Full Length Research Article

© 2024, Centre for Advanced Research in Agricultural Sciences
Research Journal of Agricultural Sciences
Volume 15; Issue 06 (Nov–Dec 2024); pp 1305–1310

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Evaluating the Senolytic and Metabolic Benefits of *Lagerstroemia speciosa* Extract in Aging-Related Disorders: A Focus on Cardiovascular Health, Diabetes, Obesity, and Urinary Tract Infections

P. S. Sujatha*[1] and G. Ganesan[2]

[1-2] PG and Research Department of Zoology, Government Arts College (Autonomous), Coimbatore - 641 018, Tamil Nadu, India

Received: 26 Oct 2024; Revised accepted: 06 Dec 2024

Abstract

Aging is a complex biological process characterized by cellular deterioration, increased oxidative stress, and metabolic dysfunction. Conditions such as diabetes, obesity, and urinary tract infections (UTIs) exacerbate these aging-related processes, leading to heightened cellular senescence. This study evaluates the senolytic effects of *Lagerstroemia speciosa* leaf extract (LELE) and its active constituents, resveratrol and corosolic acid, on physical and metabolic parameters, which are crucial indicators of anti-aging properties. At baseline, the control group exhibited the highest physical measurement values, followed by the metformin-treated group, while the LELE low-dose group showed a significantly lower value, suggesting an initial effect of LELE. By day 42, all groups exhibited increased physical measurements, with the metformin group showing the highest increase, indicating its effectiveness. The LELE high-dose group also showed a noticeable increase compared to the low-dose group, though these differences were not statistically significant when compared to the control group. Cardiovascular metabolic markers, including total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL), were also evaluated. The control group's TC levels did not significantly differ from treatment groups, suggesting that LELE does not contribute to hypercholesterolemia. LELE treatment showed a significant increase in HDL levels, surpassing standard agents like resveratrol and corosolic acid, indicating improved cardiovascular health. Additionally, LELE treatment led to a reduction in LDL levels, suggesting potential anti-aging benefits, although this was not statistically significant. The study demonstrates that *Lagerstroemia speciosa* and its bioactive compounds, particularly at higher doses, may enhance cardiovascular health and metabolic function, which are critical in mitigating the effects of aging and chronic conditions. These findings highlight the potential of natural interventions in promoting healthy aging and combating age-related metabolic disorders.

***Key words*:** Senolytic, Metabolic, *Lagerstroemia speciosa,* Cardiovascular health, Diabetes, Obesity, Urinary tract infections

Aging is a complex process marked by cellular and tissue deterioration, which leads to decreased physiological function and increased disease susceptibility. At the cellular level, aging involves heightened oxidative stress, chronic inflammation, and impaired repair mechanisms. Conditions such as diabetes, obesity, and urinary tract infections (UTIs) accelerate these processes. Diabetes increases reactive oxygen species (ROS), causing oxidative damage, while obesity triggers chronic inflammation, impairing metabolism and increasing insulin resistance. UTIs, especially in the elderly, cause recurring inflammation and oxidative stress, further weakening cellular integrity. These interconnected conditions amplify cellular aging, emphasizing the need for effective strategies to mitigate their impact. While synthetic anti-aging medications may cause side effects, medicinal plants provide a safer, natural alternative [1]. The interconnected conditions of recurrent inflammation, oxidative stress, and cellular aging highlight the need for holistic, effective strategies. Medicinal plants, with their rich array of bioactive compounds, offer a promising and safer alternative to synthetic medications for managing these challenges.

Rich in polyphenols and antioxidants, medicinal plants help reduce oxidative stress and inflammation, promoting cellular health and slowing aging without the risks associated with pharmaceuticals. Bioactive compounds such as polyphenols, flavonoids, and triterpenoids neutralize ROS, reduce cellular damage, and enhance repair mechanisms, supporting the body's defences against age-related diseases. Resveratrol, a polyphenol found in grapes and red wine, and corosolic acid, from *Lagerstroemia speciosa* leaves, have shown promise in promoting longevity. Resveratrol mimics calorie restriction, activating sirtuin pathways to enhance

***Correspondence to:** P. S. Sujatha, E-mail: sujatha2724@gmail.com

Citation: Sujatha PS, Ganesan G. 2024. Evaluating the senolytic and metabolic benefits of *Lagerstroemia speciosa* extract in aging-related disorders: A focus on cardiovascular health, diabetes, obesity, and urinary tract infections. *Res. Jr. Agril. Sci.* 15(6): 1305-1310.

cellular resilience, while corosolic acid improves glucose metabolism and reduces oxidative stress, beneficial for managing diabetes and obesity [2].

This study aims to assess the senolytic effects of these polyphenols, focusing on their antioxidant properties in mitigating oxidative stress linked to aging and chronic conditions. By targeting senescent cells and enhancing repair, these compounds may counteract the effects of metabolic disorders, contributing to healthier aging and improved metabolic health. In addition to their antioxidant and anti-inflammatory properties, resveratrol and corosolic acid regulate metabolic health. Resveratrol improves mitochondrial function and cellular energy production, essential for maintaining tissue health during aging, while corosolic acid helps regulate blood sugar levels and insulin sensitivity. These compounds offer a dual benefit: slowing the aging process and alleviating the metabolic disorders often associated with aging. The findings from this study may offer valuable insights into how polyphenols can be used as natural interventions to delay aging and enhance quality of life for individuals affected by chronic conditions.

In vivo studies

The in vivo studies were conducted using animal models prone to age-related changes. The selected models were administered standardized doses of the *Lagerstroemia speciosa* extracts over a defined period. The effects on aging biomarkers, tissue health, and systemic inflammation were monitored through blood analysis, histological examination of tissues, and molecular assays to determine changes in the expression of senescence-associated genes and inflammatory markers. These combined approaches aimed to provide a comprehensive understanding of the efficacy and mechanisms of the plant extracts in promoting cellular health and mitigating aging processes [3].

MATERIALS AND METHODS

Plant profile

Lagerstroemia speciosa, commonly known as the Queen's Crape Myrtle or Pride of India, is a deciduous tree native to tropical and subtropical regions of Southeast Asia. It belongs to the family Lythraceae and is admired for its vibrant, showy flowers that bloom in shades of pink, purple, and white. The plant thrives in warm climates and is often cultivated for ornamental purposes due to its appealing aesthetic. Beyond its decorative appeal, *Lagerstroemia speciosa* is valued for its significant medicinal properties. Traditional systems of medicine like Ayurveda and other folk practices have long recognized the therapeutic potential of *Lagerstroemia speciosa*. Its bioactive compounds include corosolic acid, ellagic acid, and various flavonoids. Its leaves contain bioactive compounds such as corosolic acid, flavonoids, and ellagic acid, which exhibit potent antioxidant, anti-inflammatory, and anti-diabetic effects. Traditionally used in herbal medicine, extracts from the leaves have been employed to manage conditions like diabetes, metabolic syndrome, and age-related disorders. Its leaves brewed into teas or used in extracts for managing diabetes and promoting overall well-being Research has highlighted the potential anti-aging properties of the plant, attributed to its ability to modulate oxidative stress and support cellular health, all while demonstrating a favourable safety profile.

Collection and authentication of plant samples

The leaves of *Lagerstroemia speciosa* were collected from the P. G. Girls Hostel, Government Arts College (Autonomous), Coimbatore District, Tamil Nadu, India. The identification and authentication of *L. speciosa* are done by the Botanical Survey of India, Coimbatore, and the voucher specimens numbered BSI/SRC/5/23/2020/Tech/50 were placed in the Department of Zoology, Government Arts College (Autonomous), Coimbatore.

Extraction process

The green leaves of *L. speciosa* were collected, washed, and shade-dried for 2 weeks. The leaves were ground into a fine powder (100 g) and soaked in ethanol (1000 ml). The extract is placed in a stoppered container with the solvent and allowed to stand at room temperature for a period of at least 3 days with frequent agitation until the soluble matter has dissolved. The crude drug was strained, pressed, clarified, and filtered before being dried at room temperature [4].

Extraction of phytochemicals

- *Solvent extraction*: Use a hydroethanolic solution (70-80% ethanol) for extraction, as both resveratrol and corosolic acid dissolves effectively in ethanol. The plant powder is soaked in ethanol (e.g., 1:10, w/v) and kept for 24-48 hours.

- *Sonication/heat reflux*: Enhance extraction by either sonication or heating. Sonication with ultrasound waves improves solvent penetration, while reflux extraction (e.g., Soxhlet) maximizes yield.

- *Storage*: Once isolated, resveratrol and corosolic acid are sensitive to light and oxygen, so storing them under low temperatures and in inert conditions (e.g., nitrogen) is advisable.

- *Quality control analysis*: The ethanolic leaf extracts of *L. speciosa* were subjected to a qualitative phytochemical analysis using methods described by Harborne [5] and Trease and Evans [6]. The GC-MS analysis at the South Indian Textile Research Association in Coimbatore identified important compounds in *L. speciosa* ethanolic extracts of green and red leaves. The analysis used Thermo GC-Trace Ultra ver. 5.0 and Thermo MS DSQ 11 chromatography [7]. TLC was performed to analyze the variation in bioactive chemical constituents.

Table 1 Phytochemical analysis of ethanolic leaf extracts of *Lagerstroemia speciosa*

Phytoconstituents	LELE
Carbohydrates	+
Tannins	+
Saponins	+
Flavonoids	+
Alkaloids	+
Quinones	+
Glycosides	+
Terpenoids	+
Triterpenoids	+
Phenols	+
Coumarins	+
Steroids	+

'+' indicates the presence of phytoconstituents
'-' indicates the absence of phytoconstituents

Lagerstroemia speciosa ethanolic leaf extract (LELE) is rich in various bioactive phytochemicals, including alkaloids, flavonoids, saponins, phenols, tannins, proteins, amino acids, reducing sugars, steroids, glycosides, phytosterols, coumarins,

and quinones. Notably, LELE contains a significant presence of corosolic acid and quinones. GC-MS analysis of LELE highlights the predominance of plant sterols at a high rate (84.29%). Thin-layer chromatography (TLC) assessments further reveal the active presence of flavonoids, phenols, polyphenols, and alkaloids. The plant's main contributions to antioxidant and anti-aging properties are more attributed to corosolic acid and other polyphenolic compounds.

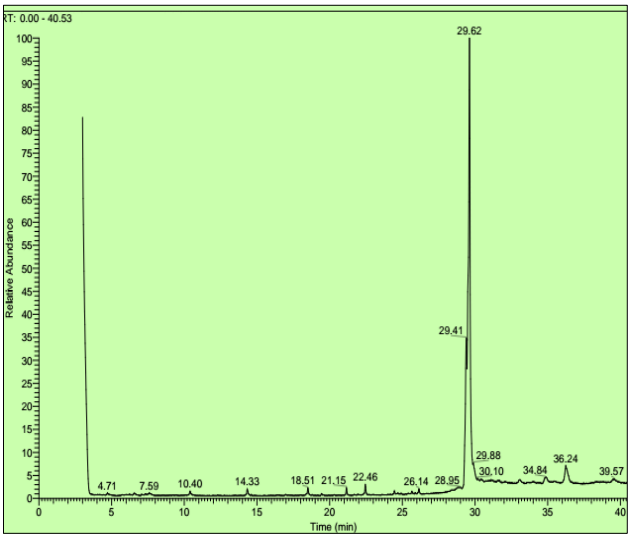

Fig 1 Shows GC-MS spectrum of ethanolic leaf extract of *Lagerstroemia speciosa*

In vivo study

Studying skin aging in mice involves a range of methods to assess changes that mimic those observed in human skin aging. Mice are commonly used as models due to their genetic similarities to humans and the availability of various genetic tools and interventions.

Experimental animals

The Albino Wistar female rats aged 10–12 weeks, weighing between 130 and 230 g, were used in this study. They were raised in the animal house of the Department of Pharmacy, KMCH, Coimbatore, Tamil Nadu. All the animals were placed in polypropylene cages at room temperature with a 12-hour cycle (light/dark). They had free access to water and a standard diet. Rats were acclimatised to laboratory conditions for 7 days before carrying out the experiments.

This study was approved by the Institutional Animal Ethics Committee of KMCH College of Pharmacy in Coimbatore, Tamil Nadu (Approval No. KMCRET/ReRc/Ph. D/24/2021). The animal protocol was accomplished in accordance with the guidelines of the Institutional Animal Ethics Committee of the KMCH College of Pharmacy and Use of Laboratory Animals Manual (8th Edition).

Research on acute oral toxicity

The study involved 14-day toxicological research on acute oral toxicity of ethanolic extract leaves, administered to a group of (n=6) experimental animals, to determine potential fatality rates [8].

Experimental design

The experimental plant, *L. speciosa*, was used in the form of ethanol leaf extracts. A stock solution of the extract was prepared and administered to the experimental groups at both low and high doses to evaluate dose-dependent effects.

Dose application

The experimental groups were organized to receive different treatments, including low and high doses of *L. speciosa* ethanol leaf extract. To provide a comprehensive comparison, metformin was used as a negative standard due to its known effects on baseline aging markers. Positive standards included resveratrol and corosolic acid, both recognized for their significant anti-aging and senolytic properties. The control group received only a vehicle treatment to establish a baseline. The low and high dose groups of *L. speciosa* were designed to assess the dose-dependent impact of the extract on cellular and physiological aging markers. Metformin allowed for comparison with an established baseline treatment, while resveratrol and corosolic acid served as benchmarks to highlight the potential effectiveness of the plant extract. This setup aimed to evaluate the plant extract's ability to reduce cellular senescence and promote cell health in relation to well-known anti-aging compounds.

Group I: Control Animals (Received 1 ml of normal saline per 200 g body weight for 21 days)

Group II: Standard (Received Levofloxacin at 250 mg/kg, 1 ml per day for 21 days)

Group III: Resveratrol Oral Administration Low Dose (250 mg/kg, 1 ml per day for 21 days)

Group IV: Corosolic Acid Oral Administration High Dose (250 mg/kg, 1 ml per day for 21 days)

Group V: LEGLE Oral Administration Low Dose (250 mg/kg, 1 ml per day for 21 days)

Group VI: LEGLE Oral Administration High Dose (500 mg/kg, 1 ml per day for 21 days)

Fig 2 Experimental groups and treatment protocols for assessing the effects of *Lagerstroemia speciosa* on cellular senescence

Table 2 Physical measurements of experimental groups at baseline and 42nd Day

Group	Control	Standard	Resveratrol	Corosolic acid	LEGLE L. D	LEGLE H. D
1st day	149.8±6.12	179±8.266^{ns}	134±5.209^{ns}	135.8±3.39^{ns}	107.5±4.801*	1426.3±1.16^{ns}
42nd day	198±.65	223.8±1.52^{ns}	180±3.92^{ns}	188.2±3.44^{ns}	171±3.39^{ns}	193.4±3.66^{ns}

Statistical comparison: Each group (n=6), each value represents Mean ± SEM. One way ANOVA, followed by Dunnett comparison was performed. (****P*<0.001) control group was compared with std group-III. (****P*<0.001, ***P*<0.01, **P*<0.05) treated groups IV, V, VI and VII was compared With Group I.

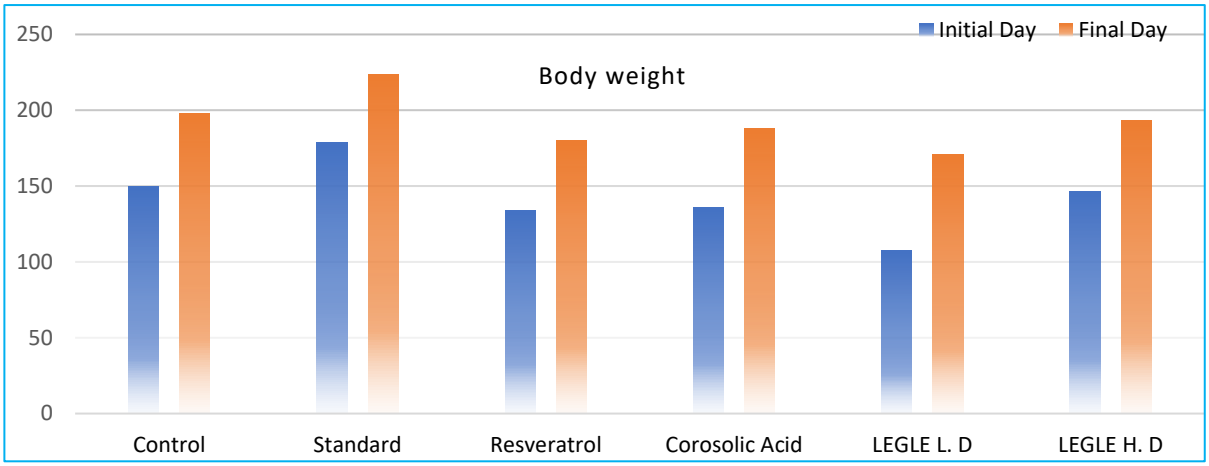

Fig 3 Physical measurements of experimental groups at baseline and 42nd day

Table 3 Effects of *Lagerstroemia speciosa* on cellular senescence in *in vivo* studies

Groups	Control	Standard	Resveratrol	Corosolic acid	LEGLE L. D	LEGLE H. D
HB	14.13±1.73	13.6±0.56^{ns}	12.12±1.19^{ns}	11.1±0.46^{ns}	11.67±0.63^{ns}	13.67±0.393^{ns}
PCV	46.2±4.75	32.13±1.19^{ns}	42±3.055^{ns}	49±1.08^{ns}	31.17±0.48^{ns}	42.33±1.178^{ns}
WBC count	8.5±0.58	15.03±1.68^{ns}	13.83±0.81^{ns}	14.57±0.23^{ns}	18.8±0.09*	13.6±1.99^{ns}
Polymorphs	7.67±0.64	5.33±0.02^{ns}	7±1.58*	9±1.32^{ns}	8.67±1.764*	7.667±0.81^{ns}
Lymphocytes	78.33±1.04	93.33±2.08^{ns}	74±3.05^{ns}	97.33±1.56^{ns}	93±1.87^{ns}	91.33±1.33^{ns}
Monocytes	5±2.092	4.33±1.333^{ns}	7±1.155^{ns}	6±1.28^{ns}	8.03±0.93^{ns}	7.67±1.7^{ns}
Eosinophils	4±0.474	3±0.574^{ns}	5±1.58^{ns}	4.67±0.81^{ns}	5.12±1^{ns}	4.33±0.81^{ns}
RBC count	7.23±0.75	6.03±0.09^{ns}	8.47±0.38^{ns}	9.37±0.14^{ns}	6.01±0.02^{ns}	6.26±0.18^{ns}
MCV	76.8±4.351	78.17±0.32^{ns}	84.17±2.35^{ns}	86.2±1.35^{ns}	83.03±1.8^{ns}	84.97±0.87^{ns}
MCH	22.23±1.38	22.17±0.90^{ns}	28.13±0.240^{ns}	29.5±0.74^{ns}	28.57±0.753^{ns}	31.43±0.31^{ns}
MCHC	37.17±0.28	37.4±0.312^{ns}	31.3±0.586^{ns}	38.47±0.61^{ns}	30.77±0.819^{ns}	31.67±0.66^{ns}
Platelet count	514.3±36.64	580.4±46.02^{ns}	607.3±7.55^{ns}	598.1±1.5^{ns}	617.3±2.57^{ns}	701±23.30*

Statistical comparison: Each group (n=6), each value represents Mean ± SEM. One-way ANOVA, followed by Dunnett comparison was performed. (****P*<0.001) control group was compared with std group-III. (****P*<0.001, ***P*<0.01, **P*<0.05) treated groups IV, V, VI and VII was compared With Group I

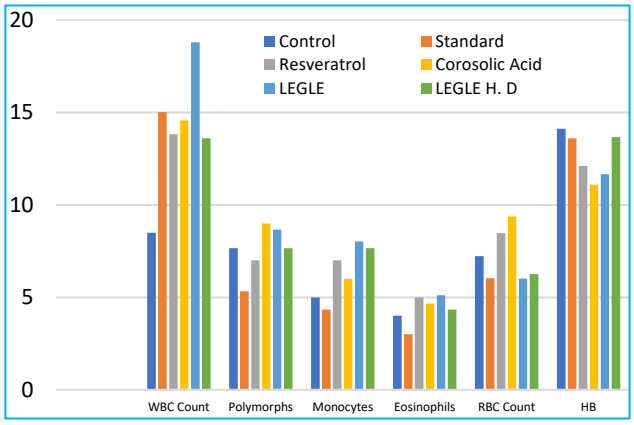

Fig 4 Effects of *Lagerstroemia speciosa* on cellular senescence in *in vivo* studies

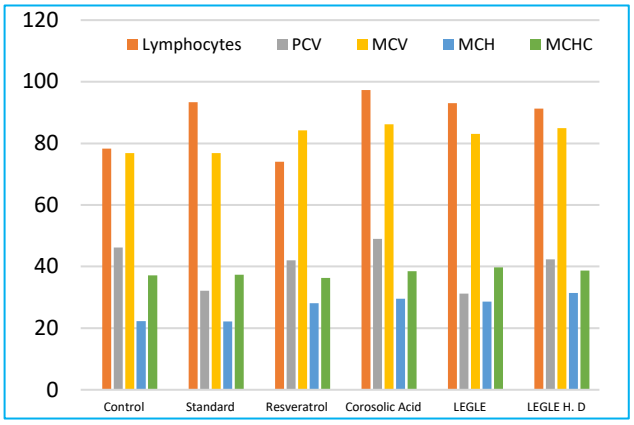

Fig 5 Effects of *Lagerstroemia speciosa* on cellular senescence in *in vivo* studies

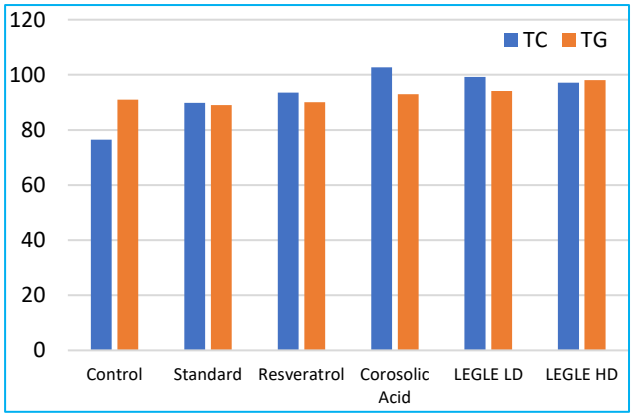

Fig 6 Effect of *Lagerstroemia speciosa* on metabolic cardiovascular markers in *in vivo* studies

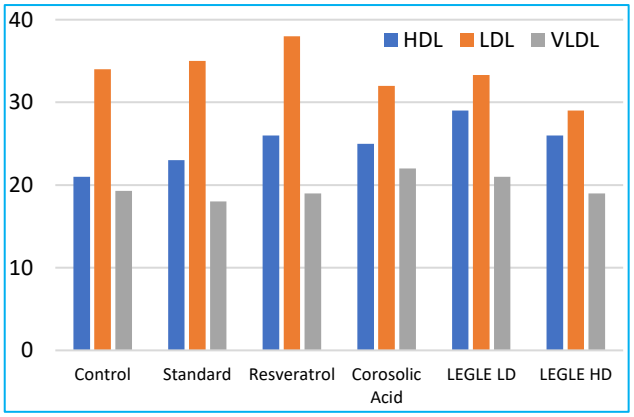

Fig 7 Effect of *Lagerstroemia speciosa* on metabolic cardiovascular markers in *in vivo* studies

Table 4Effect of *Lagerstroemia speciosa* on metabolic cardiovascular markers in *in vivo* studies

Groups	TC	TG	HDL	LDL	VLDL
Control	76.43±3.61^{ns}	91±1.1^{ns}	21±0.57*	34±0.25	19.3±0.76
Standard	89.83±4.89^{ns}	89±1.2^{ns}	23±1.41^{ns}	35±1.98	18±0.49
Resveratrol	93.57±4.52^{ns}	90±1.7^{ns}	26±2.26***	38±2.12	19±0.02
Corosolic acid	102.7±4.11^{ns}	93±0.5^{ns}	25±2.81***	32±1.18	22±0.43
LELE	99.23±4.4^{ns}	94.12±0.3^{ns}	29±2.95***	33.3±1.14	21±0.27

Statistical comparison: Each group (n=6), each value represents Mean ± SEM. One-way ANOVA, followed by Dunnett comparison was performed. (***P<0.001) control group was compared with std group-III. (***P<0.001, **P<0.01, *P<0.05) treated groups IV, V, VI and VII was compared With Group I

RESULTS AND DISCUSSION

The physical measurements indicate that, at baseline (1st day), the control group exhibited the highest value (149.8±6.123), followed by the standard group metformin with 179±8.266. The LELE Low Dose group had a significantly lower value (107.5±4.801), suggesting a potential initial effect of LELE on physical measurement parameters. However, these values did not show significant differences compared to the other groups at this stage [8-10].

On the 42nd day, there was a general increase in the physical measurements of all groups. The standard group metformin showed the highest increase in measurements (223.8±1.52), indicating its effective impact on the physical parameters. The LELE High Dose group (193.4±3.66) also demonstrated a noticeable increase compared to the low dose (171±3.39), but neither of these groups showed a statistically significant difference when compared to the control group (198±0.65). The Resveratrol and Corosolic acid groups showed moderate increases, but none were significantly different from the control or other groups. The data in Table 3 provide valuable insights into the impact of *L. speciosa* and its active constituents on cardiovascular metabolic markers, which are important indicators of anti-aging properties in *in vivo* studies. Cardiovascular health plays a significant role in the aging process, as dyslipidaemia is often linked to age-related decline and increased risk of cardiovascular diseases [11-16].

Total cholesterol (TC)

The control group's mean TC level (76.43±3.61) did not significantly differ from the treatment groups, indicating that while *Lagerstroemia speciosa* (LELE) shows a trend toward higher TC levels (99.23±4.4), these changes were not statistically significant (ns). This suggests that the extract does not contribute to hypercholesterolemia, which is beneficial for anti-aging effects since excessive cholesterol can accelerate cellular aging processes.

Triglycerides (TG)

The TG (Triglycerides) levels remained stable across the groups, with the control at 91±1.1 and LELE at 94.12±0.3. The non-significant differences imply that *Lagerstroemia speciosa*

does not negatively affect TG levels, thus maintaining metabolic homeostasis, a desirable outcome in anti-aging therapies [17].

High-density lipoprotein (HDL)

A significant increase in HDL levels was observed with LELE treatment (29±2.95, p***). This enhancement surpasses that seen with standard anti-aging agents like resveratrol and corosolic acid. High HDL levels are associated with reduced oxidative stress and better cholesterol efflux, crucial for preventing age-related atherosclerosis and promoting cellular longevity.

Low-density lipoprotein (LDL)

The reduction in LDL (Low-density lipoprotein) levels observed with LELE (33.3±1.14) suggests potential anti-aging benefits. Although not statistically significant, lower LDL is associated with decreased inflammation and reduced risk of age-related cardiovascular diseases.

Very-low-density lipoprotein (VLDL)

VLDL (Very-low-density lipoprotein) levels showed minimal variation across treatments, with LEGLE-treated mice displaying levels similar to the control (21±0.27). This stability suggests that *Lagerstroemia speciosa* does not adversely affect VLDL, further supporting its role in maintaining a balanced lipid profile essential for anti-aging [18-19].

CONCLUSION

This study investigated the potential anti-aging effects of *Lagerstroemia speciosa* ethanolic leaf extract (LELE) by evaluating its impact on physical measurements and cardiovascular metabolic markers. The results showed a general increase in physical measurements across all groups by day 42, but no significant differences were observed between the treatment and control groups. LELE, especially at higher doses, did not lead to significant changes in physical parameters. However, the extract demonstrated a significant increase in HDL levels, which is beneficial for reducing oxidative stress and protecting against age-related cardiovascular diseases. Other lipid markers, including total cholesterol, triglycerides, LDL, and VLDL, showed minimal or no significant changes. These findings suggest that LELE may support healthy aging by promoting a balanced lipid profile and increasing HDL levels, which could help prevent cardiovascular decline. Further studies are needed to explore its long-term effects and underlying mechanisms. In conclusion, this study suggests that *Lagerstroemia speciosa* ethanolic leaf extract (LELE) may offer potential anti-aging benefits, particularly through its ability to significantly increase HDL levels, which are associated with reduced oxidative stress and a lower risk of age-related cardiovascular diseases. While LELE did not show significant changes in physical measurements or lipid profile markers such as total cholesterol, triglycerides, LDL, and VLDL, it maintained a balanced lipid profile, which is beneficial for healthy aging. Further research is needed to fully understand LELE's long-term effects and mechanisms in promoting healthy aging and preventing cardiovascular decline.

LITERATURE CITED

1. Ndlovu G, Fouche G, Tselanyane M. 2013. *In vitro* determination of the anti-aging potential of four southern African medicinal plants. *BMC Complement Altern. Med.* 13: 304. https://doi.org/10.1186/1472-6882-13-304
2. Baur JA, Sinclair DA. 2006. Therapeutic potential of resveratrol: the in vivo evidence. *Nature Reviews Drug Discovery* 5(6): 493-506.
3. Wang X. 2019. The anti-aging effects of metformin: the potential mechanisms. *Ageing Research Reviews* 49: 1-9.
4. Kongkathip N. 1994. Chemistry and extraction method of neem-Bankok: 3rd Workshop in the using neem leaf extracts for control and eradicate in insects.
5. Harborne JB. 1984. *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis*. 2nd Edition, London New York.
6. Trease GE, Evans WC. 1989. *Pharmacognosy*. 11th Edition, Brailliar Tiridel Can. Macmillian Publishers.
7. Cai L. 2014. Thin layer chromatography. *Current Protocols Essential Laboratory Techniques* 8(1): 6-3.
8. Barzilai N, Crandall JP, Kritchevsky SB, Espeland MA. 2016. Metformin as a tool to target aging. *Cell Metabolism* 23(6): 1060-1065.
9. Hara Y, Masuda Y, Hirao T, Yoshikawa N. 2013. The relationship between the Young's modulus of the stratum corneum and age: a pilot study. *Skin Research and Technology* 19(3): 339-345.
10. Lez-Otin C, Blasco MA, Partridge L, Serrano M, Kroemer G. 2013. The hallmarks of aging. *Cell* 153(6): 1194-1217.
11. Miller RA. 1997. The aging immune system: Implications for health and disease. *Science* 278(5341): 236-241.
12. Kim JS. 2018. Anti-diabetic and anti-inflammatory effects of corosolic acid. *Journal of Ethnopharmacology* 219: 123-132.
13. Fisher GJ, Kang S, Varani J, Bata-Csorgo Z, Wan Y, Datta S, Voorhees JJ. 2002. Mechanisms of photoaging and chronological skin aging. *Archives of Dermatology* 138(11): 1462-1470.
14. Ganesan G, Sujatha PS. 2024. Evaluation of phyto - pharmacological properties and GC-MS studies on ethanolic extracts of red and green leaves of *Lagerstroemia speciosa* (L) Pers (Lythraceae). *Res. Jr. Agril. Sciences* 15(2): 432-436.
15. Kongkathip N. 1994. Chemistry and extraction method of neem- Bankon: 3rd workshop in the neem leaf extracts to control and eradicate insects.
16. Liu F, Kim J, Li Y, Liu X, Li J, Chen X. 2001. An extract of *Lagerstroemia speciosa* L has insulin-like glucose uptake-stimulatory and adipocyte differentiation-inhibitory activities in 3T3-L1 cells. *Journal of Nutrition* 131: 2242-2247.
17. Parhofer KG, Laufs U. 2019. The diagnosis and treatment of hypertriglyceridemia. *Dtsch Arztebl Int*. 116(49): 825-832.
18. Yagyu H, Lutz EP, Kako Y, Marks S, Hu Y, Choi SY, Bensadoun A, Goldberg IJ. 2002. Very low-density lipoprotein (VLDL) receptor-deficient mice have reduced lipoprotein lipase activity. Possible causes of hypertriglyceridemia and reduced body mass with VLDL receptor deficiency. *Jr. Biol. Chem* 277(12): 10037-10043.
19. MacDougall ED, Kramer F, Polinsky P, Barnhart S, Askari B, Johansson F, Varon R, Rosenfeld ME, Oka K, Chan L, Schwartz SM, Bornfeldt KE. 2006. Aggressive very low-density lipoprotein (VLDL) and LDL lowering by gene transfer of the VLDL receptor combined with a low-fat diet regimen induces regression and reduces macrophage content in advanced atherosclerotic lesions in LDL receptor-deficient mice. *Am. Jr. Pathology* 168(6): 2064-2073.