whitehouse Station, N.J.

Chew BP (1987) Vitamin A and beta-carotene on host defense. J Dairy Sci 70(12):2732-2743.

Christian P, West KP Jr (1998) Interactions between zinc and vitamin A: an update. Am J Clin Nutr (62:2 Suppl):45-441. doi:10.1093/ajcn/62.4.4355

Clemens KV, Schär G, Stover EP, Feldman D, Stevens D (1988) Dermatophyte-hormone relationships: characterization of progesterone-binding specificity and growth inhibition in the genera Trichophyton and Microsporum. J Clin Microbiol26(10): 2110-2115.

Deacon JW (1988) Introduction to modern mycology, 2nd ed. Oxford: Blackwell Scientific Publications. 1-239.

Erel O (2004) A novel automated direct measurement method for total antioxidant capacity using a new generation, more stable ABTS radical cation. Clin Biochem37(4):277-285.

Erel O (2005) A new automated colorimetric method for measuring total antioxidant status. Clin Biochem38(12):1103-1111.

Erkilic E, Erdogan Ö, Ogun M, Kirmizigul A, Gokce E, Kuru M, Kukurt A (2016) Relationship between hepaticid and oxidant/antioxidant status in calves with suspected neonatal septicemia. Vet World 9(11): 1238-1241.

Gong J, Xiao M (2018) Effect of organic selenium supplementation on selenium status, oxidative stress, and antioxidant status in selenium-deficient dairy cows during the periparturient period. Biol Trace Elem Res 186(2):430-440. doi:10.1007/s12011-018-1323-0.

Hashemi SJ, Sarasgani M (2004) A study for determination of relationship between serum testosterone concentration and dermatophytosis due to Epidermophyton floccosum in patients. Iranian J Publ Health 33(1):10-12.

Kahn C, Line S (2010) Dermatophytosis. In: The Merck Veterinary Manual. USA: Merck Co., Inc. Whitehouse Station, N.J.

Karapehlivan M, Uzlu E, Kaya N, Kanikavi O, Ural K, Citil, M (2007) Investigation of some biochemical parameters and the antioxidant system in calves with dermatophytosis. Turk J Vet Anim Sci 31(2):85-89.

Kurutas EB, Ozturk P (2016) The evaluation of local oxidative/nitrosative stress in patients with pityriasis versicolor: a preliminary study. Mycoses 59(11):720-725. doi:10.1111/myc.12522.

Larone DH (1995) Medically important fungi: A guide to identification, 4th Edition, American Society for Microbiology, USA. p. 272-4.

Lykkfesfeldt J, Svendsen O (2007) Oxidants and antioxidants in disease: oxidative stress in farm animals. Vet J 173(3):502-511.

Malecki EA, Greger JL (1996) Manganese protects against heart mitochondrial lipid peroxidation in rats fed high levels of polysaturated fatty acids. J Nutr 126(1):27-33. doi:10.1093/jn/126.1.27.

Martinez-Rossi NM, Peres NT, Rossi A (2017) Pathogenesis of dermatophytosis: Sensing the host tissue. Mycopathologia 182(1-2):215-227. doi:10.1007/s11046-016-0057-9

Miller J, Brzezinska-Slebodzinska E, Madsen F (1993) Oxidative stress, antioxidants, and animal function. J Dairy Sci 76(9):2812-2823.

Miraloglu M, Kurutas EB, Ozturk P, Arican O (2016) Evaluation of local trace element status and 8-iso-prostaglandin F2 alpha concentrations in patients with tinea pedis. Biol Proced Online 18:1. doi:10.1186/s12575-015-0030-x

Mittal M, Siddiqui MR, Tran K, Reddy SP, Malak AB (2014) Reactive oxygen species in inflammation and tissue injury. Antioxid Redox Signal 20(7):1126-1167. doi:10.1089/ars.2012.5149

Mizokami SS, Holmman MS, Saurengiro-Ferrari L, Carvalho TT, Zarpelon AC, Possenbol MI, de Souza AR, Veneziani RC, Arakawa NS, Casa-grande R, Verni WA Jr (2016) Promaridinoic acid inhibits carrageenin-induced inflammatory leukocyte recruitment and edema in mice: Inhibition of oxidative stress, nitric oxide and cytokine production. PLoS One 11(2):e0149656. doi:10.1371/journal.pone.0149656.

Nisbet C, Yarim G F, Cirfici G, Arslan HH, Cirfici A (2006) Effects of trichophytosis on serum zinc levels in calves. Biol Trace Elem Res 113(3):273-280. doi:10.1385/bter:113:3:273.

Or M, Bakrel, U, Tuncel H, Arun S, Karakoc Y, Dodurka HT, Barutçu UB (2002) Relation of histo-pathological changes with serum zinc and copper levels in dermatologically disease ddogs. J Fae Vetc Med Univ Istanbul 28(2):337-345.

Paksy N, Ozcelik M, Erkilec EE, Bayuk F, Metin O, Kirmizigul AH (2013) Serum Copper, Zinc and Manganese Concentrations in Bovine Dermatophytosis in Kars Region. Atatürk Univ J Vet Sci 8(3):210-215.

Pal M, Dave P (2013) Ringworm in cattle and man caused by Microsporum canis: Transmission from dog. Int J Livest Res 3(1):100-103.

Papini R, Nardoni S, Fanelli A, Mancianti F (2009) High Infection Rate of Trichophyton verrucosum in Calves from Central Italy. Zoo noses Public Health, 56 (2):59-64.

Pasa S, Kiral F (2009) Serum zinc and vitamin A concentrations in calves with dermatophytosis. J Fae Vetc Med Univ Kafkas15(1):9-12.

Prohaska JR, Brokate B (2001) Lower copper, zinc-superoxide dismutase protein but not mRNA in organs of copper-deficient rats. Arch Biochem Biophys 393(1):170-176. doi:10.1006/abbi.2001.2470.

Quinn PJ, Carter ME, Markey B, Carter GR (1999) Clinical Veterinary Microbiology. p: 381-390. London, England: Mosby-Wolfe.

Radotisim OM, Gay CC, Hinchcliff KW, Constable PD (2007) Ringworm. Veterinary Medicine. Saunders Elsevier, Edinburgh, 1476-1478.

Robert R, Pihet M (2008) Conventional methods for the diagnosis of dermatophytes. Mycopathologia 166:295-306.

Roth E (1997) Oxygen free radicals and their clinical implications. Acta Derm Venereol 77(5):305-310.

Schauffuss P, Steller U (2003) Haemolytic activities of Trichophyton speceies. Med Mycol 41(6):511-516.

Schoo C, Cai H, Parker L, Bateman K, Caswell J (2014) Hydrogen peroxide production and free radical-mediated cell stress in Mycoplasma bovis pneumonia. J Comp Pathol 150(2-3):127-137.

Shafei Neel K, Gaeini AA, Choobineh S (2011) Effect of zinc and selenium supplementation on serum testosterone and plasma lactate in cyclist after an exhaustive exercise bout. Biol Trace Elem Res 144(1-
Szczepanik M, Wilkolek P (2004) Selected parameters of nonspecific immunity in cattle suffering from trychophytosis at different levels of zinc in their serum. Medycyna Weterynaryjna 60(11):1233-1235.

Toyoda H, Himeno S, Imura N (1989) The regulation of glutathione peroxidase gene expression relevant to species difference and the effects of dietary selenium manipulation. Biochim Biophys Acta 1008(3):301-308.

Xavier GA, da Silva LB, da Silva DR, de Moraes Peixoto R, Lino GC, Mota RA (2008) Dermatophytosis caused by Microsporum canis and Microsporum gypseum in free-living Bradypus variegatus (Schiz, 1825) in the state of Pernambuco, Brazil. Braz J Microbiol 39(3):508-510.

Yildirim M, Cinar M, Ocal N, Yagci B, Askar S (2010) Prevalence of clinical dermatophytosis and oxidative stress in cattle. J Anim Vet Adv 9(14):1978-1982.

Zhang J, Wang X, Vikash V, Ye Q, Wu D, Liu Y, Dong W (2016) ROS and ROS-mediated cellular signaling. Oxid Med Cell Longev 2016:4350965.