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The Effect of Salacca Zalacca Peel Extract, Moderate-Intensity Physical Activity, and Intermittent Fasting on Fasting Blood Glucose, Lipid Profile, and Malondialdehyde (MDA) in Type 2 Diabetic Rats: Case Study

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ABSTRACT: Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance, persistent hyperglycemia, and increased oxidative stress, which together contribute to dyslipidemia and long-term complications. Natural bioactive compounds and lifestyle modifications are widely explored as complementary strategies for glycemic control. This study aimed to investigate the effects of Salacca zalacca (snake fruit) peel extract, moderate-intensity physical activity, and intermittent fasting on fasting blood glucose, lipid profile, and malondialdehyde (MDA) levels in rats with induced T2DM. A quasi-experimental pretest-posttest design was used with 25 male Wistar rats randomly assigned to five groups: negative control, metformin-treated, Salacca zalacca peel extract, moderate-intensity swimming, and intermittent fasting. Diabetes was induced using streptozotocin (STZ). Fasting blood glucose, lipid profile, and MDA levels were measured at predetermined intervals before and after the interventions. Data were analyzed using the Wilcoxon signed-rank test, with a significance level of $p \leq 0.05$. The results showed significant reductions in fasting blood glucose in several groups, particularly those receiving swimming and intermittent fasting interventions ($p \leq 0.05$). In contrast, no significant changes were observed in lipid profile parameters, including total cholesterol, triglycerides, and related fractions ($p \geq 0.05$). However, MDA levels showed notable differences before and after the interventions, indicating a modulation of oxidative stress. In conclusion, moderate-intensity swimming and intermittent fasting effectively improved glycemic control and reduced lipid peroxidation in T2DM rats, whereas their effects on lipid profile were limited. These findings support lifestyle-based interventions, alongside natural products, as promising complementary approaches in T2DM management.

1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance and progressive impairment of pancreatic β-cell function, resulting in persistent hyperglycemia. It accounts for most diabetes cases worldwide and develops through interactions among genetic susceptibility, metabolic changes, and environmental exposures. Commonly reported risk factors include older age, family history, ethnicity, excess body weight, physical inactivity, and prediabetes (Chatterjee et al., 2017; Bellou et al., 2018; Zheng et al., 2017). These factors are relevant to research using diabetic rats because they help frame the biological processes that experimental models are intended to represent.

Physical inactivity is a modifiable risk factor associated with impaired glucose regulation. Skeletal muscle uses glucose during contraction, while regular exercise can improve insulin sensitivity and glucose uptake. In people with T2DM, physical activity is therefore incorporated into comprehensive management alongside diabetes education, nutritional therapy, and medication when indicated (Colberg et al., 2016; Kanaley et al., 2022; Davies et al., 2022). In experimental research, moderate-intensity physical activity offers a way to examine how regular muscular activity may influence fasting blood glucose and related metabolic outcomes.

The global burden of diabetes underscores the need for research into prevention and complementary approaches to metabolic management. Estimates for 2019 indicated approximately 463 million adults worldwide were living with diabetes, with the number projected to rise to 700 million by 2045 (Saeedi et al., 2019). These figures refer to diabetes overall, not exclusively T2DM. The growing burden strengthens the rationale for investigating interventions that could affect glucose regulation and associated metabolic disturbances, while distinguishing experimental findings from evidence of clinical effectiveness.

Standard T2DM management combines lifestyle measures with pharmacological treatment selected according to clinical needs. Researchers have also examined dietary patterns and functional food ingredients as possible complementary strategies. Intermittent fasting, which organizes eating and fasting into defined periods, has been studied for its potential metabolic effects. However, evidence from human studies and animal experiments should not be treated as interchangeable, and fasting regimens require careful consideration when diabetes or glucose-lowering medication is involved (Patterson & Sears, 2017; de Cabo & Mattson, 2019).

The peel of Salacca zalacca, commonly known as salak, has attracted research interest due to its phytochemicals, which have been reported to have antioxidant activity. Investigations of salak peel extracts have examined their chemical composition and biological properties, including antioxidant and α-glucosidase-inhibitory activities (Saleh et al., 2018). These findings provide a rationale for testing the extract in experimental models. However, they do not by themselves establish that the extract lowers blood glucose or is safe and effective in humans. The effects may depend on the preparation, dose, and composition of the extract.

The outcomes assessed in the present study represent different aspects of diabetes-associated metabolic disturbances. Fasting blood glucose reflects glucose regulation, whereas lipid profile parameters, including cholesterol and triglyceride levels, provide information on dyslipidemia. Malondialdehyde (MDA) is commonly used as a biomarker of lipid peroxidation and oxidative stress, although its interpretation depends on the assay and biological context (Ito et al., 2019). Research on plant-derived materials, including the isolation and fractionation of lignin from sugarcane bagasse, has also explored their potential antioxidant properties (Marbun, 2025). However, antioxidant potential alone does not establish an ability to reduce oxidative stress in diabetic animal models. Therefore, assessing fasting blood glucose, lipid profiles, and MDA together provides a broader evaluation of metabolic changes following the interventions.

A study in diabetic rats can investigate the effects of Salacca zalacca peel extract, moderate-intensity physical activity, and intermittent fasting under controlled experimental conditions. If the study compares these interventions individually and in combination, it may also help assess whether combined treatment produces a different pattern of outcomes from each intervention alone. Such results would be specific to the animal model and study protocol; they should not be presented as proof of benefit in people with T2DM without appropriate clinical research.

Accordingly, this study examines the effects of Salacca zalacca peel extract, moderate-intensity physical activity, and intermittent fasting on fasting blood glucose, lipid profile, and MDA levels in type 2 diabetic rats. By evaluating glycemic, lipid, and oxidative-

stress-related outcomes, the research aims to characterize the interventions' effects within the experimental model and contribute evidence for future investigation of complementary approaches to diabetes management.

2. MATERIALS AND METHODS

2.1 Study Design and Animals

This study employed a quasi-experimental pretest-posttest design to evaluate the effects of metformin treatment, Salacca zalacca peel extract, moderate-intensity swimming, and intermittent fasting on selected metabolic parameters in rats with diabetes mellitus. The study involved 25 male Wistar rats weighing 150–200 g, with blood glucose levels >250 mg/dL. The animals were divided into five experimental groups, with five rats assigned to each group: (1) negative control, (2) metformin treatment, (3) Salacca zalacca peel extract treatment, (4) moderate-intensity swimming, and (5) intermittent fasting using a 16/8 protocol. The pretest-posttest design enabled the evaluation of changes in the measured parameters before and after the assigned interventions. All interventions were conducted over a three-week experimental period.

2.2 Induction of Type 2 Diabetes Mellitus

Diabetes mellitus was induced in the experimental animals through a single intraperitoneal injection of streptozotocin (STZ) at a dose of 45 mg/kg body weight. STZ was used to induce hyperglycemia in rats prior to evaluation of the experimental interventions. Blood glucose levels were assessed to determine the animals' glycemic status, and rats with blood glucose levels >250 mg/dL were considered eligible for inclusion in the study. Following the induction procedure, the animals were assigned to their respective experimental groups according to the study design. The specific solvent and buffer used to prepare the STZ solution were not documented in the available method description.

2.3 Intervention Protocols

The experimental interventions were administered over a period of three weeks (21 days). The study included four intervention approaches: metformin treatment, Salacca zalacca peel extract treatment, moderate-intensity swimming, and intermittent fasting. The negative control group served as the reference group for evaluating the changes observed during the experimental period. The metformin group received metformin as the pharmacological intervention, whereas the extract group received Salacca zalacca peel extract. The swimming group underwent moderate-intensity swimming exercise, while the intermittent fasting group followed a 16/8 protocol, consisting of 16 hours of fasting and an 8-hour feeding window. These interventions were evaluated to examine changes in blood glucose levels, lipid profiles, and malondialdehyde (MDA) levels. Specific treatment doses, extract preparation procedures, swimming duration and frequency, and feeding schedules beyond the stated fasting protocol were not available in the original method description.

2.4 Analytical Methods

Metabolic parameters were assessed during the experimental period to evaluate changes associated with the assigned interventions. Blood glucose levels were measured every 3 days throughout the 3-week intervention period to monitor glycemic changes. These repeated measurements provided information on the progression of blood glucose levels during treatment. Lipid profiles were evaluated before and after the intervention to assess changes in lipid-related parameters. In addition, malondialdehyde (MDA) levels were measured before the intervention and on day 21 to evaluate changes in this marker of lipid peroxidation. The pretest and posttest measurements were used to assess changes in the measured biochemical parameters following the experimental interventions. However, the specific lipid components analyzed, the instruments and laboratory assays employed, the blood collection site, and the fasting duration before sample collection were not specified in the available method description.

2.5 Statistical Analysis

The collected data were analyzed using IBM SPSS Statistics version 23. The results were presented as mean values to describe the measured parameters in each experimental group. Differences between pre-intervention and post-intervention measurements within each group were analyzed using the Wilcoxon signed-rank test. This nonparametric test was used to evaluate paired observations obtained from the same experimental subjects at two measurement points. Statistical significance was set at $p \leq 0.05$. The statistical analysis focused on changes in the measured parameters following the assigned interventions.

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Any additional comparisons between the five experimental groups should be reported separately if such analyses were performed in the original study.

3. RESULTS AND DISCUSSION

3.1 Fasting Blood Glucose Levels

Mean fasting blood glucose levels are shown in Table 1. Baseline values were similar across groups (108.6-124.6 mg/dL) and increased markedly in all groups after induction (Day 4). Between Days 4 and 19, mean glucose ranged from 373.6 to 494.6 mg/dL in the control group and from 239.0 to 343.6 mg/dL in the metformin group. The Salacca zalacca peel extract group had the lowest mean glucose on Day 4 (252.6 mg/dL) and its lowest post-induction value on Day 16 (163.5 mg/dL); the mean on Day 19 was 296.7 mg/dL. Mean glucose on Day 19 was lower than on Day 4 in the swimming group (308.0 vs 464.4 mg/dL) and in the intermittent fasting group (325.0 vs 429.8 mg/dL). Compared with the control group, glucose levels differed significantly on Days [X and Y] ($p \leq 0.05$; [test], [post hoc]).

Table 1. Mean Fasting Blood Glucose Levels in T2DM Rats (mg/dL)

Group	Day 1	Day 4	Day 7	Day 10	Day 13	Day 16	Day 19
Control	109	477.4	427.6	407.4	373.6	494.6	409.7
Metformin	115	343.6	326.2	239	283.8	288.2	309.7
Salacca Extract	108.6	252.6	308	299.75	246	163.5	296.7
Swimming	124.6	464.4	337.2	433.6	352.8	313.6	308
Intermittent Fasting	116.8	429.8	306.5	459.25	418	356.75	325

Significant improvements in fasting glucose levels were observed across several groups, particularly on days 4, 7, and 10 ($p \leq 0.05$).

3.2 Lipid Profile

Pre- and post-treatment [parameter] levels are shown in Table 2. Post-treatment means were higher than pre-treatment means in all groups (control: 105.80 ± 5.76 to 125.33 ± 13.05 mg/dL; metformin: 110.20 ± 4.87 to 192.33 ± 26.41 mg/dL). Pre–post differences were not statistically significant in any group ($p > 0.05$; [test]). Post-treatment values were available for three animals per group, except the swimming group ($n = 4$).

Table 2. Lipid Profile Pre- and Post-Treatment (mg/dL)

Subject	TP		M		EX		B		If	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	100	n/a	118	n/a	102	n/a	107	n/a	112	n/a
2	106	115	108	169	118	159	119	202	114	154
3	115	140	105	221	102	160	103	187	105	168
4	102	121	109	187	101	136	101	130	102	142
5	106	n/a	111	n/a	108	n/a	102	198	107	n/a
Average	105.8	125.33	110.20	192.33	106.20	151.67	106.4	179.2	108.00	154.67
Elementary School	5.76	13.05	4.87	26.41	7.16	13.58	7.40	33.44	4.95	13.01

3.3 Malondialdehyde (MDA) Levels

Mean MDA levels before and after the intervention are presented in Table 3. Mean MDA levels increased after the intervention in all five groups: control (2.31 to 2.86), metformin (2.55 to 2.66), Salacca zalacca peel extract (1.98 to 3.16), moderate-intensity swimming (2.09 to 2.83), and intermittent fasting (2.06 to 2.62). The largest increase was observed in the Salacca zalacca peel extract group, followed by the swimming group. The increase in the swimming group was statistically significant ($p \leq 0.05$), according to the corresponding statistical analysis.

Table 3. Mean MDA Levels Pre- and Post-Treatment

Subject	Group 1 (TP)		Group 2 - M		Group 3 - EX		Group 4 - B		Group 5 - If	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	2.08	1.77	2.08	2.51	1.58	3.53	2.60	3.18	2.17	3.13
2	2.34	2.85	2.34	2.81	1.78	3.44	2.35	2.86	2.02	2.50
3	2.52	3.95	3.95	n/a	2.14	2.52	1.58	2.71	2.29	2.24
4	2.32	n/a	2.08	n/a	2.14	n/a	1.78	2.46	1.53	n/a
5	2.31	n/a	2.34	n/a	2.24	n/a	2.14	2.96	2.28	n/a
Average	2.31	2.86	2.55	2.66	1.98	3.16	2.09a	2.83a	2.06	2.62
Elementary School	0.16	1.09	0.79	0.21	0.28	0.56	0.41	0.27	0.31	0.46

3.4 Discussion

The study found statistically significant changes in fasting blood glucose at several time points, including increases on days 1 and 4 across the control, metformin, Salacca zalacca peel extract, swimming, and intermittent fasting groups ($p \leq 0.05$). Because the increases occurred across all groups, they should not be interpreted as evidence of a treatment-specific effect without examining between-group comparisons, baseline values, and the interaction between treatment and time. Glucose concentration is dynamically regulated by hepatic glucose production, peripheral glucose uptake, and hormonal feedback, so changes during an experiment may reflect both treatment effects and time-related or physiological variation (Petersen & Shulman, 2018; Röder et al., 2016).

Under normal physiological conditions, blood glucose is maintained through coordinated metabolic pathways, including glycogenesis, glycogenolysis, glycolysis, and gluconeogenesis. The liver plays a central role by storing glucose as glycogen after feeding and releasing glucose through glycogenolysis or gluconeogenesis when circulating glucose is low. Insulin supports glucose uptake and storage while suppressing hepatic glucose production; glucagon promotes hepatic glucose release, particularly during fasting. Disruption of this balance, including hepatic insulin resistance, contributes to elevated glucose concentrations in T2DM (Petersen & Shulman, 2018; Cherrington, 1999; Han et al., 2016).

The glucose increases observed on days 1 and 4 across all groups may reflect variation in the animals' metabolic state, the timing of fasting and blood collection, handling stress, or the progression of the experimental model. These possible explanations should be evaluated against the study protocol and should not be presented as established causes unless they were measured. In addition, a significant change within each group does not by itself demonstrate that the groups responded differently. A between-group comparison or treatment-by-time analysis is needed to determine whether metformin, peel extract, swimming, or intermittent fasting altered glucose differently from the untreated control (Davies et al., 2022; Colberg et al., 2016).

For the lipid profile, no statistically significant differences were reported in the untreated, metformin, or S. zalacca peel extract groups ($p \geq 0.05$). This result indicates that the study did not detect a difference under the conditions and duration tested; it does not establish that the interventions have no lipid-related effect. Interpretation should consider the sample size, variability, intervention dose, duration, and the individual lipid measures analyzed. For botanical preparations, differences in extraction

method and phytochemical concentration may also contribute to variation between studies (Suntara et al., 2024; Ridho et al., 2019).

Phytochemical analysis of the peel extract identified flavonoids, tannins, and triterpenoids. These compounds provide a plausible basis for investigating potential effects on lipid metabolism. Studies of other plant extracts have also examined phytochemical constituents and antioxidant activity, including saponin analysis and DPPH radical-scavenging assays (Wirman et al., 2024). However, the presence of a compound class does not establish that the administered extract inhibited HMG-CoA reductase or increased cholesterol catabolism in the animals. Those mechanisms would require direct measurement, such as enzyme activity or relevant molecular markers. Evidence from other plant extracts may provide a comparative basis for further investigation, but the findings cannot be assumed to apply directly to S. zalacca peel (Andrew et al., 2025; Ridho et al., 2019).

MDA levels changed across the study groups, but the differences were not statistically significant. MDA is commonly used as an indicator associated with lipid peroxidation, a process in which reactive species damage membrane lipids. However, MDA is not a direct or comprehensive measure of all oxidative stress, and its interpretation depends on the assay method, sample handling, and the biological context. Consequently, the observed non-significant changes indicate that the study did not detect a clear difference in MDA among groups, rather than proving that oxidative processes were unchanged (Ito et al., 2019; Li Pomi et al., 2026).

The non-significant MDA result for the peel-extract group may be consistent with an antioxidant effect that was not detectable under the experimental conditions. However, it cannot establish that the extract's antioxidant activity was insufficient. Other explanations include the treatment period, dose, bioavailability of active compounds, variability among animals, or limited statistical power. Antioxidant capacity measured in chemical screening also does not necessarily translate into a measurable reduction in tissue lipid peroxidation in vivo. Follow-up studies could assess additional oxidative-stress indicators and specify the extract's chemical profile and dosing regimen (Saleh et al., 2018; Ito et al., 2019).

Overall, the findings show significant changes in fasting glucose at selected measurement points, whereas the reported lipid profile comparisons and MDA changes were not statistically significant in the specified groups. The results support a cautious interpretation: the study detected changes over time, but the available findings alone do not demonstrate that the peel extract, swimming, or intermittent fasting caused a distinct improvement in glucose, lipid, or oxidative stress outcomes. Reporting group-wise values, effect sizes, confidence intervals, and the statistical test used would help distinguish within-group change from treatment-specific effects and clarify the strength of the evidence.

4. CONCLUSION

Salacca zalacca peel extract, swimming, and intermittent fasting lowered fasting blood glucose levels in T2DM rats during the observation period, with the lowest mean value in the extract group (Day 16). However, glucose rose again on Day 19. Lipid parameters did not change significantly in any group. Malondialdehyde (MDA) levels increased significantly only in the swimming group, so no antioxidant benefit was demonstrated under the present conditions. These findings are preliminary because of the small sample size and incomplete post-treatment data. Future studies should use larger samples with complete follow-up, longer treatment periods, and multiple extract doses. They should include additional oxidative stress markers (e.g., SOD, catalase, GSH) and diabetes-related parameters (e.g., insulin, HbA1c). Swimming intensity and MDA sampling timing should also be standardized. Combined interventions (extract plus exercise or fasting) should be tested directly before they are recommended as a complementary strategy for managing type 2 diabetes.

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