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PRELIMINARY *IN VITRO* ASSESSMENT OF EFFECTS OF LEAF EXTRACTS OF VARIOUS *SANSEVIERIA* THUNB. SPECIES ON THE LIPID PEROXIDATION LEVEL IN THE EQUINE PLASMA

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The aim of this study was to evaluate the *in vitro* effect of buffer extracts obtained from the leaves of various *Sansevieria* species against lipid peroxidation in the equine plasma. The succulent leaves of living plants of *Sansevieria francisii* Chahin, *S. caulescens* N.E.Br., *S. suffruticosa* N.E.Br., *S. roxburghiana* Schult. & Schult.f., *S. metallica* Gérôme & Labroy, *S. gracilis* N.E.Br., *S. hyacinthoides* (L.) Druce, *S. cylindrica* Bojer ex Hook., *S. canaliculata* Carrière, *S. aethiopica* Thunb., *S. kirkii* Baker, *S. trifasciata* Prain, *S. forskaliana* (Schult. & Schult.f.) Hepper & J.R.I. Wood, *S. fischeri* (Baker) Marais, *S. dooneri* N.E.Br., *S. intermedia* N.E.Br., *S. parva* N.E.Br. were sampled for the study. Freshly collected leaves were washed, weighed, crushed, and homogenized in 0.1 M phosphate buffer (pH 7.4) (in proportion 1 : 19, w/w) at room temperature. The extracts were then filtered and investigated for their pro-oxidant and antioxidant activity. A volume of 0.1 mL of the various extracts was incubated with 1.9 mL of equine plasma at 37 °C for 60 min with continuous stirring. The results of the study showed that the TBARS level as a biomarker of lipid peroxidation was significantly increased after incubation with extracts of selected species belonging to the *Sansevieria* genus and these results were statistically significant. The most potent effect was demonstrated by the *S. intermedia*, *S. forskaliana*, *S. trifasciata*, *S. parva*, and *S. caulescens* leaf extracts compared to phosphate buffer as control sample (increased by 65.6, 53.2, 51.6, 50, and 48%, respectively). *S. kirkii*, *S. aethiopica*, and *S. suffruticosa* caused the less increase of the TBARS level after 1-h incubation with equine plasma (by 18.8, 27.6, and 30.8%, respectively, $p < 0.05$). To conclude, *Sansevieria* species possess a promising antioxidant and pro-oxidant potential. Further studies involving phytochemical identification of the main compounds in plants are necessary to affirm and maximize the possible use of the plants as a therapeutic remedy for the prevention of oxidative stress. The dose-depended antioxidative and pro-oxidative effects of various *Sansevieria* species in both plasma and erythrocyte suspension will be further studied in detail.

Keywords: *Sansevieria* Thunb., extracts, 2-thiobarbituric acid reactive substances (TBARS), oxidative stress, equine plasma

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Introduction

Many studies clearly demonstrate that various plants of the *Sansevieria* genus are effective agents in the treatment and prevention of many diseases and disorders. This justifies the use of the plant extract for the treatment of diarrhea. The use of these plants in folk medicinal remedies for treating various health problems has been reported. Most cases confirm the therapeutic value of the plants. These plants have been tested in the treatment of hemorrhoids, pain, smallpox, chicken-pox, and measles, venereal diseases, malnutrition, paralysis, epilepsy, convulsions, and spasm, pulmonary troubles, and a vermifuge, as well as a remedy for parasitic infections. In studies carried out in Nakuru and Maragua districts of Kenya by Khalumba et al. (2005), they identified five use categories of *Sansevieria* plants, namely medicine (33% of the reports), fibers (24%), soil conservation (22%), fodder (18%), and other uses (14%) for four species, *Sansevieria ehrenbergii* Schweinf. ex Baker, *S. parva* N.E.Br., *S. raffillii* N.E. Br., and *S. suffruticosa* N.E. Br. Chhabra et al. (1987) mentioned the use of *S. bagamoyensis* N.E.Br. for the treatment of convulsive fever in Tanzania. Watt and Breyer-Brandwijk (1962) listed the use of *S. hyacinthoides* (L.) Druce in the treatment of a toothache and earache and the use of the rhizome decoction of *S. kirkii* as a purgative both reported from East Africa. Yet, Kiringe (2006) reported on the use of *S. volkensii* Gürke for the treatment of sexually transmitted diseases such as gonorrhea. In Kenya, Owuor and Kisangau (2006) included the use of *S. parva* leaf sap for the treatment of snakebite wounds and *S. kirkii* Baker extracts for treatment of snakebite wounds. The ethanol and water extracts of *S. trifasciata* Prain leaves showed a dose-dependent and significant increase in pain threshold and possess mild analgesic properties (Anbu et al., 2009). It was suggested that *S. trifasciata* can be good medicinal plant especially as antibacterial agent due to the high toxicity level (Berame et al., 2017).

For instance, the results obtained in a study of Adeyemi et al. (2009) suggest that the aqueous root extract of *S. liberica* Gérôme & Labroy possesses antidiarrhoeal property due to inhibition of gastrointestinal propulsion and fluid secretion, possibly mediated through inhibition of the nitric oxide pathway. Moreover, Akindele et al. (2015) have evaluated the anticancer activity of root extracts of *S. liberica* using a combination of *in vitro* and *in vivo* models. The aqueous root extract of *S. liberica* is used in African folklore medicine for ailments including chronic pain, inflammatory conditions, and convulsive disorders (Amida et al., 2007). The root part of *S. liberica* is used in ethnomedicine in the treatment of fever, headache and cold, as well as analgesic, antibiotic and anti-inflammatory (Watt and Breyer-Brandwijk, 1962). Preparations of the *S. liberica* are commonly used across Nigeria for the treatment of inflammatory conditions (Akindele et al., 2015). Nevertheless, in spite of these data, Takawira-Nyenya et al. (2014) reported that the documentation of ethnobotanical uses of genus *Sansevieria* is incomplete. Results of Amida et al. (2007) indicated that the aqueous root extract of *S. liberica* shows that it is relatively safe when given orally, and there is a pointer toward possible usefulness to boost red blood cells and increase sperm quality, but findings indicate potential to affect hepatic cells at high doses, when administered chronically (Amida et al., 2007). The treatment with the plant extracts of the rhizomes of *S. liberica* protects the liver against carbon tetrachloride-induced hepatotoxicity in Wistar albino rats (Ikewuchi et al., 2011). This hepatoprotective activity may have been produced via inhibiting lipid peroxidation by

exerting a membrane-stabilizing action or inhibiting cytochrome P_{450} aromatase (Ikewuchi et al., 2011).

Recently, tropical and subtropical plants containing antioxidants have become an area of scientific research because they have greater health benefits with various pharmacological activities. The antioxidant and anti-proliferative activities of the methanol extract *S. roxburghiana* Schult. & Schult. f. and its fractions have been explored by Maheshwari et al. (2017). The results of these researchers observed that the ethyl acetate fraction of *S. roxburghiana* exhibited effective antioxidant and anti-proliferative activities. It was suggested that the phenolic compounds identified in the ethyl acetate fraction could be responsible for the activities (Maheshwari et al., 2017).

In our previous study (Buyun et al., 2016; Tkachenko et al., 2017), we have evaluated the antibacterial capacity of ten species of *Sansevieria* genus in order to validate scientifically the inhibitory activity for microbial growth attributed by their popular use and to propose new sources of antimicrobial agents. Also antimicrobial activities of extracts obtained from leaves of various species of *Sansevieria* genus were investigated (Buyun et al., 2016–2018; Tkachenko et al., 2016, 2017). Moreover, our previous study (Tkachenko et al., 2018) have demonstrated their protective effects against lipid peroxidation. Specifically, the results indicated that extracts of *S. francisii*, and *S. forskaliana* led to a decrease of TBARS concentration, a biomarker of lipid peroxidation, in erythrocytes (by 16.9% and 8.4%, p >0.05, respectively). When erythrocytes were incubated with *S. aethiopica*, *S. caulescens*, *S. roxburghiana*, *S. gracilis*, the TBARS level was similar to that of the untreated erythrocytes. In the meantime, the treatment of *S. canaliculata*, *S. suffruticosa*, *S. metallica*, *S. fischeri*, *S. dooneri*, *S. trifasciata*, *S. parva*, *S. intermedia*, and *S. kirkii* non-significantly increase the formation of intracellular TBARS in the extract-treated erythrocytes by approximately 7–20%, respectively. However, *S. hyacinthoides* and *S. cylindrica* had a significant increase of TBARS level in the extract-treated erythrocytes (by 29.7% and 21%, p <0.05, respectively). Despite the medicinal relevance of plants, our studies have suggested that these plants are potentially pro-oxidant in dose studied (5 mg per mL) (Tkachenko et al., 2018).

Therefore, the aim of this study was to evaluate the *in vitro* effect of buffer extracts obtained from the leaves of various species belonging to the *Sansevieria* genus against lipid peroxidation in equine plasma.

Material and methodology

Collection of Plant Material

The leaves of *Sansevieria* plants, cultivated under glasshouse conditions, were sampled at M.M. Gryshko National Botanic Garden (NBG), National Academy of Science of Ukraine. Specifically, the leaves of *Sansevieria francisii* Chahin, *S. caulescens* N.E.Br., *S. suffruticosa* N.E.Br., *S. roxburghiana* Schult. & Schult.f., *S. metallica* Gérôme & Labroy, *S. gracilis* N.E.Br., *S. hyacinthoides* (L.) Druce, *S. cylindrica* Bojer ex Hook., *S. canaliculata* Carrière, *S. aethiopica* Thunb., *S. kirkii* Baker, *S. trifasciata* Prain, *S. forskaliana* (Schult. & Schult.f.) Hepper & J.R.I. Wood, *S. fischeri* (Baker) Marais, *S. dooneri* N.E.Br., *S. intermedia* N.E.Br., *S. parva* N.E.Br. were

sampled for the study. Various databases available for searching collections of living plants, e.g. World Checklist of Selected Plant Families (WCSP, 2018), International Plant Names Index, The Plant List, have been used for the taxonomic identity of plants screened.

Preparation of Plant Extracts

Freshly collected leaves were washed, weighed, crushed, and homogenized in 0.1 M phosphate buffer (pH 7.4) (in proportion 1 : 19, w/w) at room temperature. The extracts were then filtered and investigated for their antioxidant activity. The extract was stored at -20 °C until use.

Horses

Eighteen healthy adult horses from the central Pomeranian region in Poland (village Strzelinko, N 54º 30' 48.0" E 16º 57' 44.9"), aged 8.9±1.3 years old, including 6 Hucul pony, 5 Thoroughbred horses, 2 Anglo-Arabian horses and 5 horses of unknown breed, were used in this study. All horses participated in recreational horseback riding. Horses were housed in individual boxes, with feeding (hay and oat) provided twice a day, at 08.00 and 18.00 h, and water available *ad libitum*. All horses were thoroughly examined clinically and screened for hematological, biochemical and vital parameters, which were within reference ranges. The females were non-pregnant.

Collection of blood samples

Blood samples were taken simultaneously in all horses from the jugular vein in the morning, 90 minutes after feeding, while the horses were in the stables (between 8:30 and 10 AM). Whole blood was stored in sterile tubes with sodium citrate as the anticoagulant and held on the ice until centrifugation at 3,000 rpm for 5 min at 4 °C using a refrigerated centrifuge to remove plasma. The separated erythrocytes were washed three times in 4 mM phosphate buffer saline (PBS), pH 7.4. After centrifugation, the supernatant and the buffy coat were carefully removed with each wash. Washed erythrocytes were finally re-suspended to the desired hematocrit level in 4 mM PBS. The erythrocytes and plasma were stored at 4 °C. A volume of 0.1 mL of the various extracts was added to 1.9 mL of equine plasma. For positive control, PBS was used. After incubation of the mixture at 37 °C for 60 min with continuous stirring, it was centrifuged at 3,000 rpm for 5 min. Plasma aliquots were used in the study.

Quantitative estimation of lipid peroxidation by determination of 2-thiobarbituric acid reactive substances (TBARS)

The most important product of lipid peroxidation reacting with 2-thiobarbituric acid (TBA) is malonic dialdehyde (MDA) (Lykkesfeldt, 2007). Therefore, the lipid peroxidation was determined by quantifying the concentration of TBARS by Kamyshnikov (2004) for determining the malonic dialdehyde (MDA) concentration. Briefly, 0.1 mL of plasma was added to 1 mL of 20% of trichloroacetic acid (TCA) and 1 mL of 0.8% of 2-thiobarbituric acid (TBA). The mixture was heated in a boiling water bath for 10 min. After cooling, the mixture was centrifuged at 3,000 g for 10 min. The absorbance of the supernatant was measured at

540 nm. The concentration of MDA (μmol per L) was calculated using 1.56 10^5 mM/cm as the extinction coefficient.

Statistical analysis

The mean ± S.E.M. values were calculated for each group to determine the significance of the intergroup difference. All variables were tested for normal distribution using the Kolmogorov-Smirnov and Lilliefors test (p >0.05). In order to find significant differences (significance level, p <0.05) between groups, the Kruskal-Wallis test by ranks was applied to the data (Zar, 1999). All statistical analyses were performed using Statistica 8.0 software (StatSoft, Krakow, Poland).

Results and discussion

Figure 1 illustrates the level of 2-thiobarbituric acid reactive substances (TBARS) in equine plasma induced by the treatment of leaf extracts of various species belonging to the *Sansevieria* genus as compared with treatment by phosphate buffer as a control samples.

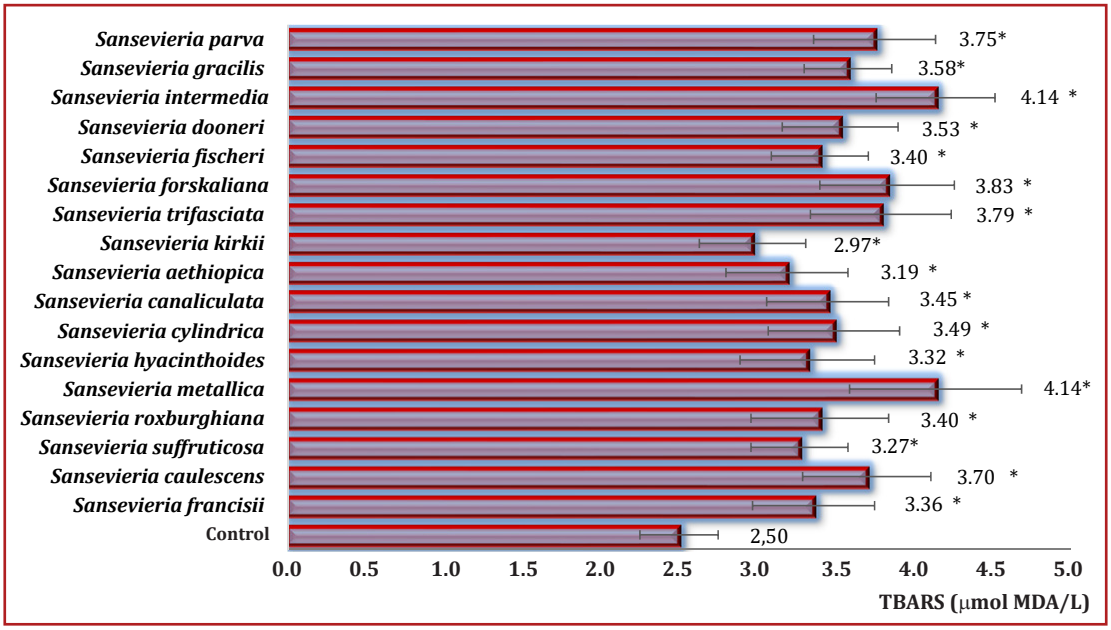

Figure 1 The level of 2-thiobarbituric acid reactive substances (TBARS) in equine plasma induced by the treatment of leaf extracts derived from various species of the *Sansevieria* genus as compared with treatment by phosphate buffer (control). The data were analyzed using one-way analysis on ranks (ANOVA) using the Kruskal-Wallis test by ranks
* *P*-value <0.05 was considered as significant (n = 18)

As presented in Figure 1, when equine plasma was incubated with extracts of various *Sansevieria* species, the TBARS level was significantly increased and these results were statistically significant. At 1 h of incubation, the TBARS concentration of untreated plasma was 2.50 ±0.25 μmol/L. Extracts of various *Sansevieria* species led to an increase of TBARS

concentration in plasma: *S. francisii* (by 34.4%, $p = 0.007$), *S. caulescens* (by 48%, $p = 0.000$), *S. suffruticosa* (by 30.8%, $p = 0.009$), *S. roxburghiana* (by 36%, $p = 0.007$), *S. metallica* (by 65.6%, $p = 0.000$), *S. hyacinthoides* (by 32.8%, $p = 0.014$), *S. cylindrica* (by 39.6%, $p = 0.003$), *S. canaliculata* (by 38.0%, $p = 0.003$), *S. aethiopica* (by 27.6%, $p = 0.032$), *S. kirkii* (by 18.8%, $p = 0.050$), *S. trifasciata* (by 51.6%, $p = 0.000$), *S. forskaliana* (by 53.2%, $p = 0.000$), *S. fischeri* (by 36.0%, $p = 0.003$), *S. dooneri* (by 41.2%, $p = 0.001$), *S. intermedia* (by 65.6%, $p = 0.000$), *S. gracilis* (by 43.2%, $p = 0.000$), and *S. parva* (by 50.0%, $p = 0.000$). These changes were statistically significant ($p > 0.05$) (Figure 1). The most potent effect was demonstrated by the *S. intermedia*, *S. forskaliana*, *S. trifasciata*, *S. parva*, and *S. caulescens* compared to phosphate buffer as a control sample (increased by 65.6, 53.2, 51.6, 50.0, and 48.0%, respectively). *S. kirkii*, *S. aethiopica*, and *S. suffruticosa* caused the less increase of the TBARS level after 1-h incubation with equine plasma (by 18.8, 27.6, and 30.8%, respectively, $p < 0.05$) (Figure 1).

Therefore, the results indicated that the treatment of equine plasma with extracts of various *Sansevieria* species significantly enhance the formation of intracellular TBARS in the extract-treated plasma samples by approximately 18–66%, respectively (Figure 1).

The chemical compounds responsible for the toxic effects of plants are probably produced as part of the plant's defense mechanism against pest and herbivores or to gain an advantage over competing for plants (Ighodaro et al., 2017). According to the results obtained, we addressed the hypothesis that by-products in the extracts of various *Sansevieria* species can be responsible for their pro-oxidant activity. In previous phytochemical screening of the *Sansevieria* plants different groups of chemical were observed to be isolated: carbohydrates, saponins, glycosides, flavonoids, steroids in the leaves (Mimaki et al., 1996, 1997). The screening of the plant material revealed the presence of the alkaloids, tannins, and antrhaquinones in the leaves and roots of *S. trifasciata* (Berame et al., 2017). Additionally, phytochemical analysis of extracts of *S. cylindrica* leaves showed the presence of steroids, flavonoids, saponins, tannins, and phenolic acids (Ahamad et al., 2017). The interest in the possible health benefits of flavonoids has increased owing to their potent antioxidant and free radical scavenging activities observed *in vitro*. Nevertheless, the antioxidant efficacy of flavonoids *in vivo* is less documented and their pro-oxidant properties have been actually described *in vivo* (Procházková et al., 2011). It was reported that compounds with antioxidant activity can act as pro-oxidants under certain conditions or in high concentrations. Studies evidently indicate that natural antioxidants, including polyphenols, flavonoids, anthocyanins, and carotenoids, can act as pro-oxidants, which produce reactive oxygen species and cause oxidative stress (Eghbaliferiz and Iranshahi, 2016). Due to their pro-oxidant properties, they are able to cause oxidative damage by reacting with various biomolecules, such as lipids, proteins, and DNA (Procházková et al., 2011). The pro-oxidant activity is typically catalyzed by metals, particularly transition metals such as Fe and Cu, present in biological systems (Eghbaliferiz and Iranshahi, 2016).

A series of 40 flavonoids were investigated by Baldin et al. (2017) with the purpose of correlating these properties via structure and activity analyses based on integrated networks and QSAR models. The classical groups for the antioxidant activity of flavonoids were combined in order to explain the influence of antioxidant and pro-oxidant activities on the

anti-parasitic properties. Flavonoids have demonstrated *in vivo* and *in vitro* leishmanicidal, trypanocidal, antioxidant, and pro-oxidant properties. The chemotherapy of trypanosomiasis and leishmaniasis lacks efficacy, presents high toxicity, and is related to the development of drug resistance. The dual activity of flavonoids presenting both anti- and pro-oxidant activities revealed that the existence of a balance between these two features could be important to the development of adequate therapeutic strategies (Baldin et al., 2017).

These results are also comparable to those found by Cherrak et al. (2016) who have revealed that flavonoids possess both pro-oxidant and antioxidant activity depending on the nature and concentration of the flavonoids and metal ions. Natural flavonoids such as quercetin, (+) catechin and rutin as well as four methoxylated derivatives of quercetin used as models were investigated to elucidate their impact on the oxidant and antioxidant status of human red blood cells (RBCs). The impact of these compounds against metal toxicity was studied as well as their antiradical activities with DPPH assay. Antihemolytic experiments were conducted on quercetin, (+) catechin and rutin with an excess of Fe, Cu, and Zn (400 μM), and the oxidant (malonic dialdehyde, carbonyl proteins) and antioxidant (reduced glutathione, catalase activity) markers were evaluated. The results showed that Fe and Zn have the highest pro-oxidant effect (37 and 33% of hemolysis, respectively). Quercetin, rutin and (+) catechin exhibited strong antioxidant properties toward Fe, but this effect was decreased with respect to Zn ions. However, the Cu showed a weak antioxidant effect at the highest flavonoid concentration (200 μM), while a pro-oxidant effect was observed at the lowest flavonoid concentration (100 μM) (Cherrak et al., 2016).

A wide range of polyphenols possesses anticancer and apoptosis-inducing properties (Khan et al., 2012). Notably, an important aspect of the chemopreventive action of polyphenols is their differential activity in selectively targeting cancer cells while sparing normal cells. Although polyphenols are generally recognized as antioxidants, they also act as pro-oxidants inducing DNA degradation in the presence of metal ions such as copper. Since it is known that tissue and cellular copper levels are significantly elevated in a number of malignancies, cancer cells would be more subject to redox cycling between copper ions and polyphenols to generate reactive oxygen species (ROS) responsible for DNA breakage (Khan et al., 2012).

Our present findings are in agreement with results obtained in our previous study including the assessment of antioxidant activity of extracts obtained from leaves of selected *Sansevieria* species (Tkachenko et al., 2017, 2018; Pażontka-Lipiński et al., 2018). When erythrocytes were incubated with leaf extracts of various species from the *Sansevieria* genus, the aldehydic derivatives level was significantly reduced by 13.6% (p <0.05) for *S. forskaliana* extract. Moreover, all extracts (except *S. francisii* extract) reduced the formation of intracellular aldehydic derivatives of oxidatively modified proteins (OMP) in the extracts-treated erythrocytes, but these results were non-significant. Treatment by extracts of various *Sansevieria* species reduced the concentration of ketonic derivatives of OMP when compared to untreated erythrocytes. The most potent effect was demonstrated by the *S. canaliculata*, *S. forskaliana*, *S. aethiopica*, *S. cylindrica*, *S. metallica*, *S. hyacinthoides*, and *S. kirkii* compared to control samples (phosphate buffer) (16.1, 14.7, 13.4, 12.9, 12.9, 12.7, and 12.1%, respectively). However, there were no significant changes in other extracts. The experimental evidence

obtained in our previous study indicated that various species of *Sansevieria* genus are a rich source of compounds that manifest antioxidant activity and can effectively protect erythrocytes against oxidative-induced damage. Thus, *S. canaliculata*, *S. forskaliana*, *S. aethiopica*, *S. cylindrica*, *S. metallica*, *S. hyacinthoides*, and *S. kirkii* may be considered as a valuable source of natural antioxidants that may potentially be recommended for applications in medicine and veterinary practice. According to the above-mentioned antioxidant mechanisms, extracts of various *Sansevieria* species may inhibit the formation of protein carbonyl by scavenging free radicals formed *in vitro*. According to many supporting documents, it can be assumed that secondary plant metabolites, i.e. polyphenolic compounds in extracts of various species from *Sansevieria* genus extract may contribute to the antioxidant activity. Therefore, these findings may be potentially contributive to the validation of the medicinal use of various *Sansevieria* species for the prevention of oxidative stress (Tkachenko et al., 2017). Moreover, the results of our previous study (Tkachenko et al., 2018) also showed that the leaves of *S. francisii* and *S. forskaliana* led to a non-significantly decrease of 2-thiobarbituric acid reactive substances (TBARS) concentration in erythrocytes. However, *S. hyacinthoides* and *S. cylindrica* had a significant increase of TBARS level in the extract-treated erythrocytes (by 29.7 and 21%, p <0.05, respectively). The outcome of this study suggests that *Sansevieria* species has a promising antioxidant and prooxidant potential (Tkachenko et al., 2018).

Similar findings were discovered in our other several works, which have been conducted to evaluated the lipid peroxidation biomarkers and total antioxidant capacity in the muscle tissue of rainbow trout (*Oncorhynchus mykiss* Walbaum) under incubation with extracts derived from the leaves of various *Sansevieria* species, aimed at the further improving methods for preventing and treating fish diseases by increasing the natural resistance of fish organism using antibacterial and antioxidant agents in aquaculture (Maryniuk et al., 2017, 2018). It has been found that the most potent antioxidant effect was demonstrated for the extracts of *S. caulescens*, *S. suffruticosa*, *S. hyacinthoides*, *S. canaliculata*, *S. aethiopica*, *S. gracilis*, and *S. parva* as compared to phosphate buffer control (46.6, 66.8, 77.3, 49.8, 71.1, 63.4, and 39.4%, respectively). Likewise, the results showed that extracts of *S. hyacinthoides* and *S. aethiopica* efficiently increased the total antioxidant capacity in rainbow trout muscle tissue (Maryniuk et al., 2017). Among plant extracts screened for *in vitro* antioxidant properties in rainbow trout muscle tissue, the strongest toxicity responses were exhibited by *S. cylindrica*, *S. canaliculata*, *S. trifasciata*, *S. metallica* leaf extracts (Maryniuk et al., 2017).

Moreover, we also assessed the *in vitro* antibacterial activity of ethanolic extract prepared from various *Sansevieria* plants (Buyun et al., 2018). The results of antibacterial activity clearly showed that the *S. cylindrica* extract has shown antibacterial activity against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* strains, clinically important bacteria, which are indicator organisms commonly used in programs to monitor antibiotic resistance. The extract has shown better activity against *S. aureus* and *P. aeruginosa* strains compared to the *E. coli* strains. The extract has shown less antimicrobial activities against *P. aeruginosa*. Finally, the ethanolic extract exhibited mild antibacterial activity against *E. coli* (Buyun et al., 2018).

Thus, it can be inferred from this study, that *Sansevieria* species have a promising antioxidant and pro-oxidant potential. However, the precise mechanisms underlying these potential need to be evaluated in future studies. Further studies involving bioassay-guided identification of the main compounds in plants are necessary to affirm and maximize the possible use of the plant as a therapeutic remedy for the prevention of lipid peroxidation in the blood. The obtained information may be useful in the clinical usage of plants in medicine and veterinary. Finally, these findings justify the traditional uses of *Sansevieria* plants for therapeutic purposes.

Conclusions

The results of the study showed that the TBARS level was significantly increased after incubation with extracts of selected species belonging to the *Sansevieria* genus and these results were statistically significant. Moreover, it was revealed that *Sansevieria* leaf extracts were found to have different levels of antioxidant properties in the test model. The most potent effect was demonstrated by the *S. intermedia*, *S. forskaliana*, *S. trifasciata*, *S. parva*, and *S. caulescens* compared to phosphate buffer as a control sample (increased by 65.6, 53.2, 51.6, 50, and 48%, respectively). *S. kirkii*, *S. aethiopica*, and *S. suffruticosa* caused the less increase of the TBARS level after 1-h incubation with equine plasma (by 18.8, 27.6, and 30.8%, respectively, p <0.05). *Sansevieria* species possess a promising antioxidant and pro-oxidant potential. Further studies involving phytochemical identification of the main compounds in plants are necessary to affirm and maximize the possible use of the plants as a therapeutic remedy for the prevention of oxidative stress. It was concluded, that the dose-depended antioxidative and pro-oxidative effects of various *Sansevieria* species in both plasma and erythrocyte suspension will be further studied in detail.

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References

ADEYEMI, O.O., AKINDELE, A.J., OGUNLEYE, E.A. 2009. Evaluation of the antidiarrhoeal effect of *Sanseviera liberica* Gerome & Labroy (Agavaceae) root extract. In *J. Ethnopharmacol.*, vol. 123(3), p. 459–463. https://doi.org/10.1016/j.jep.2009.03.023

AHAMAD, T., NEGI, D.S., KHAN, M.F. 2017. Phytochemical analysis, total phenolic content, antioxidant and antidiabetic activity of *Sansevieria cylindrica* leaves extract. In *J. Nat. Prod.* Resour., vol. 3(2), p. 134–136.

AKINDELE, A.J., WANI, Z.A., SHARMA, S., MAHAJAN, G., SATTI, N.K., ADEYEMI, O.O., MONDHE, D.M., SAXENA, A.K. 2015. *In Vitro* and *In Vivo* Anticancer Activity of Root Extracts of *Sansevieria liberica* Gerome and Labroy (Agavaceae). In *Evid. Based Complement. Alternat. Med.*, vol. 2015, p. 560404. https://doi.org/10.1155/2015/560404

AMIDA, M.B., YEMITAN, O.K., ADEYEMI, O.O. 2007. Toxicological assessment of the aqueous root extract of *Sanseviera liberica* Gerome and Labroy (Agavaceae). In *J. Ethnopharmacol.*, vol. 113(1), p. 171–175. https://doi.org/10.1016/j.jep.2007.03.033

ANBU, J.S., JAYARAJ, P., VARATHARAJAN, R., THOMAS, J., JISHA, J., MUTHAPPAN, M. 2009. Analgesic and antipyretic effects of *Sansevieria trifasciata* leaves. In *Afr. J. Tradit. Complement. Altern. Med.*, vol. 6(4), p. 529–533.

BALDIM, J.L., DE ALCÂNTARA, B., DOMINGOS, O., SOARES, M. G., CALDAS, I.S., NOVAES, R.D., OLIVEIRA, T.B., LAGO, J.H.G., CHAGAS-PAULA, D.A. 2017. The Correlation between Chemical Structures and Antioxidant, Prooxidant, and Antitrypanosomatid Properties of Flavonoids. In *Oxidative medicine and cellular longevity*, vol. 2017, p. 3789856. https://doi.org/10.1155/2017/3789856

BERAME, J.S., CUENCA, S.M.E., CABILIN, D.R.P., MANABAN, M.L. 2017. Preliminary phytochemical screening and toxicity test of leaf and root parts of the snake plant (*Sansevieria trifasciata*). In *J. Phylogenetics Evol. Biol.*, vol. 5, p. 187. https://doi.org/10.4172/2329-9002.1000187

BUYUN, L., MARYNIUK, M., TKACHENKO, H., OSADOWSKI, Z. 2017. Antibacterial evaluation of an ethanolic extract from *Sansevieria trifasciata* Prain against *Staphylococcus aureus*. In *Proceedings of the International Scientific and Practical Internet Conference „Problems and perspectives of modern agricultural science"*. Mykolayiv: Mykolaiv DDSS IZZ, p.. 88.

BUYUN, L., TKACHENKO, H., GÓRALCZYK, A., MARYNIUK, M., OSADOWSKI, Z. 2018. A promising alternative for treatment of bacterial infections by *Sansevieria cylindrica* Bojer ex Hook leaf extract. In *Agrobiodiversity for Improving Nutrition, Health, and Life Quality*, vol. 2, p. 82–93. https://doi.org/10.15414/agrobiodiversity.2018.2585-8246.082-93

BUYUN, L., TKACHENKO, H., OSADOWSKI, Z., MARYNIUK, M. 2016. Antibacterial activity of certain *Sansevieria* species against *Staphylococcus aureus*. In *Słupskie Prace Biologiczne*, vol. 13, p. 19–36.

CHERRAK, S.A., MOKHTARI-SOULIMANE, N., BERROUKECHE, F., BENSENANE, B., CHERBONNEL, A., MERZOUK, H., ELHABIRI, M. 2016. *In Vitro* Antioxidant versus Metal Ion Chelating Properties of Flavonoids: A Structure-Activity Investigation. In *PLoS One*, vol. 11(10), p. e0165575. https://doi.org/ 10.1371/journal.pone.0165575

CHHABRA, S.C., MAHUNNAH, R.L.A., MSHIU, E.N. 1987. Plants used in traditional medicine in Eastern Tanzania 1. Pteridophytes and Angiosperms (Acanthaceae to Canellaceae). In *Journal of Ethnopharmacology*, vol. 21(3), p. 253–277. https://doi.org/10.1016/0378-8741(87)90103-6

EGHBALIFERIZ, S., IRANSHAHI, M. 2016. Prooxidant Activity of Polyphenols, Flavonoids, Anthocyanins and Carotenoids: Updated Review of Mechanisms and Catalyzing Metals. In *Phytother. Res.*, vol. 30(9), p. 1379–1391. https://doi.org/10.1002/ptr.5643

IGHODARO, O.M., ADEOSUN, A.M., OJIKO, B.F., AKOREDE, A.T., FUYI-WILLIAMS, O. 2017. Toxicity status and antiulcerative potential of *Sansevieria trifasciata* leaf extract in Wistar rats. In *J. Intercult. Ethnopharmacol.*, vol. 6(2), p. 234–239. https://doi.org/10.5455/jice.20170421103553

IKEWUCHI, J.C., IKEWUCHI, C.C., IGBOH, N.M., MARK-BALM, T. 2011. Protective effect of aqueous extract of the rhizomes of *Sansevieria liberica* Gérôme and Labroy on carbon tetrachloride induced hepatotoxicity in rats. In *EXCLI J.*, vol. 10, p. 312–321.

KAMYSHNIKOV, V.S. 2004. *A reference book on the clinic and biochemical researches and laboratory diagnostics*. MEDpress-inform, Moscow.

KHALUMBA, M.L., MBUGUA, P.K., KUNG'U, J.B. 2005. Uses and conservation of some highland species of the genus *Sansevieria* Thunb. in Kenya. In *African Crop Science Conference Proceedings*, vol. 7, p. 527–532.

KHAN, H.Y., ZUBAIR, H., ULLAH, M.F., AHMAD, A., HADI, S.M. 2012. A prooxidant mechanism for the anticancer and chemopreventive properties of plant polyphenols. In *Curr. Drug Targets*, vol. 13(14), p. 1738–1749. https://doi.org/10.2174/138945012804545560

KIRINGE, J.W. 2006. A survey of traditional health remedies used by the Maasai of Southern Kaijiado District, Kenya. In *Ethnobotany Research and Applications*, vol. 4, p. 61–73. https://doi.org/10125/238

LYKKESFELDT, J. 2007. Malondialdehyde as a biomarker of oxidative damage to lipids caused by smoking. In *Clin. Chim. Acta*, vol. 380, p. 50–58. https://doi.org/10.1016/j.cca.2007.01.028

MAHESHWARI, R., SHREEDHARA, C.S., POLU, P.R., MANAGULI, R.S., XAVIER, S.K., LOBO, R., SETTY, M., MUTALIK, S. 2017. Characterization of the Phenolic Compound, Gallic Acid from *Sansevieria roxburghiana* Schult and Schult. f. Rhizomes and Antioxidant and Cytotoxic Activities Evaluation. In *Pharmacogn. Mag.*, vol. 13(Suppl. 3), p. S693–S699. https://doi.org/10.4103/pm.pm_497_16

MARYNIUK, M., KHARCHENKO, I., BUYUN, L., TKACHENKO, H., WITASZEK, M., PAŻONTKA-LIPIŃSKI, P., OSADOWSKI, Z. 2017. Total antioxidant capacity in the muscle tissue of the rainbow trout (*Oncorhynchus mykiss* Walbaum) under *in vitro* incubation with extracts from leaves of various species of *Sansevieria* Thunb. (Asparagaceae). In *Scientific and Technical Bulletin of Institute of Animal Husbandry, National Academy of Agrarian Sciences of Ukraine*, vol. 118, p. 14–21.

MARYNIUK, M., KHARCHENKO, I., TKACHENKO, H., BUYUN, L., WITASZEK, M., PAŻONTKA-LIPIŃSKI, P., OSADOWSKI, Z. 2017. *In vitro* study of lipid peroxidation markers in the muscle tissue of the rainbow trout (*Oncorhynchus mykiss* Walbaum) under incubation with extracts from leaves of various species of *Sansevieria* Thunb. (Asparagaceae). In *Scientific Journal of DALRYBVTUZ*, vol. 43(4), p. 27–34.

MARYNIUK, M., TKACHENKO, H., BUYUN, L., KHARCHENKO, I., OSADOWSKI, Z. 2018. Oxidative stress biomarkers in the muscle tissue of the rainbow trout (*Oncorhynchus mykiss* Walbaum) after *in vitro* treatment of *Sansevieria* caulescens N.E.Br. extract. In *Agrobiodiversity for Improving Nutrition, Health, and Life Quality*, vol. 2, p. 111–123. https://doi.org/10.15414/agrobiodiversity.2018.2585-8246.111-123

MIMAKI, Y., INOUE, T., KURODA, M., SASHIDA, Y. 1996. Steroidal saponins from *Sansevieria trifasciata*. In *Phytochemistry*, vol. 43(6), p. 1325–1331. https://doi.org/10.1016/S0031-9422(96)00397-4

MIMAKI, Y., INOUE, T., KURODA, M., SASHIDA, Y. 1997. Pregnane glycosides from *Sansevieria trifasciata*. In *Phytochemistry*, vol. 44(1), p. 107–111. https://doi.org/10.1016/S0031-9422(96)00477-3

OWUOR, B.O., KISANGAU, D.P. 2006. Kenyan medicinal plants used as antivenin: A comparison of plant usage. In *Journal of Ethnobiology and Ethnomedicine*, vol. 2(7), p. 1–8. https://doi.org/10.1186/1746-4269-2-7

PAŻONTKA-LIPIŃSKI, P., WITASZEK, M., TKACHENKO, H., MARYNIUK, M., BUYUN, L., OSADOWSKI, Z. 2018. Modulation of oxidative damage of proteins in equine erythrocytes by extracts obtained from various *Sansevieria* Thunb. species (Asparagaceae). In *Youth and Progress of Biology: Program and Abstracts of XIV International Scientific Conference for Students and Ph.D. Students, dedicated to the 185th anniversary from the birthday of B. Dybowski* (Lviv, April 10–12, 2018). Lviv, p. 66–67.

PROCHÁZKOVÁ, D., BOUŠOVÁ, I., WILHELMOVÁ, N. 2011. Antioxidant and prooxidant properties of flavonoids. In *Fitoterapia*, vol. 82(4), p. 513–523. https://doi.org/10.1016/j.fitote.2011.01.018

TAKAWIRA-NYENYA, T., NEWTON, L.E., WABUYELE, E., STEDJE, B. 2014. Ethnobotanical uses of *Sansevieria* Thunb. (Asparagaceae) in Coast Province of Kenya. In *Ethnobotany Research and Application*, vol. 12(1), p. 51–69. https://doi.org/10.17348/era.12.0.051-069

TKACHENKO, H., BUYUN, L., MARYNIUK, M., OSADOWSKI, Z. 2018. A comparative study of the effect of various *Sansevieria* Thunb. leaf extracts on the lipid peroxidation in the equine erythrocyte suspension. In *Agrobiodiversity for Improving Nutrition, Health, and Life Quality*, vol. 2, p. 69–81. https://doi.org/10.15414/agrobiodiversity.2018.2585-8246.069-081

TKACHENKO, H., BUYUN, L., OSADOWSKI, Z., MARYNIUK, M. 2016. Potential *In Vitro* Antibacterial Effects of the Leaf Extracts of *Sansevieria canaliculata* Carrière (Dracaenaceae) Against *Staphylococcus aureus*. In *Topical Issues in Biology and Medicine: Proceedings of the XIV Interregional Conference*, December 22–23, 2016, Starobelsk. p. 206–210.

TKACHENKO, H., BUYUN, L., OSADOWSKI, Z., MARYNIUK, M. 2017. The antibacterial activity of certain *Sansevieria* Thunb. species against *Escherichia coli*. In *Agrobiodiversity For*

Improving Nutrition, Health, and Life Quality, vol. 1, p. 446–453. https://doi.org/10.15414/agrobiodiversity.2017.2585-8246.446-453

TKACHENKO, H., BUYUN, L., OSADOWSKI, Z., MARYNIUK, M. 2017. The antibacterial screening of certain *Sansevieria* species against *Escherichia coli* strain. In *Youth and Progress of Biology: Book of Abstracts of XIII International Scientific Conference for Students and Ph.D. Students* (Lviv, 25–27 April 2017), Lviv, p. 220–221.

TKACHENKO, H., BUYUN, L., PAŻONTKA-LIPIŃSKI, P., WITASZEK, M., OSADOWSKI, Z. 2017. *In vitro* protective effect of extracts obtained from various *Sansevieria* species against oxidative damage of proteins in equine erythrocytes. In *Słupskie Prace Biologiczne*, vol. 14, p. 247–265.

TKACHENKO, H.M., BUYUN, L.I., OSADOWSKI, Z., MARYNIUK, M.M. 2017. *In vitro* antibacterial activity of ethanolic extracts from leaves of various *Sansevieria* species against *Escherichia coli*. In *XII International Pirogov Scientific Medical Conference of Students and Young Scientists, Federal State Budget Educational Institution of Higher Education "N.I. Pirogov Russian National Research Medical University"*, March 17, 2017. Moscow, p. 295.

WATT, J.M., BREYER-BRANDWIJK, M.G. 1962. *The Medicinal and Poisonous Plants of Southern and Eastern Africa*. E & S Livingstone Ltd., Edinburgh, Scotland.

World Checklist of Selected Plant Families (WCSP): Royal Botanic Garden, Kew, 2018): https://wcsp.science.kew.org/

ZAR, J.H. 1999. *Biostatistical Analysis*. 4th ed., Prentice Hall Inc., New Jersey.