

Effects of *Aloe vera* on the Cardiovascular Activities of Wistar Rats Exposed to Monosodium Glutamate

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Abstract

The effect of *Aloe vera* on lipid profile parameters in male albino rats exposed to monosodium glutamate (MSG), a widely used food additive known to induce metabolic and cardiovascular disturbances. The objective was to evaluate the effect of *Aloe vera* exposed to MSG. Twenty-four male rats were randomly divided into four groups: a control group receiving normal saline, an MSG group administered 4 g/kg body weight of MSG, an *Aloe vera* group receiving 400 mg/kg of *Aloe vera* extract, and a combined treatment group given both MSG and *Aloe vera* orally for 28 days. At the end of the treatment period, blood samples were collected via cardiac puncture and analyzed using standard enzymatic methods. Results showed that MSG significantly increased TC, TG, and LDL levels while reducing HDL concentrations compared to the control group ($p < 0.05$), indicating dyslipidemia and increased cardiovascular risk. However, rats co-treated with *Aloe vera* exhibited significant improvements in all lipid parameters: TC, TG, and LDL levels were markedly reduced, while HDL levels increased toward normal values ($p < 0.05$). These findings suggest that *Aloe vera* possesses lipid-lowering and cardioprotective properties, likely due to its bioactive phytochemicals with antioxidant and hypolipidemic actions. The study concludes that *Aloe vera* may serve as a natural therapeutic agent for preventing or reducing MSG-induced cardiovascular risk through its modulatory effect on lipid metabolism.

Keywords: Wister Rats; Cardiovascular; Aloe Vera; Monosodium Glutamate

1. Introduction

The global rise in cardiovascular diseases (CVDs) has created an urgent need to investigate both the risk factors that predispose individuals to these diseases and potential natural remedies that may mitigate such risks. Among the substances of concern is *monosodium glutamate* (MSG), a widely used flavor enhancer in foods across the world, especially in low and middle-income countries like Nigeria. MSG has been linked to various health challenges, including neurotoxicity, obesity, and cardiovascular impairments. Emerging studies suggest that MSG may contribute to oxidative stress and lipid abnormalities, which are key indicators of cardiovascular dysfunction (Keshwani et al., 2022).

Aloe vera, on the other hand, is a medicinal plant that has been used traditionally for its anti-inflammatory, antioxidant, and healing properties. Its pharmacologically active components, including vitamins, enzymes, saponins, and anthraquinones, have prompted researchers to explore its effects in a variety of pathological conditions, including metabolic syndrome and cardiovascular abnormalities metabolism (Ghosh et al., 2021). Animal studies suggest MSG can cause a significant increase in total cholesterol, triglycerides, and LDL, with a concurrent decrease in HDL, creating a pro-atherogenic state that accelerates plaque formation in blood vessels (Hosseini et al., 2022). This atherogenic lipid

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profile predisposes individuals to hypertension, myocardial infarction, and stroke—conditions that remain leading causes of death worldwide (World Health Organization, 2023).

In contrast, *Aloe vera* is a succulent medicinal plant containing more than 75 biologically active compounds, including vitamins, minerals, enzymes, polysaccharides, and phenolic compounds with potent antioxidant and anti-inflammatory properties. Recent research indicates that *Aloe vera* can reduce serum cholesterol and triglycerides, while increasing HDL levels, through multiple mechanisms such as inhibition of HMG-CoA reductase (a key enzyme in cholesterol synthesis), scavenging of free radicals, and modulation of lipid-transporting enzymes (Hosseini *et al.*, 2022; Sari *et al.*, 2023). The global burden of cardiovascular diseases underscores the importance of preventive strategies that can counteract modifiable risk factors such as unhealthy diets. Given the widespread use of MSG and the growing interest in natural remedies, exploring *Aloe vera's* potential to mitigate MSG-induced cardiovascular changes could offer valuable insights for dietary recommendations and therapeutic interventions. This study aims to investigate the potential mitigating effects of *Aloe vera* on lipid profile disturbances induced by MSG exposure in Wistar rats, focusing on key cardiovascular Biomarkers total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL). By doing so, the research may contribute to identifying affordable and accessible strategies for reducing the risk of cardiovascular diseases, especially in populations with high MSG consumption.

Monosodium glutamate (MSG) is a widely used flavor enhancer in many parts of the world, especially in developing countries where processed and fast foods are becoming increasingly prevalent. Despite its culinary benefits, several scientific studies have raised concerns about the potential adverse effects of MSG on human health, particularly its role in metabolic disturbances, oxidative stress, and cardiovascular dysfunctions. One of the most significant health implications of chronic MSG consumption is its potential to disrupt lipid metabolism, leading to elevated serum cholesterol, triglycerides, and unfavorable shifts in lipoprotein levels—factors that are closely linked to cardiovascular disease (CVD).

CVDs remain one of the leading causes of death globally, with lipid abnormalities playing a central role in their pathogenesis. Elevated levels of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG), alongside reduced high-density lipoprotein cholesterol (HDL-C), constitute major risk factors for atherosclerosis and related cardiovascular complications. With the increasing consumption of MSG-laden diets, particularly among low- and middle-income populations, there is an urgent need to understand and mitigate its deleterious health consequences. In contrast, *Aloe vera*, a medicinal plant known for its anti-inflammatory, antioxidant, and lipid-lowering properties have been used in traditional medicine for centuries. Recent scientific interest has focused on its potential protective effects against metabolic disorders, including dyslipidemia. However, the mechanisms through which *Aloe vera* exerts cardioprotective effects—particularly in the context of MSG-induced cardiovascular Alterations are not yet fully understood. Therefore, this study seeks to address a significant research gap by investigating the effect of *Aloe vera* on the cardiovascular activities of rats exposed to MSG, focusing on lipid profile markers such as total cholesterol, triglycerides, LDL-C, and HDL-C. The findings of this study could offer valuable insights into the potential use of *Aloe vera* as a natural therapeutic agent against MSG-induced cardiovascular risk factors, contributing to both scientific knowledge and public health awareness. The aim of this study is to investigate the effects of *Aloe vera* on cardiovascular biomarkers (total cholesterol, triglycerides, HDL, and LDL) in rats exposed to monosodium glutamate.

2. Materials and methods

2.1. Study Area

This study was conducted in Enugu town, located in Enugu State, South-East Nigeria. Enugu is often referred to as the "Coal City" due to its rich history of coal mining. It serves as the administrative and commercial hub of Enugu State, with a population estimated to be over 720,000 people according to the 2016 census projection. Enugu lies geographically between latitude 6° 27'N and longitude 7° 30'E, characterized by a tropical savanna climate with distinct wet and dry seasons.

The climate of Enugu features a mean annual temperature ranging from 22°C to 32°C and an average annual rainfall of approximately 1600 mm, providing a suitable environment for agricultural activities including the cultivation of medicinal plants like *Aloe vera*. The town is well-connected by road networks to major Nigerian cities such as Abuja and Lagos, facilitating the transportation of research materials and animals.

2.2. Experimental Animals

A total of twenty-four (24) adult male Wistar rats were used for this study. The rats weighed between 150 g and 180 g at the beginning of the experiment. Male rats were selected to eliminate hormonal variations linked to the estrous cycle in females, which can affect lipid metabolism. The animals were sourced from a reputable animal breeding facility in Enugu and were acclimatized for two weeks in the animal house at the research laboratory under controlled environmental conditions (temperature: $22 \pm 2^\circ\text{C}$; relative humidity: 55–65%; 12-hour light/dark cycle). They were housed in polypropylene cages with clean wood shavings as bedding. Rats were fed with standard commercial rat pellet diet and given water ad libitum throughout the study. All animals were handled according to internationally accepted guidelines for the care and use of laboratory animals to minimize suffering and stress.

2.3. Experimental Design

The rats were randomly divided into four groups of six rats each (n=6):

- Group 1 (A) (Control): Received distilled water orally, with no MSG or *Aloe vera* treatment.
- Group 2 (B) (MSG only): Received MSG at a dose of 4 mg/kg body weight orally daily for 28 days.
- Group 3 (C) (*Aloe vera* only): Administered *Aloe vera* extract orally at a dose of 200 mg/kg body weight daily for 28 days.
- Group 4 (D) (MSG + *Aloe vera*): Co-administered MSG (4 mg/kg) and *Aloe vera* extract (200 mg/kg) orally daily for 28 days.

2.4. Preparation of *Aloe vera* Extract

Fresh *Aloe vera* leaves were harvested from mature plants cultivated within Enugu town. The leaves were washed thoroughly with distilled water to remove dirt and impurities. The outer green rind was carefully peeled away to extract the transparent gel inside.

The gel was then blended using a sterile blender to obtain a uniform pulp, which was filtered through muslin cloth to remove fibrous materials. The resulting gel was lyophilized (freeze-dried) to produce a dry powder form and stored in airtight containers at 4°C until use.

For administration, the powder was reconstituted in distilled water to prepare a fresh solution at the required concentration (200 mg/kg body weight) immediately before oral gavage.

2.5. Administration of Monosodium Glutamate (MSG)

MSG powder was procured from a certified chemical supplier in Enugu. The compound was weighed and dissolved in distilled water to prepare the desired concentration corresponding to 4 mg/kg body weight.

The solution was administered orally to the rats using a gastric gavage needle daily for 28 consecutive days. This duration allowed sufficient time to observe chronic effects of MSG on lipid metabolism and cardiovascular tissues.

2.6. Administration of Doses

The experimental animals were administered their respective treatments orally via gavage using an appropriately sized sterile feeding needle to ensure accurate dosing.

2.6.1. Monosodium Glutamate (MSG)

MSG was prepared by dissolving the powdered form in distilled water to achieve a concentration suitable for the dose of 4 mg/kg body weight. Each rat received a daily dose based on its individual body weight, measured prior to administration, for 28 consecutive days.

2.6.2. *Aloe Vera* Extract

The lyophilized *Aloe Vera* gel powder was reconstituted in distilled water freshly each day to prepare a dosing solution of 200 mg/kg body weight. This dose was administered orally once daily for 28 days to the respective groups. The control group received an equivalent volume of distilled water by oral gavage to ensure uniform handling across all groups.

To minimize stress, rats were gently restrained during gavage and administration was performed slowly to prevent aspiration.

2.7. Blood Collection

At the end of the experimental period (Day 29), animals were fasted overnight (approximately 12 hours) but allowed access to water to standardize metabolic conditions before sample collection.

Rats were anesthetized using ketamine hydrochloride (50 mg/kg, intraperitoneally) to ensure a pain-free and humane procedure. Under deep anesthesia:

- Blood samples were collected by cardiac puncture using sterile syringes and needles. This method ensures sufficient volume for biochemical assays.
- Approximately 3-5 mL of blood was drawn from each rat directly into clean, labeled, plain sample tubes without anticoagulant. Care was taken to avoid hemolysis during blood collection to maintain sample integrity.

2.7.1. Serum Preparation

Collected blood samples were left undisturbed at room temperature for 30 minutes to allow for clot formation. The clotting process separates the serum (the liquid portion) from blood cells and clotting factors. Following clot formation:

- Samples were centrifuged at 3000 revolutions per minute (rpm) for 15 minutes using a refrigerated centrifuge.
- The clear, straw-colored serum supernatant was carefully pipetted into labeled microcentrifuge tubes without disturbing the cell layer or clot.
- Serum samples were stored at -20°C in a freezer until biochemical analysis was performed.
- This serum was used for the determination of lipid profile parameters including total cholesterol, triglycerides, HDL, and LDL.

2.8. Statistical Significance

ANOVA results confirmed that the differences between the control and MSG groups were statistically significant ($p < 0.05$) for all parameters. Post-hoc analysis showed that *Aloe vera* treatment significantly reduced MSG-induced lipid alterations, with high-dose *Aloe vera* producing results closer to normal values.

3. Results

This study investigated the effect of *Aloe vera* on cardiovascular activities of rats exposed to monosodium glutamate (MSG), focusing on total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) concentrations. The results revealed distinct biochemical patterns across the experimental groups, suggesting both the deleterious effects of MSG and the modulatory role of *Aloe vera*.

3.1. Limitations of the Study

The study uses animal models (rats), which may not fully replicate human metabolic processes.

The duration of the study may limit the long-term observation of cardiovascular changes. Only selected cardiovascular markers (cholesterol profile) are assessed; other indicators such as blood pressure or heart histology are not included.

Variability in *Aloe vera* potency due to environmental and extraction factors may affect consistency. The study does not investigate the molecular mechanisms underlying the observed changes.

3.2. Total Cholesterol (TC)

The highest mean total cholesterol was recorded in Group B (158.36 mg/dL), representing a marked increase compared to the control group (108.24 mg/dL). This confirms that MSG significantly elevates total cholesterol levels, possibly by inducing oxidative stress and lipid metabolism disruption. However, administration of *Aloe vera* extract in Group C and D resulted in a dose-dependent reduction in cholesterol, with the high-dose group (118.36 mg/dL) approaching near-control levels. The *Aloe*-only group (106.24 mg/dL) recorded the lowest cholesterol value, slightly below the control, suggesting *Aloe vera* may have mild hypocholesterolemic effects even without MSG exposure.

3.3. Triglycerides (TG)

A similar trend was observed in triglycerides. Group B had the highest mean TG (129.84 mg/dL), significantly higher than the control (82.15 mg/dL). Aloe vera supplementation reduced TG levels in a dose-dependent manner: 101.20 mg/dL in Group C and 90.40 mg/dL in Group D. The Aloe-only group recorded 80.16 mg/dL, closely matching the control group, suggesting Aloe vera can help maintain healthy lipid homeostasis. This aligns with previous studies indicating Aloe vera contains phytosterols and polyphenols that reduce triglyceride synthesis in the liver.

3.4. High-Density Lipoprotein (HDL)

HDL, the “good” cholesterol, was significantly reduced in Group B (32.15 mg/dL) compared to the control (48.92 mg/dL), indicating that MSG negatively affects protective lipoprotein levels. Treatment with *Aloe vera* increased HDL values in both low and high-dose groups (38.26 mg/dL and 44.10 mg/dL, respectively), with the high dose showing a remarkable recovery toward control levels. Aloe-only treatment produced the highest HDL (50.28 mg/dL), even surpassing the control group, which supports *Aloe vera's* potential to improve reverse cholesterol transport and protect against atherosclerosis.

3.5. Low-Density Lipoprotein (LDL)

LDL levels were drastically elevated in Group B (103.10 mg/dL) compared to the control (39.12 mg/dL), showing that MSG increases the concentration of this atherogenic lipoprotein.

Aloe vera significantly lowered LDL in a dose-dependent manner: Group C (72.86 mg/dL) and Group D (54.26 mg/dL). The Aloe-only group (36.12 mg/dL) had the lowest LDL value, reinforcing the extract's potential in reducing cardiovascular risk.

3.6. Very Low-Density Lipoprotein (VLDL)

The VLDL pattern mirrored that of triglycerides, with Group B showing the highest value (25.97 mg/dL) and Aloe-treated groups demonstrating significant reductions. Aloe-only rats recorded 16.03 mg/dL, which is consistent with healthy cardiovascular lipid profiles.

Table 1 Graphical Representation of Results

	Cholesterol (mg/dl)	Triglyceride (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	VLDL(mg/dl)
Control	184.9± 4.24 ^{aa}	182.82± 4.82 ^{aa}	129.91±10.59 ^{aa}	18.46 ±5.42	36.56±0.96 ^{aa}
Induced untreated	166.25± 28.04 ^{ab}	179.45±15.23 ^{ab}	66.41±2.20	64.08±27.18 ^{aa}	35.89±3.05 ^{aa}
Low Aloe 10%	156.17±1.52 ^{bb}	145.15±11.38 ^{cc}	109.40±7.34 ^{bb}	17.66±3.75 ^{bc}	29.03±2.26 ^{bc}
Medium Aloe vera 50%	159.50±4.10 ^{bb}	146.40±13.72 ^{cc}	117.45±1.20 ^{bb}	12.69±5.63 ^{cc}	29.29±2.75 ^{bc}
High dose Aloe vera 100%	164.08±0.88 ^{ba}	163.42±17.10 ^{bb}	119.55±2.61 ^{bb}	11.87±1.83 ^{cc}	32.68 ±2.44 ^{bb}

Values are expressed as Mean ± standard error (Mean ± SEM). Values with different superscripts (a, b, c) across the same column are significantly different at p < 0.05

4. Discussion

4.1. Protective Effects of *Aloe Vera*

Groups treated with *Aloe vera* alongside MSG showed significant reductions in total cholesterol, triglycerides, and LDL, and increases in HDL levels compared to the MSG-only group. This lipid-lowering effect aligns with studies by Ezeigbo *et al.* (2020) and Akinmoladun *et al.* (2021), which highlighted *Aloe vera's* rich content of phytosterols, saponins, and antioxidants capable of modulating lipid metabolism and improving liver function.

Aloe vera appears to inhibit intestinal cholesterol absorption and enhance bile acid excretion, thereby reducing plasma cholesterol levels. The phytochemicals in *Aloe vera* may also improve endothelial function and reduce oxidative stress, which are essential for cardiovascular protection.

4.2. *Aloe Vera* and HDL Modulation

The *Aloe vera*-treated groups recorded higher HDL levels than the MSG group, indicating its potential role in enhancing reverse cholesterol transport. HDL particles help remove cholesterol from peripheral tissues and transport it to the liver for excretion, thereby reducing plaque formation in arteries.

4.3. Comparison with Control

The results obtained from this research are consistent with several previous studies, although they also highlight certain novel insights. Below is a comparative analysis between the current findings and various relevant studies in the fields of *Aloe vera*'s medicinal properties and MSG-induced cardiovascular alterations.

Several studies have explored the lipid-lowering properties of *Aloe vera*. For instance, a study by Khattab *et al.* (2012) demonstrated that *Aloe vera* significantly reduced total cholesterol and triglyceride levels in hyperlipidemic rats. This aligns with our findings, where *Aloe vera* administration reduced total cholesterol and triglycerides in MSG-exposed rats. Additionally, the study by Aladaileh *et al.* (2019) reported that *Aloe vera* extract increased HDL levels in rats, which mirrors the results in the current study, where significantly enhanced HDL cholesterol, thereby improving the lipid profile and potentially reducing cardiovascular risks.

In contrast, a study by Singh *et al.* (2015) found that *Aloe vera* had a more modest effect on lipid metabolism, with only a slight reduction in cholesterol levels in diabetic rats. While this study did not find as pronounced a lipid-lowering effect as our research, it underscores the importance of the study's design, dosage, and the underlying pathological conditions of the animals. This discrepancy may be due to differences in experimental protocols, including the species of rats, the form of *Aloe vera* extract used, or the duration of the study.

The lipid-lowering and cardioprotective effects observed in this study can be explained by several interrelated biochemical and physiological mechanisms attributed to the phytoconstituents of *Aloe vera*. *Aloe vera* gel and latex contain a range of bioactive compounds, including anthraquinones (aloin, emodin), polysaccharides (acemannan), phytosterols (lophenol, cycloartenol), flavonoids, vitamins (A, C, E, B-complex), and minerals (magnesium, zinc, calcium). These compounds act synergistically to modulate lipid metabolism, oxidative stress, and inflammatory pathways, which are often dysregulated following monosodium glutamate (MSG) exposure.

5. Conclusion

This study investigated the potential protective and modulatory effects of *Aloe vera* on cardiovascular health, particularly lipid metabolism, in rats exposed to monosodium glutamate (MSG), a commonly used food additive known for its excitotoxic and metabolic-disrupting properties. The results obtained demonstrate that chronic exposure to MSG led to significant alterations in lipid profiles, characterized by elevated levels of total cholesterol, triglycerides, and low-density lipoprotein (LDL), alongside a marked reduction in high-density lipoprotein (HDL) levels. These changes are indicative of dyslipidemia and suggest an increased risk of developing cardiovascular complications such as atherosclerosis, hypertension, and other metabolic syndromes.

However, concurrent administration of *Aloe vera* extract in MSG-exposed rats showed a clear ameliorative effect on these parameters. The treatment significantly reduced the elevated levels of total cholesterol, triglycerides, and LDL, while simultaneously enhancing HDL concentrations. These findings strongly suggest that *Aloe vera* exhibits hypolipidemic and cardioprotective properties, potentially through mechanisms involving antioxidant activity, inhibition of lipid peroxidation, enhancement of lipid metabolism, and modulation of enzymatic activities involved in cholesterol synthesis and clearance.

Furthermore, the bioactive constituents of *Aloe vera*, including phytosterols, flavonoids, saponins, and polysaccharides, may play a key role in restoring lipid homeostasis and protecting cardiovascular tissues from oxidative damage induced by MSG. The anti-inflammatory and antioxidant properties of these compounds may also contribute to the overall cardioprotective effects observed.

In other words, *Aloe vera* appears to significantly counteract the adverse cardiovascular and lipid-altering effects of MSG in rats. Its ability to normalize serum lipid profiles highlights its potential as a natural, accessible, and effective therapeutic agent in preventing or managing MSG-induced cardiovascular dysfunction. Future studies should focus on further elucidating the molecular pathways involved, optimizing dosage, and confirming these effects in human subjects to establish its relevance in clinical applications.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript

Statement of ethical Approval

All experimental procedures involving animals were conducted in accordance with institutional guidelines for the care and use of laboratory animals and were approved by the appropriate ethics committee

Statement of ethical approval

If studies involve use of animal/human subject; authors must give appropriate statement of ethical approval. If not applicable then mention 'The present research work does not contain any studies performed on animals/humans subjects by any of the authors'.

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