REVIEW

Effect of yerba mate (*Ilex paraguariensis* A. St.-Hil.) supplementation on oxidative stress in ruminants

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ABSTRACT

Nutrition, especially antioxidant-rich herbal supplementation, is one of the most important factors in the reaction to oxidative stress. Moreover, it influences animal productivity and reproduction. When oxidant production exceeds the capacity of antioxidant defense, this results in oxidative damage to lipids, DNA, and proteins. Oxidative stress, which is described as an imbalance between oxidant and antioxidant levels, is a current field of research in ruminant medicine, and it has been involved in numerous disease processes, including sepsis, mastitis, acidosis, and ketosis. Interest in plant extracts has therefore increased due to the high amount of natural biologically active substances that are potential natural fodder additives. This paper focused on yerba mate tea, an infusion made from the leaves of the *Ilex paraguariensis* A. St.-Hil. tree, which is a widely consumed traditional beverage in South America. There is growing interest for the properties of yerba mate. Supplementation of *I. paraguariensis* for large and small ruminants resulted in lower oxidative stress and also improved their productive and reproductive performance.

Key words: Antioxidants, biomarkers of oxidative stress, dairy cows, fodder additives, *Ilex paraguariensis*.

INTRODUCTION

Nowadays, consumers are likely to pay attention to the origin and quality of food. There is a growing awareness of the dangers of chemical use in agriculture and the harmfulness of residues in food products. Given greater consumer demands for organic production, the livestock industry must seek new alternatives and healthy animal feeding strategies. There is also increased interest in alternative growth promoters and the use of herbs in the prevention and treatment of animal diseases. Herb applications in human medicine are well known and have been applied in livestock production and farm animal feeding (Windisch et al., 2008). The superiority of the herbal substances obtained by chemical, rather than the same substance obtained synthetically, is due to the active substance contained in the plant that readily affects the body. The plant's active ingredient is in physiological equilibrium with other compounds and is therefore better absorbed by the animal organism (Kowalczuk et al., 2008). Herbs can act as vitamins or biocatalysts, regulating and speeding up animal metabolism. They positively affect the secretion of digestive juices, increase appetite and intestinal peristalsis, and improve the absorption processes of ingredients (Rózanski and Drymel, 2009). Herb antioxidant properties are designated

as bioactive compounds such as polyphenols, carotenoids, and flavonoids. The main herbs with antioxidant properties include rosemary, thyme, oregano, sage, chamomile, dandelion, and marigold (Carlsen et al., 2010). Phytogenic feed additives protect lipids from oxidative damage. It is advisable to use generally available herbs that enrich feed, fortify it into valuable nutrients, and stimulate the metabolism. Herbal supplementation can be used with a single herb or standardized herbal extracts. Due to the wide variety of active substances contained in herbs, there are also herbal blends to provide a synergistic effect. The bioactive substances favorably influence the animal immune processes and antioxidant effects. The active compounds also stimulate gut microflora. It is better to use a nutrient dose. Studies also indicate increased quality of animal origin products after introducing herbs. By affecting animal health, herbs can reduce production costs and improve the economic balance of farming and animal husbandry (Mandelker, 2011). Ruminants associated with milk production are exposed to oxidative stress. The supplementation of the lactating cow diet is often not sufficient and poor in antioxidants. The aim of this paper was to present the potential of yerba mate as a supplement with antioxidant properties for ruminants that has an impact on oxidative stress reduction.

OXIDATIVE STRESS IN RUMINANTS

Oxidative stress is mainly defined as the inner balance disorder of the organism between oxidants and antioxidants (free radicals and reactive oxygen species). Under high oxygen supply conditions, reactive oxygen species (ROS) concentrations increase. These compounds interact with the cells of the organism from which they acquire the electron; this leads to permanent damage of proteins, lipids, and DNA. Weakened cells lose their ability to multiply and regenerate, and this is a basic cause of weakening the immune system. Under these conditions, the incidence of disease increases. According to Mandelker (2011), the main risk factors for oxidative stress are infections, toxins, hypoxia/ischemia, hyperglycemia, xenobiotics (drug metabolism), hyperlipidemia, hyperproteinemia, cancer, inflammation, phagocytic activity, immune reactions, and elevated metabolic rates.

Oxidants can be subdivided into various groups, depending on their chemical nature or reactivity. One widely used classification system is based on whether or not the oxidants are (free) radicals, that is, they contain an unpaired electron in their outer orbital that renders the molecule unstable. The radical group includes species such as hydroxyl radical ($HO^{\bullet}$), nitric oxide ($NO^{\bullet}$), and superoxide ($O_2^{\bullet-}$). Antioxidants are able to donate electrons to oxidants, thus quenching their reactivity under controlled conditions and making them harmless to cellular macromolecules. A highly important second level of defense is the ability to detect and repair or remove oxidized and damaged molecules. The ability to induce programmed cell death is of major importance in a variety of bodily functions, including tissue growth control, and it is apparently under the control of several signaling pathways. However, one of these appears to be that apoptosis is induced by increased oxidative stress and constitutes a final resort to encapsulate and isolate the damaged cells (Lykkesfeldt and Svendsen, 2007).

The performance level and production cycle phase are important determinants of oxidative stress occurrence in dairy cows. According to many authors, the perinatal period (3 wk before and 3 wk after calving) in high-performance animals is characterized by a high degree of metabolic activity (Konvicná et al., 2015). Mobilization and lipid peroxidation in the period after calving increases the production of free radicals and reactive oxygen species, which, in excess, leads to oxidant-antioxidant imbalance (Celi and Gabai, 2015). In addition, the body needs increased nutrients at the beginning of the lactation period, mainly for energy. Feed supplementation in the perinatal period with a high ratio of corn decreases total antioxidant capacity (TAC) in cow serum, which indicates the presence of oxidative stress (Celi, 2010). Oxidative stress contributes to decreased immunity, which causes many diseases. The most frequent metabolic disorders in dairy cows include placenta retention and ketosis (Celi, 2011; Konvicná et al., 2015). Some reports have indicated a high correlation between oxidative stress and the prevalence of mammary gland inflammation in the early lactation period (Józwik et al., 2012).

Mammary gland inflammation is the most devastating disease for dairy animals; despite improved management practices and dry cow therapy, mastitis remains a worldwide problem and a major economic threat for dairy farmers. The main cause is infection caused by pathogenic microorganisms that penetrate the teat canal directly into the mammary gland (Ezzat-Alnakip et al., 2014).

Among many factors, nutrition is decisive for animal health. Study results by many authors (Sharma et al., 2011; Nisar et al., 2013) indicate that an effective way to reduce the incidence of oxidative stress during the perinatal period in ruminants is to add compounds with antioxidant properties to the feed ration. The current knowledge of yerba mate (*Ilex paraguariensis* A. St.-Hil.) photochemistry is an opportunity to use it as an appropriate ruminant supplement (Cogoi et al., 2013).

Yerba mate chemical characteristics and antioxidant properties

Yerba mate is the infusion of *I. paraguariensis* leaves, and its consumption is steadily increasing throughout the world. It was formerly used in rituals by indigenous peoples of South America before the arrival of the colonizers. In countries where it is produced (e.g., Argentina or Brazil), yerba mate is not only an important branch of agriculture, but it also has a significant impact on their economy (Cogoi et al., 2013). *Ilex paraguariensis* is increasingly exported to Europe, the United States, and Japan where it is sold ground or as an extract used in herbal medicines as well as active additives for various foods. According to the Argentine Food Code, yerba mate is defined as a product exclusively consisting of dried, slightly roasted, and ground *I. paraguariensis* leaves, which can contain fragments of young branches, pedicels, and stalks (Pasquali et al., 2011; Cogoi et al., 2013). Dried yerba mate, also with leaves and green stems, is used as a green dye in the classic "Chimarrao", "Mate", and "Terere" in powdered form to make teas and as an essence for various industrial purposes (Cansian et al., 2008a). Depending on the type of infusion solutions, they are prepared with hot or cold water. However, regardless of the method used, water or other extracts are characterized by significantly active biological effects, particularly antioxidant properties. In many countries *I. paraguariensis* is used in folk medicine as a panacea for various body dysfunctions. *In vitro* studies indicate that yerba mate exhibits a hypolipidemic effect, regulates obesity genes (especially by suppressing genes associated with adipogenesis), and has an antiglycation effect. There are many animal studies evaluating the effect of diet with yerba mate to treat obesity and its complications. There are also clinical trials that demonstrate the influence of yerba mate supplementation on patients with diabetes, obesity, and metabolic syndrome. The results of these selected studies (*in vitro*, animal studies, and clinical trials) are displayed in Table 1. *Ilex paraguariensis* (Aquifoliaceae) represents a potential source of natural biologically active substances. The active compounds that may be responsible for its health benefits are polyphenols (e.g., chlorogenic acid), xanthines (e.g., caffeine and theobromine), purine alkaloids (e.g., caffeic acid), flavonoids (quercetin, rutin), vitamins (such as vitamin A, B complex, C, and E), and tannins (Bracesco et al., 2011; Celi, 2013).

Ilex paraguariensis extracts are rich in polyphenols; the level of polyphenols in yerba mate extracts is greater than in green tea and similar to levels in red wine (Bastos et al., 2007; Bravo et al., 2007; Gugliucci and Bastos, 2009; Gugliucci et al., 2009). *Ilex paraguariensis* extracts are particularly rich in chlorogenic acid. It is a strong antioxidant and can inhibit the development of various diseases. In addition to the antioxidant, chlorogenic acid and its derivatives have a hepatoprotective (to protect the liver and facilitate regeneration) and hypoglycemic (lowering blood glucose level) action and inhibit virus development (Onakpoya et al., 2015). Rutin, which belongs to the flavonoid group, represents the polyphenols in yerba mate. It exhibits antioxidant properties and prevents some highly reactive free radicals as well as reduces the cytotoxicity of oxidized cholesterol (Kessler et al., 2003). Xanthines are one of the purine alkaloids found in many plants and beverages, for example, coffee, tea, and chocolate. Yerba mate contains alkaloids, which include theophylline, theobromine, and caffeine. One of the distinctive characteristics of *Ilex* sp. is its high antioxidant concentration, mainly caffeoyl derivatives and flavonoids, which play a very important role by inhibiting free radicals in the organism. The role of polyphenols extracted from yerba mate as efficient scavengers of free radicals is evaluated (*in vitro*) in several studies; however, there are not enough *in vivo* animal studies that evaluate the impact of yerba mate supplementation on oxidative stress. It is necessary to promote yerba mate as a valuable supplement for ruminants and transform knowledge into practical use (Deladino et al., 2013; Celi, 2013).

Application of yerba mate: fodder additives for ruminants

Animal husbandry practices currently use herbs as alternative feed additives. The use of alternative feedstuff in ruminant nutrition represents a novel management tool that is green, clean, ethical, and extremely easy to use (Martin and Kadokawa, 2006). This practice is evolving into a new benefit to improve overall ruminant health and immunity. Natural antioxidants should be common ingredients in ruminant diets. Given the high availability of yerba mate and its waste products in South America, it is a great opportunity to use it as an alternative ruminant feed supplement. Oxidative stress, considered

Table 1. Application of yerba mate (*Ilex paraguariensis* A. St.-Hil.).

Effect	References	Observation
		In vitro studies
Anti-obesity effect	Martins et al., 2010	Inhibition of *in vitro* pancreatic lipase activity Hypolipidemic effect on high-fat diet-induced obese mice Decreased liver lipid content
	Gosmann et al., 2012	Inhibition of triglyceride accumulation in adipocytes Modulatory anti-adipogenic Effect on the expression of genes connected with adipogenesis as leptin, TNF-α
Anti-diabetic effect	Bains and Gugliucci, 2017	Inhibition of enteral fructose AGEs (advanced glycation end product)
		In animal studies
Anti-obesity effect	Arcari et al., 2009	Modulatory expression effect on several genes related to obesity Decreased epididymal fat-pad weight in obese mice Restoration of biochemical parameters (cholesterol, triglycerides, LDL cholesterol, and glucose levels)
	Lima et al., 2014	Improvement of inflammatory markers in the hypothalamus and adipocytes of adult rats Reducing body weight, adiposity, and triglyceride levels in blood
Anti-inflammation effect	Lanzetti et al., 2008	Reduced acute lung inflammation in mice exposed to cigarette smoke
		Clinical studies
Anti-obesity effect	Boaventura et al., 2012	Significant decrease in total fat and saturated fatty acid intakes in dyslipidemic patients Increased plasma and blood antioxidant protection
	Kim et al., 2015	Decreases in body fat mass and percent body fat in obese patients (after 12 wk supplementation) compared with placebo group
	Morais et al., 2009	Improved lipid parameters in normolipidemic and dyslipidemic patients: reduced LDL-and increased HDL-cholesterol (after 40 d supplementation)

a serious problem, is associated with increased cow productivity and can lead to diseases and reproductive problems. Through their antioxidant and free radical scavenger properties, polyphenols can help to eliminate the negative effects of oxidative stress and improve metabolic status (Celi and Robinson, 2010). Review of the literature confirms many positive effects of yerba mate supplementation in ruminants. Celi and Robinson (2010) conducted a study on Holstein calves that were randomly divided into two groups. The control group was fed fresh milk and the other fresh milk supplemented with 50 g ground yerba mate. Calves were fed twice daily. They received the dietary treatments for 10 wk and were monitored weekly for liveweight. Blood samples were analyzed for oxidative status markers (advanced oxidation protein products [AOPP], 8-isoprostane [8-Iso] and TAC). A significant effect was observed for TAC (significant effect of sampling time × diet interaction). In the present study, calves with the yerba mate diet exhibited lower TAC levels (0.69 mmol L^{-1}) in the last week of the trial compared with the control group (0.84 mmol L^{-1}). Plasma concentrations of AOPP and 8-Iso were relatively constant during the trial. The TAC levels often depend on the regulation complex of endogenous antioxidant expression. Redox homeostasis is based on modulating various substances that form the antioxidant defense system. The TAC level trends require in-depth studies because no clear trend was identified in this study (no group has consistently high or low TAC levels). In another study, the effect of yerba mate was tested on dairy cows during mid-lactation (Experiment 1) and during the dry period (Experiment 2). In the first experiment, cows were fed a control diet and others were fed the control diet with 250 g cow^{-1} d^{-1} yerba mate. In the second experiment, pregnant Holstein-Friesian cows were divided into three dietary treatments: control diet, control diet with 250 g cow^{-1} d^{-1} yerba mate, and control diet with 500 g cow^{-1} d^{-1} yerba mate. During experiment 2, plasma was analyzed for AOPP, reactive oxygen metabolites (ROMs), and biological antioxidant potential (BAP). The oxidative stress index (OSI = (ROMs/BAP) ∗100) was also measured. The effect of the sampling time × diet interaction on plasma AOPP concentration was observed in experiment 1. Cows fed with a yerba mate diet had a significantly higher AOPP level than the controls at 3 wk. Plasma concentrations of ROMs, BAP, and AOPP in experiment 2 were not affected by diet with yerba mate; however, the effect of time was significant. A significant effect

of the sampling time × diet interaction on OSI was noted. Cows with 500 g yerba mate supplementation had lower OSI levels than the control cows (Celi, 2013). The influence of yerba mate supplementation on small ruminants was detected in the study conducted by Po et al. (2012a). The addition of 2.5% yerba mate caused a significant effect on the sampling time × diet interaction of plasma AOPP concentrations. Lambs with yerba mate supplementation have higher AOPP levels than control lambs at 4 and 5 wk. the AOPP concentration was similar in existing research (Celi and Robinson, 2010; Celi, 2010; Po et al., 2012a; Celi, 2013). The higher AOPP levels, which are classified as protein oxidation markers, indicate inflammation and oxidative stress. This is due to the high level of feed intake, which is negatively associated with rumen buffering capacity and can cause subacute ruminal acidosis. In these studies, yerba mate supplementation has no impact on TAC. The fact that TAC did not change after yerba mate intake is associated with the strong buffering capacity of the redox system in ruminants as well as endogenous antioxidant expression. Exogenous antioxidants also have potential pro-oxidant scavenging ability.

Another benefit associated with yerba mate supplementation is improved welfare despite the effect of lower oxidative stress. Calves fed with yerba mate have reduced liveweight (Celi and Robinson, 2010; Celi, 2013), significantly higher plasma triglyceride concentration than controls, and significantly lower plasma concentration of total protein and albumin (Celi and Robinson, 2010). It was observed that yerba mate supplemented cows had higher milk yield than the control group (Celi, 2013). In a study involving lambs, it was demonstrated that yerba mate supplemented lambs ate more than the control and were characterized by 25% higher wool growth rate than the control (Po et al., 2012a). In another study, the inclusion of 2.5% yerba mate in the lamb diet changed milk composition, especially increasing milk fat, protein, and total solid contents as well as lower lactose content (Po et al., 2012b).

The literature review reveals a few studies about how yerba mate added to meat or as a fodder additive can improve meat quality. Most research using yerba mate extract was designed for broilers. Broilers drinking an aqueous yerba mate extract improved the oxidative stability of the precooked breast meat. This same effect was noticed when dried yerba mate leaves or aqueous yerba mate leaf extract were added to chicken meatballs (Racanicci et al., 2011). In another study, cattle supplemented with yerba mate extract at 0.5%, 1.0%, and 1.5% exhibited increased levels of inosine monophosphate, creatine, and carnosine in fresh meat. The authors of the study confirmed an increase in conjugated linoleic acid content, which was proportional to the yerba mate extract in the feed. Yerba mate supplementation in the cattle diet improved oxidative stability and the sensory quality of beef, which was especially concerned with more tenderness as well as higher consumer acceptability (de Zawadzki et al., 2017).

CONCLUSIONS

Using herbs to supplement animal feed is currently required. The literature review shows the antioxidant properties of yerba mate, which has a high concentration of polyphenols and caffeolyl derivates. Yerba mate (as well as its waste products) is available and produced on a large scale in South America and can produce higher farm profits. The literature review presents a beneficial effect of supplementation. Ruminants fed with yerba mate supplementation have improved their oxidative status. The studies about the AOPP stress biomarkers were significantly higher in yerba mate supplemented ruminants (dairy calves and lambs) than the controls. This is due to increased feed intake, which can cause a state of inflammation or oxidative stress. The concentration of AOPP is also higher in dairy cows fed with maize silage. The other stress biomarker, total antioxidant capacity (TAC) was not influenced by a diet with yerba mate in some studies (Po et al., 2010a; Celi and Robinson, 2010). The unchanged concentration of TAC is because ruminants have a strong buffering capacity of the redox system as well as endogenous antioxidant expression. Redox homeostasis is changed by various substances, which form the antioxidant defense system. One of the satisfactory stress biomarkers is oxidative stress index (OSI). The supplemented dairy cows showed significantly lower levels than the control cows (Celi, 2013). It is necessary to use OSI more as a stress biomarker than a ritual veterinary practice.

This review paper also addresses improved cow welfare and quality of meat after yerba mate supplementation. It was noted, for example, that milk yield improved and liveweight decreased. Yerba mate can be a good natural antioxidant in meat, which can protect against lipid oxidation as well as improve the fatty acid profile and meat tenderness. There is a lack of animal studies with yerba mate supplementation. The results presented in this review need in-depth studies to better understand the mechanism of antioxidants on oxidative stress in ruminants.

REFERENCES

Arcari, D.P., Bartchewsky, W., Dos Santos, T.W., Oliveira, K.A., Funck, A., Pedrazzoli, J., et al. 2009. Antiobesity effects of yerba mate extract (*Ilex paraguariensis*) in high-fat diet-induced obese mice. Obesity 17:2127-2133.

Bains, Y., and Gugliucci, A. 2017. *Ilex paraguariensis* and its main component chlorogenic acid inhibit fructose formation of advanced glycation endproducts with amino acids at conditions compatible with those in the digestive system. Fitoterapia 117:6-10.

Bastos, D.H., de Oliveira, D.M., Matsumoto, R.L.T., de Oliveira-Carvalho, P., and Ribeiro, M.L. 2007. Yerba mate: pharmacological properties, research and biotechnology. Medicinal and Aromatic Plant Science and Biotechnology 1:37-46.

Boaventura, B.C.B., Di Pietro, P.F., Stefanuto, A., Klein, G.A., de Morais, E.C., de Andrade, F., et al. 2012. Association of mate tea (*Ilex paraguariensis*) intake and dietary intervention and effects on oxidative stress biomarkers of dyslipidemic subjects. Nutrition 28:657-664.

Bracesco, N., Sanchez, A.G., Contreras, V., Menini, T., and Gugliucci, A. 2011. Recent advances on *Ilex paraguariensis* research: Minireview. Journal of Ethnopharmacology 136:378-384.

Bravo, L., Goya, L., and Lecumberri, E. 2007. LC/MS characterization of phenolic constituents of mate (*Ilex paraguariensis*, St. Hil.) and its antioxidant activity compared to commonly consumed beverages. Food Research International 40:393-405.

Cansian, R.L., Mossi, A.J., Mosele, S.H., Toniazzo, G., Treichel, H., Paroul, N., et al. 2008a. Genetic conservation and medicinal properties of mate (*Ilex paraguariensis* St. Hil.) Pharmacognosy Reviews 2:326-338.

Carlsen, M.H., Halvorsen, B.L., Holte, K., Bohn, S.K., Dragland, S., Sampson, L., et al. 2010. The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. Nutrition Journal 9:1-11.

Celi, P. 2010. The role of oxidative stress in small ruminants' health and production. Revista Brasileira de Zootecnia 39:348-363.

Celi, P. 2011. Oxidative stress in ruminants. p. 191-231. In Mandelker, L., and Vajdovich, P. (eds.) Studies on veterinary medicine. 5th ed. Humana Press, New York, USA.

Celi, P. 2013. Yerba Mate (*Ilex paraguariensis*) as strategic supplement for dairy. p. 11-18. In Makkar, H.P.S. (ed.) Enhancing animal welfare and former income through strategic animal feeding. Some case studies. FAO Animal Production and Health Paper Nr 175, Rome, Italy.

Celi, P., and Gabai, G. 2015. Oxidant/antioxidant balance in animal nutrition and health: the role of protein oxidation. Frontiers in Veterinary Science 2:48.

Celi, P., and Robinson, A. 2010. Effects of Yerba Mate (*Ilex paraguariensis*) supplementation on the performance of dairy calves. Animal Production Science 50:376-381.

Cogoi, L., Giacomino, M.S., Pellegrino, N., Anesini, C., and Filip, R. 2013. Nutritional and phytochemical study of *Ilex paraguariensis* fruits. Internet Journal of Chemistry 2013:750623. https://www.hindawi.com/journals/jchem/2013/750623/.

de Zawadzki, A., Arrivetti, L.O.R., Vidal, M.P., Catai, J.R., Nassu, R.T., Tullio, R.R., et al. 2017. Mate extract as feed additive for improvement of beef quality. Food Research International 99:336-347. http://dx.doi.org/10.1016/j.foodres.2017.05.033.

Deladino, L., Teixeira, A., Reta, M., García, A.D., Navarro, A.S., and Martino, M.N. 2013. Major phenolics in yerba mate extracts (*Ilex paraguariensis*) and their contribution to the total antioxidant capacity. Food and Nutrition Science 4:154-162.

Ezzat-Alnakip, M., Quintela-Baluja, M., Böhme, K., Fernández-No, I., Caamaño, S., Calo-Mata, P., et al. 2014. The immunology of mammary gland of dairy ruminants between healthy and inflammatory conditions. Journal of Veterinary Medicine 2014:659801.

Gosmann, G., Barlette, A.G., Dhamer, T., Arcari, D.P., Santos, J.C., de Camargo, E.R., et al. 2012. Phenolic compounds from mate (*Ilex paraguariensis*) inhibit adipogenesis in 3T3-L1 preadipocytes. Plant Foods for Human Nutrition 67:156-161.

Gugliucci, A., and Bastos, D.H. 2009. Chlorogenic acid protects paraoxonase 1 activity in high density lipoprotein from inactivation caused by physiological concentrations of hypochlorite. Fitoterapia 80:138-142.

Gugliucci, A., Bastos, D.H., Schulze, and J., Souza, M.F. 2009. Caffeic and chlorogenic acids in *Ilex paraguariensis* extracts are the main inhibitors of AGE generation by methylglyoxal in model proteins. Fitoterapia 80:339-344.

Józwik, A., Krzyzewski, J., Strzalkowska, N., Polawska, E., Bagnicka, E., Wierzbicka, A., et al. 2012. Relations between the oxidative status, mastitis, milk quality and disorders of reproductive functions in dairy cows – a review. Animal Science Papers and Reports 30:297-307.

Kessler, M., Ubeaud, G., and Jung, L. 2003. Anti- and pro-oxidant activity of rutin and quercetin derivatives. Journal of Pharmacy and Pharmacology 55:131-142.

Kim, S.Y., Oh, M.R., Kim, M.G., Chae, H.J., and Chae, S.W. 2015. Anti-obesity effects of yerba mate (*Ilex paraguariensis*): a randomized, double-blind, placebo-controlled clinical trial. BMC Complementary and Alternative Medicine 15:338.

Konvicná, J., Vargová, M., Paulíková, I., Kovác, G., and Kostecká, Z. 2015. Oxidative stress and antioxidant status in dairy cows during prepartal and postpartal periods. Acta Veterinaria Brno 84:133-140.

Kowalczuk, E., Klebaniuk, R., and Lechtanska, M. 2008. Dodatki ziolowe w zywieniu bydla. Hodowla Bydla 9:28-34.

Lanzetti, M., Bezerra, F.S., Romana-Souza, B., Brando-Lima, A.C., Koatz, V.L.G., Porto, L.C., et al. 2008. Mate tea reduced acute lung inflammation in mice exposed to cigarette smoke. Nutrition 24:375-381.

Lima, N., de Oliveira, E., da Silva, A.P.S., Maia, L., de Moura, E.G., and Lisboa, P.C. 2014. Effects of *Ilex paraguariensis* (yerba mate) treatment on leptin resistance and inflammatory parameters in obese rats primed by early weaning. Life Sciences 115:29-35.

Lykkesfeldt, J., and Svendsen, O. 2007. Oxidants and antioxidants in disease: oxidative stress in farm animals. Veterinary Journal 173:502-511.

Mandelker, L. 2011. Oxidative stress, free radicals, and cellular damage. p. 1-17. In Mandelker, L., and Vajdovich, P. (eds.) Studies on veterinary medicine. 5th ed. Humana Press, New York, USA.

Martin, G.B., and Kadokawa, H. 2006. "Clean, green and ethical" animal production. Case study: reproductive efficiency in small ruminants. Journal of Reproduction and Development 52:145-152.

Martins, F., Noso, T.M., Porto, V.B., Curiel, A., Gambero, A., Deborah, H.M., et al. 2010. Maté tea inhibits *in vitro* pancreatic lipase activity and has hypolipidemic effect on high-fat diet-induced obese mice. Obesity 18:42-47.

Morais, E.C., Stefanuto, A., Klein, G.A., Boaventura, B.C., De Andrade, F., Wazlawik, E., et al. 2009. Consumption of yerba mate (*Ilex paraguariensis*) improves serum lipid parameters in healthy dyslipidemic subjects and provides an additional LDL-cholesterol reduction in individuals on statin therapy. Journal of Agricultural and Food Chemistry 57:8316-8324.

Nisar, A.N., Sultana, M., and Ashraf, H. 2013. Oxidative stress - threat to animal health and production. International Journal of Livestock Research 3:76-83.

Onakpoya, I.J., Spencer, E.A., Thompson, M.J., and Heneghan, C.J. 2015. The effect of chlorogenic acid on blood pressure: a systematic review and meta-analysis of randomized clinical trials. Journal of Human Hypertension 29:77-81.

Pasquali, T.R., Macedo, S.M.D., Roman, S.S., Dal Prá, V., Cansian, R.L., Mossi, A.J., et al. 2011. Acute toxicity and anti-inflammatory effects of supercritical extracts of *Ilex paraguariensis*. African Journal of Pharmacy and Pharmacology 5:1162-1169.

Po, E., Horsburgh, K., Raadsma, H.W., and Celi, P. 2012a. Yerba mate (*Ilex paraguarensis*) as a novel feed supplement for growing lambs. Small Ruminant Research 106:131-136.

Po, E., Xu, Z., and Celi, P. 2012b. The effect of yerba mate (*Ilex paraguarensis*) supplementation on the productive performance of Dorper ewes and their progeny. Asian-Australasian Journal of Animal Sciences 25:945-949.

Racanicci, A.M.C., Menten, J.F.M., Alencar, S.M., Buissa, R.S., and Skibsted, L.H. 2011. Mate (*Ilex paraguariensis*) as dietary additive for broilers: performance and oxidative stability of meat. European Food Research and Technology 232:655-661.

Rózanski, H., and Drymel, W. 2009. Naturalne alternatywy dla antybiotykowych stymulatorów wzrostu i kokcydiostatyków. Polskie Drobiarstwo 11:54-57.

Sharma, N., Singh, N.K., Singh, O.P., Pandey, V., and Verma, P.K. 2011. Oxidative stress and antioxidant status during transition period in dairy cows. Asian-Australasian Journal of Animal Sciences 24:479-484.

Windisch, W., Schedle, K., Plitzner, C., and Kroismayr, A. 2008. Use of phytogenic products as feed additives for swine and poultry. Journal of Food Science 86:140-148.