

Protective Effects of Moringa Oleifera Leaves on Glutathione Levels, Liver Enzymes, Urea, and Creatinine in Ram Lambs Exposed to Mycotoxins

Raheem Kadhim Abaas¹, Adil jabar Atiyah^{1*}, Shuai Huang²

¹ Department of Veterinary Public Health, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq

² School of Tropical Agriculture and Forestry, Hainan University, Haikou, PR China, 570228

ABSTRACT

Background: Mycotoxins are toxic secondary metabolites produced by fungi that pose significant health risks to livestock, leading to oxidative stress, liver dysfunction, and renal impairment. Moringa oleifera leaves are known for their antioxidant and hepatoprotective properties, which may mitigate the adverse effects of mycotoxin exposure. **Objective:** This study aimed to evaluate the protective effects of Moringa oleifera leaves on glutathione (GSH) levels, liver enzymes, and kidney function in ram lambs exposed to mycotoxins. **Methods:** Twenty ram lambs (average weight: 23 kg, age: 4–5 months) were randomly assigned to four dietary treatment groups and housed in controlled conditions. The study was conducted at the animal farm of Baghdad's College of Veterinary Medicine from January 24, 2023, to March 24, 2023. The dietary treatments were as follows: Control (C): Fed a concentrate ration (2.5% body weight) with alfalfa hay. G1: Fed the same control diet supplemented with 50 g of Moringa oleifera leaves daily. G2: Fed a diet contaminated with mycotoxins. G3: Fed the same mycotoxin-contaminated diet as G2 but supplemented with 50 g of Moringa oleifera leaves daily. All animals had free access to water. Blood and serum samples were collected at baseline (0 days), one month, and two months post-treatment to assess glutathione (GSH) levels, liver enzymes (ALT, AST, ALP), and kidney function markers (urea and creatinine). **Results:** Mycotoxin exposure (G2) significantly increased serum ALT, AST, ALP, urea, and creatinine levels, indicating hepatic and renal dysfunction. Additionally, GSH levels were markedly reduced in the mycotoxin-exposed group compared to the control. However, supplementation with Moringa oleifera leaves (G3) significantly improved antioxidant activity, as evidenced by increased GSH levels and a reduction in liver enzyme and kidney function markers compared to the mycotoxin-exposed group. **Conclusion:** Moringa oleifera leaves demonstrated a protective role against mycotoxin-induced oxidative stress and organ dysfunction by enhancing antioxidant defense mechanisms and improving liver and kidney function. These findings support the potential use of Moringa oleifera as a natural dietary supplement to mitigate the toxic effects of mycotoxin contamination in livestock feed.

Keywords: Moringa Oleifera, GSH, Urea, Liver Enzymes and Creatinine

INTRODUCTION

Mycotoxins are toxin secondary metabolites which contaminate different food substances [1, 2] effect on public health [3] and by presence of their residue in serum, milk [4, 5] kidney and liver [6, 7] Strategies to prevent mycotoxin in per harvest or post-harvest by chemical method (chitosan, ozone treatment). Mycotoxins cause human and animal health problems and mortality [8-10], as well as increased health and veterinary care costs [11], decreased production efficiency, and rendering commodities unsuitable for national or international trade. Physical method (processing, storage, radiation), chemical method [12], biological method (yeast, fungi, food fermentation) enzymatic detoxification and noval detoxification strategies by plant extraction [13]. Contaminated diet reduced feed ingestion, had adverse effect on the liver and immunosuppression in sheep [14].

Mycotoxins cause human and animal health problems and mortality [15, 16], as well as increased health and veterinary care costs [17], decreased production efficiency, and making commodities unsuitable for national or international trade [18]. The use of medicinal plants has an effective effect in many diseases that affect human and animals because it contain important substance such as antioxidant and antimicrobials [4, 19]. Many studies have been conducted to use medicinal plants to reduce the effect of mycotoxins [20]. The tree's leaves are known for their high concentration of crude

protein, vital vitamins, minerals, and amino acids [21]. According to Akinbamijo et al., [22] Among other nutrients, MOLs frequently include dry matter, crude protein, ash, ether extract, and crude fiber. It has received much research due to their potential as a high-quality feed source for grazing ruminants and as a supplement to boost herbivore productivity on limited feed sources. Among other nutrients, the chemical makeup of MOLs often includes dry matter, crude protein, ash, ether extract, and crude fiber [19]. Moringa oleifera is renowned as the miracle tree due to its numerous medicinal advantages and great nutritional value over the world [23].

Moringa leaves, on the other hand, effectively prevent morphological changes and oxidative damage in humans and animals by increasing antioxidant enzyme activity, reducing lipid peroxidation intensity, and inhibiting free radical generation [24, 25]. Based on these findings, we postulated that MOLE, by activating the pathways that upregulate the antioxidant defense system, may effectively protect skeletal muscle cells exposed to a pro-oxidant environment. And it has been used to promote the immune system against microorganisms infection [26, 27]. Moringa oleifera, leaves have a rich source of calcium, protein, potassium and natural antioxidants like vitamin C (Leone *et al* the leaves of M.oleifera are used in treatment of a variety of human ailments such as hepatic and renal disorders, cardiovascular [28].

MATERIALS AND METHODS

The experiment was completed in 2 months. Thirty twenty local males rams were imported at age of 4-5 months, with a mean body weight of 20 kg, and were housed in the cage of the animals' house of the veterinary college, Baghdad University. Ram lambs were obtained from a recognized owner. The animals were healthy and free of both external and internal parasites. All animals were fed the same concentrate diet, and water and feed were provided for two weeks. The animals were then separated into four equal groups of five animals each, as shown below. The first group was provided a concentrated diet and served as a control group (C), whereas the second group was offered a concentrated diet containing Moringa Oleifera leaves (G1). The third group was fed a concentrate diet tainted with mycotoxins (G2). The fourth group was fed a mycotoxin-contaminated concentrated food and got 50 gm/kg of *M. oleifera* leaves communis (G3)

Preparation of Mycotoxin

The process of preparing mycotoxin was done naturally through the contaminated yellow corn and barely, which was taken from the place where the corn was moldy, the corn was mixed with the concentrated diet according to standard percentage of the control diet. After mixed it well and estimation the concentration of mycotoxin tow time in the beginning of the study, middle and at the end of the study by using ELISA test. Aflatoxin corn 18.678-23.130 (ppb), barley 2.762-15.189 T2 corn 1-59.937 µg/kg, barely 1-62.082 µg/kg, Ochratoxin corn 1.538-2.317 µg/kg, barely 1-2.450 µg/kg Zearalenone corn 1-139.869 µg/kg, barely 1-139.869 µg/kg Don corn 0.264-0.769 µg/kg, barely 0.002 -0.463 µg/kg

Collection of the Plant and Preparation of the Extract

Freshly leaves of *Moringa Oleifera* collected from local trees in Baghdad, pounded to a fine powder in electrical processor.

Table 1: Effect of Dietary Treatment of (Moringa Oleifera Leaves) with Ram Lambs Feed Contaminated by Mycotoxins on Glutathione Concentration (U/L) at (2) Months (Mean $\pm$ SEM).

Groups	Zero Time	After One Month	After 2 Months
G1	A218.50 $\pm$ 8.65a	B229.25 $\pm$ 8.04 b	B224.75 $\pm$ 2.08 b
G2	C215.00 $\pm$ 9.26a	A243.50 $\pm$ 7.06 a	BA236.25 $\pm$ 9.03 a
G3	A216.22 $\pm$ 7.23 a	B191.20 $\pm$ 7.77 d	C152.20 $\pm$ 8.08 c
G4	B218.33 $\pm$ 9.10a	C207.60 $\pm$ 10.12c	A222.80 $\pm$ 10.11ab
LSD	5.65		

Values are Presented as Means.SE with Different Tiny Letters in the Same Column show Significant Differences ($p < 0.05$)

ALP Change

At the end of CG, G1, G2 and G3 after 1-month Awassi Ram Lambs fed with G2 had significant effect on body ALP as compared to G1 and G3 groups. the comparable effect was observed after 1 month of body ALP.

Blood Samples

Blood sample were collected on zero-time, first month and Second month of the experimental to evaluate the above-mentioned parameters. Blood samples were withdrawing (5ml) from vein after sterilization the site of blood drawn by using disposable syringe sterilized. the samples while the other part of the bloods samples kept in sterilized tube (6ml) includes gel and clot activator then separated by centrifuge (3000 rpm) for 5 minutes.

The GSH content was determined according to Beutler et al.[29]. Urea content was determined according to Fawcett et al., [30]. Alanine Amino Transferase Activity (ALT) and Aspartate AST (AST) are determined using Reitman and Frankel's [18] methods. We also utilized the DEA kit Aspartate Aminotransferase. Estimation of blood serum creatinine, the concentration of creatinine in the blood, using the kinetic approach (Automated method) described by Crocker et al. (1988) using a creatinine kit. The Bio-system- Spain Company created all of the kits.

Statistical Analysis

SAS (Statistical analysis system, version 9.1) was used to do statistical analysis on the data. To analyze significant differences across means, a two-way ANOVA with interaction and a least significant difference (LSD) post-hoc test was used (SAS, 2010).

Results And Discussion

Glutathione Changes

In Table 1 the total GSH values a significant ($p < 0.05$) difference starting in 1 month. G1 shows a significant ($p < 0.05$) increase compared with G1 in the first month. Effect the moringa Oleifera compared with G1in first month Ram Lambs. The effect moringa oleifera leaves compared on GSH in treatment group G3.

The comparable effect moringa oleifera on G3 of the fed mycotoxin with moringa oleifera leaves had significant on body ALP. The overall body ALP was A370.56 $\pm$ 28.14 a, A231.00 $\pm$ 26.70 b, B198.40 $\pm$ 11.86 c and B137.17 $\pm$ 8.23 d in groups G2, G3, G1 and CG, respectively.

Table 2: Effect of Dietary Treatment of (Moringa Oleifera Leaves) with Ram Lambs Feed Contaminated by Mycotoxins on ALP concentration (U/L) at (2) Months (Mean $\pm$ SEM).

Groups/ALP	Zero Time	After One Month	After 2 Months
G1	A170.40 $\pm$ 23.03a	B137.17 $\pm$ 8.23 d	B132.82 $\pm$ 11.05d
G2	A176.12 $\pm$ 41.91a	B198.40 $\pm$ 11.86c	B196.72 $\pm$ 45.27c
G3	B176.46 $\pm$ 28.76a	A370.56 $\pm$ 28.14a	A377.92 $\pm$ 21.20a
G4	C173.86 $\pm$ 37.42a	A231.00 $\pm$ 26.70b	B210.18 $\pm$ 51.81b
LSD	5.65		

Value is Represented as Means.SE with Different Tiny Letters in the Same Column Show Significant Differences ($p < 0.05$)

Alanine Amino Transferase Changes (ALT)

Total alanine amino transferase values in table 4.4 showed a significant ($p < 0.05$) difference from the first to end experiment, with

G1 expressing a significant ($p < 0.05$) increase compared to the other groups, G2 expressing a significant ($p < 0.05$) decrease compared to G1 and G3 at the first month.

Table 3: Effect of DIETARY TREATMENT of (Moringa oleifera leaves) with Ram Lambs feed contaminated by mycotoxins on ALT concentration (U/L) at (2) months (Mean $\pm$ SEM).

Groups	Zero Time	After One Month	After 2 Months
G1	A27.55 $\pm$ 3.53a	A22.37 $\pm$ 0.93b	B17.50 $\pm$ 1.35c
G2	B27.15 $\pm$ 3.26a	A32.30 $\pm$ 0.86a	A35.48 $\pm$ 1.27a
G3	B29.30 $\pm$ 0.80a	A35.48 $\pm$ 1.27a	A32.82 $\pm$ 2.20ab
G4	A28.86 $\pm$ 3.42a	A22.62 $\pm$ 1.86b	A28.86 $\pm$ 7.01b
LSD	5.65		

Different Value are expressed as Means.SE having a Different Small Letter in ti Same Column are Significantly ($p < 0.05$)

Aspartate Amino Trasferase Changes (AST)

Table 4_5 demonstrate that there was significant change in AST in G1, G2 and G3. A flatoxin has a marked effect on liver. but Activity

elevation of aminotransferase (AST) by aflatoxin in G2. Effect Moringa oleifera leaves on aflatoxin reduce effect on AST G3 of fersit month. Table (4) Effect of Moringa oleifera leaves on (AST) of Ram Lambs by Contaminated diet by mycotoxins

Table 4: Effect of Dietary Treatment of (Moringa Oleifera Leaves) with Ram Lambs feed contaminated by Mycotoxins on AST Concentration (U/L) at (2) months (Mean $\pm$ SEM).

Groups	Zero Time	After One Month	After 2 Months
G1	B79.00 $\pm$ 2.53a	A87.72 $\pm$ 5.59c	B72.32 $\pm$ 4.67b
G2	B78.45 $\pm$ 8.92a	A104.50 $\pm$ 4.86b	B74.40 $\pm$ 3.81b
G3	B84.44 $\pm$ 8.25a	A146.16 $\pm$ 17.54a	A92.30 $\pm$ 3.20a
G4	B80.44 $\pm$ 6.42a	A89.90 $\pm$ 4.20c	B77.70 $\pm$ 9.01b
LSD	5.65		

Different Value are Expressed as Means.SE having a Different Small Letter in ti Same Column are Significantly ($p < 0.05$)

Uera Changes

At the end of CG, G1, G2 and C3 after 2 months Awassi Ram Lambs fed with G2 had significant effect on body uera as compared to G1 and G3 groups (Table 1). The comparable effect was observed after 1month of body uera. The comparable effect Moringa Oleifera of G3

was observed after 1 month of body uera. During the 1 month and 2 months of the treatment groups decreased significantly compared with the control group. The overall body uera was 67.90 $\pm$ 4.34, 19.32 $\pm$ 1.27, 18.00 $\pm$ 0.54 and 19.64 $\pm$ 0.81 mmol/L in groups G2, G1, CG and G3, respectively.

Table 5: Effect of Dietary Treatment of (Moringa Oleifera Leaves) with Ram Lambs feed Contaminated by Mycotoxins on Urea Concentration (mg/dl) at (2) months (Mean $\pm$ SEM).

Groups	Zero Time	After One Month	After 2 Months
G1	A18.42 $\pm$ 1.29a	A18.42 $\pm$ 0.40b	A18.00 $\pm$ 0.54b
G2	A18.37 $\pm$ 1.47a	A19.35 $\pm$ 1.86b	A19.32 $\pm$ 1.27b
G3	B19.10 $\pm$ 5.81a	A71.12 $\pm$ 5.14a	A67.90 $\pm$ 4.34a
G4	A20.68 $\pm$ 1.02a	A18.06 $\pm$ 1.70b	A19.64 $\pm$ 0.81b
LSD	5.65		

Value is expressed as Means.SE having a Different Small Letter in the Same Column are Significantly Different ($p < 0.05$)

Creatinine Change

The results of Creatinine showed there were significant ($p < 0.05$) increased in Creatinine G2 from first month to tge end compared to the other groups, mycotoxin effects on high creatinine, Moringa

oleifera leaves effects postave on creatinine where significant ($p < 0.05$) in G2and G3 where decreased of creatinine, we have shown that proteinaceous fractions in the m.oleifera leaves extract have an effect on lowering the creatinine.

Table 6: Effect of Dietary Treatment of (Moringa Oleifera Leaves) with Ram Lambs Feed Contaminated by Mycotoxins on Creatinine Concentration (mg/dl) at (2) Months (Mean $\pm$ SEM).

Groups	Zero Time	After One Month	After 2 Months
G1	A0.91 $\pm$ 0.03a	A0.86 $\pm$ 0.04b	A0.83 $\pm$ 0.08b
G2	A1.00 $\pm$ 0.08a	A1.01 $\pm$ 0.06b	A0.93 $\pm$ 0.03b
G3	A1.03 $\pm$ 0.09a	B2.04 $\pm$ 0.05a	B2.08 $\pm$ 0.08a
G4	A0.99 $\pm$ 0.10a	A1.02 $\pm$ 0.12b	A0.99 $\pm$ 0.11b
LSD	5.65		

Different Value are Expressed as Means.SE having a Different Small Letter in ti Same Column are Significantly ($p < 0.05$)

Discussion

Glutathione (GSH)

Moriga appears to have several advantages, including the treatment of ascites, rheumatism, and poisonous bites, as well as cardiac and circulatory restorative [31], hepatoprotective, and anti-

malignancy properties [12]. For the efficient treatment of athlete's foot and tinea [31]. Moriga oleifera plant leaves can be used as an antiaflatoxinogenic agent and its extract having a lot of Bioactive compounds to control aflatoxin production these advantages occur due to positive changes in antioxidants, support and activation of liver and kidney functions. Ibrahim et al.,[27]. In our current study, we found that the effects of mycotoxins are clear in reducing antioxidants

such as GSH [16], and that adding *Moringa oleifera* leaf powder at a concentration of 5% contributed to increasing the percentage of GSH in the blood, which helped it reduce the severity of Mycotoxin this agreed with. Ibrahim et al. [27], who showed the increased of GSH to reduce the harm effect of AFB1 also Sreelatha and, Padma [32], and Hussein et al., [33] who noticed that adding the moringa olevera led to protective effect on liver damage by decreasing the oxidative stress [34, 35]. Adding *Moringa oleifera* as an antioxidant reduces liver toxicity and kidney toxicity and raises the defense status as antioxidants [36]. The value of liver reduced glutathione (GSH) concentration was considerably lower in the mycotoxin group when compared to GC, G2 and G3 [37]. These findings are consistent with those of Mobio et al. [16]. AF induction caused a complicated, substantial metabolic dysfunction of the endogenous oxidative and antioxidative systems [38]. The accumulation of AF and its metabolites depletes the GSH due to the formation of high amounts of epoxides that could activate and development of various cancers [39]. *M.oleifera* attenuates the oxidative stress and enhances the levels of activity of antioxidative enzymes [40] and may be because contains important substances like phenolics mpolyphenol, vitamin A,C and E in addition to macro and micro minerals like Ca, Mg, Cu, K, Zn, Mn, Na and Fe [41] *M.oleifera* leaves are a renewable source of chlorophylls, phenolics, B-carotein, and saponin [42]. Chlorophylls can operate as an interceptor molecule by forming tight molecular complexes with AF, antioxidant, and inhibitor of cytochrome p450 enzymes [17]. These findings are consistent with the experimental findings that *M.oleifera* leaves boost GSH [43].

Liver Enzymes

Mycotoxins [44] have harmful effects on the body's organs, especially the liver, as it is the body's first defender as a result of toxins entering it [35] showed increase in activity of liver enzymes after affected by mycotoxins [45]. In our study, these effects appeared clear through an increase in liver enzymes in the blood, which is evidence of the destruction that happens in the liver cells, and then the enzymes go down to the blood [46, 47]. This appeared clearly through an increase in enzymes (ALP, ALT, AST) in the third group fed with feed contaminated with mycotoxins, while there were a small percentage in the rest of the groups, noting that the fourth group fed on feed contaminated with mycotoxins with the addition of Moringa, the percentage of these enzymes was higher than the control group and the group of feed to which Moringa was added without toxins, as there

is a clear effect of Moringa this agreed with Mansour et al. [48] when who notice the amelorative effect to in liver and kidney this may be through supporting the immune system and the presence of some vitamins E - B + C and their effects on the liver, and the presence of phenophyllans in Moringa has an important and essential role in activating cells, including liver cells [49, 50]. *Moringa Oleifera* therapy protects the liver from damage and oxidative stress caused by mycotoxin intoxication by scavenging free radicals and inhibiting inflammation, as well as restoring natural antioxidant defence systems [31, 51]. The findings are consistent with those of [35], who found statistically significant stimulation in ALT, AST, and ALP activities in groups given contaminated bassl diet mycotoxins compared to control groups. The AF induction generated the same trend in kidney function as that of the liver, with kidney (urea acid, urea, and creatinine levels in serum) following the same pattern as liver parameters [52]. These results from the trial on the effects of MOL are consistent with Furthermore, Sheikh et al. [34] discovered that *M.oleifera* leaves prevented xenobiotic-induced injury in liver function (AST, ALP, and ALT) and protected liver damage [43, 53].

Urea and Creatinine

Through our study, it appeared that there was a clear significant increase in the urea and Creatinine the group fed with feed containing mycotoxins [54], where the increase in urea and Creatinine was due to disturbances in the functions of the epithelial cells of the renal tubules and these clear effects of the mycotoxins [55, 56]. While note that the fourth group, after using *Moringa oleifera*, was seen a low concentration of both urea and Creatinine, and it is confirmed that there has been an improvement in kidney function as a result of the presence of important substances in the composition of Moringa, including antioxidants and flavonoids, which have a positive and supportive effect on cells, as well as the presence of the essential essential vitamins E and B this agreement with Sheikh et al. [34] found that *M.oleifera* leaves abrogated the xenobiotic induced harm in kidneys function.

Conclusion

In conclusion, that *Moringa oleifera* supplementation had a positive impact on the ram that consumed feed contaminated with some mycotoxins, especially antioxidant and liver and kidney function which suffered from harmful effects of mycotoxins.

References

- [1] C. Gurikar, D. Shivaprasad, L. Sabillón, N. N. Gowda, and K. Siliveru, "Impact of mycotoxins and their metabolites associated with food grains," *Grain & Oil Science and Technology*, vol. 6, no. 1, pp. 1-9, 2023.
- [2] M. Gozzi, M. Blandino, R. Bruni, L. Capo, L. Righetti, and C. Dall'Asta, "Mycotoxin occurrence in kernels and straws of wheat, barley, and tritordeum," *Mycotoxin Research*, vol. 40, no. 1, pp. 203-210, 2024.
- [3] N. Benkerroum and A. Ismail, "Human breast milk contamination with aflatoxins, impact on children's health, and possible control means: A review," *International Journal of Environmental Research and Public Health*, vol. 19, no. 24, p. 16792, 2022.
- [4] A. Zentai, Á. Józwiak, M. Süth, and Z. Farkas, "Carry-over of aflatoxin B1 from feed to cow milk—a review," *Toxins*, vol. 15, no. 3, p. 195, 2023.
- [5] M. B. Yitbarek and B. Tamir, "Mycotoxines and/or aflatoxines in milk and milk products," *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, vol. 4, no. 1, pp. 1-32, 2013.
- [6] B. A. AL-Fatlawi, "Evaluation of Aflatoxin B1 and Patulinin Blood of Iraqi Renal Failure patients," *Medico-Legal Update*, vol. 21, no. 2, 2021.
- [7] H. Alnaemi, "Estimation of aflatoxin M1 levels in some dairy products manufactured from raw milk experimentally inoculated with Toxin," *The Iraqi Journal of Veterinary Medicine*, vol. 43, no. 1, pp. 50-58, 2019.
- [8] N. Gowda, R. Suganthi, V. Malathi, and A. Raghavendra, "Efficacy of heat treatment and sun drying of aflatoxin-contaminated feed for reducing the harmful biological effects in sheep," *Animal Feed Science and Technology*, vol. 133, no. 1-2, pp. 167-175, 2007.
- [9] S. Huang et al., "Effects of aflatoxin B1 combined with ochratoxin A and/or zearalenone on metabolism, immune function, and antioxidant status in lactating dairy goats," *Asian-Australasian journal of animal sciences*, vol. 31, no. 4, p. 505, 2018.

- [10] N. A.-S. Hussein and A. J. Atiyah, "The effect of N-carbamylglutamate supplement on carryover of aflatoxin B1 in liver and muscle tissues of male rabbits fed with contaminated diet by AFB1," *Plant Arch*, vol. 20, no. 2, pp. 4653-4659, 2020.
- [11] M. H. Minati and M. K. Mohammed-Ameen, "First Report of Three kinds of Mycotoxins Dioxynivalenol, Nivalenol and Fumonisin B2 in Seeds of Seven Wheat Cultivars in Iraq," *The Iraqi Journal of Veterinary Medicine*, vol. 43, no. 1, pp. 43-49, 2019.
- [12] C. Wang and Y. Q. Xu, "Diphenyl dimethyl bicarboxylate in the treatment of viral hepatitis, adjuvant or curative?," *Gastroenterology research*, vol. 1, no. 1, p. 2, 2008.
- [13] B. Mikhilif and A. Atiyah, "Effect of L-arginine and N-carbamoyl glutamate on kidney and liver induced aflatoxin B1 histopathology in female rabbits," 2019.
- [14] S. Vijayanandraj *et al.*, "Detoxification of aflatoxin B1 by an aqueous extract from leaves of *Adhatoda vasica* Nees," *Microbiological Research*, vol. 169, no. 4, pp. 294-300, 2014.
- [15] D. Liu *et al.*, "Conductive polymer based hydrogels and their application in wearable sensors: a review," *Materials Horizons*, vol. 10, no. 8, pp. 2800-2823, 2023.
- [16] T. A. Mobio *et al.*, "Comparative study of the toxic effects of fumonisin B1 in rat C6 glioma cells and p53-null mouse embryo fibroblasts," *Toxicology*, vol. 183, no. 1-3, pp. 65-75, 2003.
- [17] P. A. Egner *et al.*, "Chlorophyllin intervention reduces aflatoxin-DNA adducts in individuals at high risk for liver cancer," *Proceedings of the National Academy of Sciences*, vol. 98, no. 25, pp. 14601-14606, 2001.
- [18] S. Reitman and S. Frankel, "A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases," *American journal of clinical pathology*, vol. 28, no. 1, pp. 56-63, 1957.
- [19] F.-F. Hsu and J. Turk, "Characterization of ceramides by low energy collisional-activated dissociation tandem mass spectrometry with negative-ion electrospray ionization," *Journal of the American Society for mass spectrometry*, vol. 13, no. 5, pp. 558-570, 2002.
- [20] W. Song *et al.*, "Biosynthesis-based quantitative analysis of 151 secondary metabolites of licorice to differentiate medicinal *Glycyrrhiza* species and their hybrids," *Analytical chemistry*, vol. 89, no. 5, pp. 3146-3153, 2017.
- [21] M. R. Mahdi and A. J. Atiyah, "Biodegradation of lycopene on AFB1 naturally contaminated feed and their residue in liver and muscles tissues of local male rabbits," *Annals of the Romanian Society for Cell Biology*, pp. 385-393, 2021.
- [22] S. J. Liu, Y. N. Wu, and L. Chan, "Application of metabonomics approach in food safety research-a review," *Food Reviews International*, vol. 36, no. 6, pp. 547-558, 2020.
- [23] X. Guo *et al.*, "Application of conductive polymer hydrogels in flexible electronics," *Journal of Polymer Science*, vol. 60, no. 18, pp. 2635-2662, 2022.
- [24] A. A. Assumaidade, N. M. Ali, and S. W. Ahmed, "Zearalenone mycotoxicosis: pathophysiology and immunotoxicity," 2020.
- [25] R. J. Johnson, T. Nakagawa, D. Jalal, L. G. Sánchez-Lozada, D.-H. Kang, and E. Ritz, "Uric acid and chronic kidney disease: which is chasing which?," *Nephrology Dialysis Transplantation*, vol. 28, no. 9, pp. 2221-2228, 2013.
- [26] K. Garg, F. Villavicencio-Aguilar, F. Solano-Rivera, and L. Gilbert, "Analytical validation of a direct competitive ELISA for multiple mycotoxin detection in human serum," *Toxins*, vol. 14, no. 11, p. 727, 2022.
- [27] I. M. Farag *et al.*, "Ameliorative role of ethanolic extract of *Moringa oleifera* leaf on aflatoxin B1-induced genotoxicity and biochemical alterations in rats," *Journal of The Arab Society for Medical Research*, vol. 13, no. 1, pp. 60-70, 2018.
- [28] S. J. Mahmood and A. J. Atiyah, "Ameliorative effect of aqueous *Myrtus communis* extract on AFB1 residue in liver and kidney and some blood biochemical parameter of local male rabbits feeding naturally contaminated by mycotoxins," *Biochemical & Cellular Archives*, vol. 21, no. 2, 2021.
- [29] E. Beutler, O. Duron, and B. M. Kelly, "Improved method for determination of blood glutathione," 1963.
- [30] J. Fawcett and J. Scott, "A rapid and precise method for the determination of urea," *Journal of clinical pathology*, vol. 13, no. 2, pp. 156-159, 1960.
- [31] M. Oniha, A. Eni, O. Akinnola, E. A. Omonigbehin, E. F. Ahuekwe, and J. F. Olorunshola, "In vitro antifungal activity of extracts of *Moringa oleifera* on phytopathogenic fungi affecting *Carica papaya*," *Open Access Macedonian Journal of Medical Sciences*, vol. 9, no. A, pp. 1081-1085, 2021.
- [32] S. Sreelatha and P. R. Padma, "Protective mechanisms of *Moringa oleifera* against CCl4-induced oxidative stress in precision-cut liver slices," *Forschende Komplementärmedizin/Research in Complementary Medicine*, vol. 17, no. 4, pp. 189-194, 2010.
- [33] S. Hussein, O. El-tawil, E. Laz, and W. Taha, "A potent antioxidants property of *Moringa oleifera* on mycotoxin induced oxidative stress in rats," *Benha Veterinary Medical Journal*, vol. 35, no. 2, pp. 384-392, 2018.
- [34] A. Sheikh *et al.*, "Protective effects of *Moringa oleifera* Lam. leaves against arsenic-induced toxicity in mice," *Asian Pacific journal of tropical biomedicine*, vol. 4, pp. S353-S358, 2014.
- [35] L.-A. Corcuera *et al.*, "Genotoxicity of Aflatoxin B1 and Ochratoxin A after simultaneous application of the in vivo micronucleus and comet assay," *Food and Chemical Toxicology*, vol. 76, pp. 116-124, 2015.
- [36] S. I. Inc, *SAS/STAT user's guide for personal computers: Release 9.13*. SAS Institute Inc., 2010.
- [37] L. De Vega, R. P. Fernández, M. C. Martín Mateo, J. B. Bustamante, A. M. Herrero, and E. B. Munguira, "Glutathione determination and a study of the activity of glutathione-peroxidase, glutathione-transferase, and glutathione-reductase in renal transplants," *Renal failure*, vol. 24, no. 4, pp. 421-432, 2002.
- [38] F. J. Gella *et al.*, "A simple procedure for the routine determination of aspartate aminotransferase and alanine aminotransferase with pyridoxal phosphate," *Clinica chimica acta*, vol. 153, no. 3, pp. 241-247, 1985.
- [39] R. Makhuvele, R. Matshoga, R. Antonissen, L. Pieters, L. Verschaeve, and E. E. Elgorashi, "Genotoxicity and antigenotoxicity of selected South African indigenous plants," *South African Journal of Botany*, vol. 114, pp. 89-99, 2018.
- [40] V. Prasanna and S. Sreelatha, "Synergistic effect of *Moringa oleifera* attenuates oxidative stress induced apoptosis in *Saccharomyces cerevisiae* cells: evidence for anticancer potential," 2014.
- [41] B. Vongsak, P. Sitisarn, S. Mangmool, S. Thongpraditchote, Y. Wongkrajang, and W. Gritsanapan, "Maximizing total phenolics, total flavonoids contents and antioxidant activity of *Moringa oleifera* leaf extract by the appropriate extraction method," *Industrial crops and products*, vol. 44, pp. 566-571, 2013.
- [42] P. M. P. Ferreira, D. F. Farias, J. T. d. A. Oliveira, and A. d. F. U. Carvalho, "Moringa oleifera: bioactive compounds and nutritional potential," *Revista de Nutrição*, vol. 21, pp. 431-437, 2008.
- [43] D. Ezejindu, O. Udemezue, and K. Chinweife, "Hepatoprotective effects of *Moringa oleifera* extract on liver of wistar rats," *International journal of research in medical and health sciences*, vol. 3, no. 5, pp. 23-27, 2014.
- [44] A. J. de la Vega, I. H. DeLacy, and S. C. Chapman, "Progress over 20 years of sunflower breeding in central Argentina," *Field Crops Research*, vol. 100, no. 1, pp. 61-72, 2007.
- [45] B. I. Al-Kaisie, "Study of important moulds isolated from milk and its products in Baghdad—with experimental study the pathogenesis of *Aspergillus Fumigatus* moulds in mice: Bushra. I. Al-Kaisie, Jinan Khalid," *The Iraqi Journal of Veterinary Medicine*, vol. 29, no. 2, pp. 67-80, 2005.
- [46] R. J. Johnson *et al.*, "Sugar, uric acid, and the etiology of diabetes and obesity," *Diabetes*, vol. 62, no. 10, pp. 3307-3315, 2013.
- [47] G. Duranti *et al.*, "Moringa oleifera leaf extract upregulates Nrf2/HO-1 expression and ameliorates redox status in C2C12 skeletal muscle cells," *Molecules*, vol. 26, no. 16, p. 5041, 2021.
- [48] H. H. Mansour, M. G. Abd El Azeem, and N. E. Ismael, "Protective effect of *Moringa oleifera* on γ -radiation-induced hepatotoxicity and nephrotoxicity in rats," *AJPCT*, vol. 2, no. 4, pp. 495-508, 2014.

- [49] R. Ceci *et al.*, "Moringa oleifera leaf extract protects C2C12 myotubes against H₂O₂-induced oxidative stress," *Antioxidants*, vol. 11, no. 8, p. 1435, 2022.
- [50] A. Papastergiadis, E. Mubiru, H. Van Langenhove, and B. De Meulenaer, "Malondialdehyde measurement in oxidized foods: evaluation of the spectrophotometric thiobarbituric acid reactive substances (TBARS) test in various foods," *Journal of agricultural and food chemistry*, vol. 60, no. 38, pp. 9589-9594, 2012.
- [51] K. T. Mahmood, T. Mugal, and I. U. Haq, "Moringa oleifera: a natural gift-A review," *Journal of Pharmaceutical Sciences and Research*, vol. 2, no. 11, p. 775, 2010.
- [52] M. F. Mahomoodally, "Traditional medicines in Africa: an appraisal of ten potent African medicinal plants," *Evidence-Based Complementary and Alternative Medicine*, vol. 2013, no. 1, p. 617459, 2013.
- [53] N. Magan and D. Aldred, "Post-harvest control strategies: minimizing mycotoxins in the food chain," *International journal of food microbiology*, vol. 119, no. 1-2, pp. 131-139, 2007.
- [54] K. Qiu *et al.*, "Gas-Phase SiO₂ Composite Hydrogel Polymer Electrolytes for Near-Neutral Zinc-Air Batteries," *Journal of Physical Chemistry*, pp. 1-8, 2023.
- [55] Z. Dun, C. Sun, Z. Zhang, F. Shu, Q. Zhang, and M. Liu, "Performance Study of PAAc-NHS Ester/Gelatin Composite Hydrogel Oral Patches," *Oral Medicine*, vol. 43, no. 04, pp. 301-307, 2023, doi: 10.13591/j.cnki.kqyx.2023.04.003.
- [56] O. Erel and S. Neselioglu, "A novel and automated assay for thiol/disulphide homeostasis," *Clinical biochemistry*, vol. 47, no. 18, pp. 326-332, 2014.



This is an open-access article distributed under the terms of the Creative Commons Attribution License.