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The Effect of Lemongrass Extract (Cymbopogon Citratus), Moderate-Intensity Physical Activity, Intermittent Fasting (IF) on Fasting Blood Glucose Levels, Lipid Profile, and MDA in Type 2 Diabetes Rats: Case Study

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ABSTRACT: The International Diabetes Federation reported that 537 million adults aged 20-79 years lived with diabetes in 2021, and this number is projected to reach 643 million by 2030 and 784 million by 2045. The Western Pacific region carries the largest burden, with approximately 206 million cases. Type 2 diabetes mellitus (T2DM) is closely associated with hyperglycemia, dyslipidemia, and oxidative stress, which encourages the exploration of complementary, non-pharmacological approaches. This study aimed to determine the effects of lemongrass (Cymbopogon citratus) extract, moderate-intensity physical activity, and intermittent fasting on fasting blood glucose levels, lipid profiles, and malondialdehyde (MDA) levels in T2DM rat models. A laboratory quasi-experimental study with a pretest-posttest group design was conducted using 25 male Wistar rats divided into five groups: negative control, metformin, lemongrass extract, moderate-intensity physical activity (swimming), and intermittent fasting. Fasting blood glucose, lipid profiles, and MDA levels were measured before and after the intervention and analyzed using the nonparametric Wilcoxon test at a significance level of $p \leq 0.05$. Fasting blood glucose levels changed significantly between the measurement points on days 1 and 4 in one group ($p \leq 0.05$). No significant changes in lipid profiles were found in any group ($p \geq 0.05$). A significant difference in MDA levels between pre- and post-intervention measurements was observed in one group ($p \leq 0.05$). The interventions did not significantly alter lipid profiles, while significant changes in fasting blood glucose and MDA were limited to specific groups. Further research is needed.

1. INTRODUCTION

Diabetes mellitus is a chronic metabolic disease characterized by elevated blood glucose. Type 2 diabetes mellitus (T2DM), the most common form, involves impaired insulin action, inadequate insulin secretion, or both. Persistent hyperglycemia can contribute to damage in multiple organs and increase the risk of long-term complications. The global burden remains

substantial: an estimated 537 million adults were living with diabetes in 2021, and the number is projected to increase in the coming decades (Sun et al., 2022).

Abnormalities in lipid metabolism frequently accompany T2DM. Dyslipidemia, including elevated triglycerides and low high-density lipoprotein cholesterol, is relevant to cardiovascular risk in people with diabetes. Because glucose and lipid metabolism are both influenced by insulin action, evaluating glycemic and lipid outcomes together can provide a broader view of metabolic responses to an intervention. Metformin, a widely used glucose-lowering medicine, acts through several cellular and molecular mechanisms, including effects on hepatic glucose production (LaMoia & Shulman, 2020).

Lifestyle approaches are also considered in diabetes management. Intermittent fasting (IF) alternates periods of eating with periods of restricted or no caloric intake. Its effects on metabolism have been investigated in experimental and clinical settings, but outcomes depend on the fasting regimen, duration, population, and concurrent treatments. Experimental research has examined metabolic adaptations when intermittent fasting is combined with exercise (Real-Hohn et al., 2018). In diabetic rats, fasting and exercise interventions have also been studied in relation to glucose-metabolic and oxidative pathways (Chijiokwu et al., 2022). These findings provide a rationale for further investigation but do not, by themselves, establish the effects of the specific fasting protocol used in the present study.

Oxidative stress is another relevant feature of diabetes and its complications. Malondialdehyde (MDA), a product of lipid peroxidation, is commonly measured as an indicator associated with oxidative damage. Research on plant-derived compounds has also investigated antioxidant activity using in vitro assays, including the DPPH method (Wirman et al., 2024). Research on lemongrass (Cymbopogon citratus) has examined its antioxidant and hypoglycemic properties, including studies of extracts and isolated compounds (Wang et al., 2022). Lemongrass extract has also been studied in rats for its effects on antioxidant status and atherogenic indices (Somparn et al., 2018). In diabetic animal models, research on lemongrass-derived phenolic compounds has examined oxidative stress and related outcomes (Falode et al., 2023). However, differences in extract preparation, dose, model, and treatment duration mean that results from these studies cannot be assumed to predict the response to the extract used in the present experiment.

Physical activity is another component of diabetes management. Exercise can improve insulin sensitivity and glucose regulation, although responses depend on the type, intensity, and duration of exercise, as well as individual characteristics. A consensus statement on physical activity in people with T2DM describes the role of exercise in diabetes care (Kanaley et al., 2022). Experimental studies have also investigated exercise-related effects on insulin resistance and skeletal-muscle metabolism in diabetic models (Yang et al., 2020). Swimming provides a form of physical activity that can be tested under controlled experimental conditions. However, its effects should be evaluated using the specific protocol and outcomes applied in each study.

The three approaches considered here may influence metabolic outcomes through different pathways. Research has examined intermittent fasting and exercise in relation to energy metabolism (Real-Hohn et al., 2018), while lemongrass studies have assessed glucose-related, antioxidant, and lipid-related outcomes (Wang et al., 2022; Somparn et al., 2018). Evidence from related interventions also highlights the value of measuring glycemic, lipid, and oxidative-stress outcomes together rather than relying on glucose alone (Liu et al., 2020). Nevertheless, findings from human studies, other plant extracts, or other animal models do not constitute direct evidence for the effects of lemongrass, swimming, or IF in the present T2DM rat model.

These interventions have generally been examined using different study designs and protocols. Their effects have therefore not been directly compared within the specific experimental framework used in this study. The present study aimed to evaluate the effects of lemongrass extract (Cymbopogon citratus), moderate-intensity swimming, and intermittent fasting on fasting blood glucose, lipid profile, and MDA levels in rats with T2DM. Specifically, it examined whether each intervention was associated with changes in these outcomes during the study period.

2. MATERIALS AND METHODS

2.1 Study Design, Time, and Place

This study used a laboratory experimental design with a quasi-experimental pretest-posttest group approach, in which measurements were taken before and after the intervention within each group to evaluate within-group changes. The study consisted of environmental adaptation, STZ administration, treatment administration, and observation of the results. Type 2

diabetes mellitus (T2DM) was induced in the experimental animals, which were then divided into five groups: a non-treated group, a metformin group, a lemongrass extract group, a swimming group, and an intermittent fasting group. The treatments were administered for 3 weeks. The study was conducted from November to December 2023 at the Medan City Laboratory.

2.2 Instruments, Materials, and Experimental Animals

The instruments used in this study were a UV-Vis spectrometer, a gravimeter, an ELISA reader, and a Glucodr test meter. The Glucodr test meter was used to measure fasting blood glucose levels, and [instrumen untuk lipid dan MDA, misalnya ELISA reader] was used to measure the lipid profile and MDA levels. The materials used were streptozotocin (STZ), ketamine, metformin 500 mg, Gengigel® gel 20 ml, and lemongrass ethanol extract (EES).

Twenty-five adult male white rats of the Wistar strain (Rattus norvegicus) were used in this study. The inclusion criteria were male sex, body weight of 150-200 g, good health with no wounds, and blood glucose levels > 250 mg/dL. The animals were obtained from [sumber hewan] and kept under [kondisi kandang].

2.3 Preparation of Lemongrass Extract

The lemongrass extract was prepared by maceration using ethanol as the solvent to obtain the active content of lemongrass. The [bagian tanaman] of lemongrass (Cymbopogon citratus) was macerated in ethanol for [lama maserasi] to obtain the lemongrass ethanol extract (EES).

2.4 Grouping, Induction of Diabetes, and Treatment

The rats were adapted to the laboratory environment for 1 week. Blood glucose levels were measured via the tail vein (vena coccygea). All rats were marked on the tail with a marker and divided into five groups of five rats each:

K- (no treatment)

K+1 (metformin)

P1 (lemongrass ethanol extract, EES)

P2 (moderate-intensity physical activity, swimming)

P3 (intermittent fasting, IF)

Before STZ induction, the rats were fasted for 12 hours, and their blood glucose levels were measured to confirm that they were within the normal range. Streptozotocin (STZ) was administered intraperitoneally as a single dose of 45 mg/kg body weight, calculated individually for each rat. This dose was selected with reference to a previously reported STZ-induced rat model (Okoduwa et al., 2017). A high-fat diet (HFD) and sucrose-supplemented drinking water were provided alongside STZ administration. The animals were monitored for 48 hours after injection.

After the T2DM condition was established, the treatments were given for 3 weeks. The K- group received no treatment. The K+1 group received metformin at [dosis metformin]. The P1 group received EES at [dosis ekstrak]. The P2 group underwent moderate-intensity swimming ([durasi dan frekuensi renang]). The P3 group underwent intermittent fasting ([jadwal puasa]).

2.5 Measurement of Parameters and Statistical Analysis

Fasting blood glucose levels, lipid profile, and MDA levels were measured as the outcome parameters. Fasting blood glucose was measured at several measurement points, including days 1 and 4 ([lengkapi seluruh titik pengukuran]). The lipid profile was measured at each measurement point ([sebutkan komponen lipid, misalnya TC, TG, HDL, LDL]). MDA levels were measured before (pre) and after (post) the intervention ([metode pengukuran MDA]). Blood samples were collected from [lokasi pengambilan darah] after fasting.

The data were analyzed using the Wilcoxon test, a nonparametric test, to compare the measurement points within each group. A p-value of ≤ 0.05 was considered statistically significant. The analysis was performed using IBM SPSS Statistics version 23.

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2.6 Ethical Clearance

Before the animal experiments were conducted, ethical clearance was obtained from the Health Research Ethics Commission (KEPK) of Prima Indonesia University.

3. RESULTS AND DISCUSSION

Based on the results of the study entitled "The Effect of Intermittent Fasting, Lemongrass Extract (Cymbopogon citratus), Moderate Intensity Physical Activity, Intermittent Fasting (IF) on Fasting Blood Glucose Levels, Lipid Profiles, and MDA in Type 2 Diabetes Rats". The research was conducted using environmental adaptation, STZ administration, treatment administration, and observation of results. With the following results:

Table 1. Fasting Blood Glucose Levels in DMT Rats

Group	Blood Glucose Levels Blood													
	Day 1		Day 4		Day 7		Day 10		Day 13		Day 16		Day 19	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Without Treatment	112.4a	12.66	344.20a	97.68	295.60	208.89	407.40	123.09	337.40	113.55	347.40	166.91	204.00	195.94
Metformin	130	17.75	232.00	71.62	302.00	104.18	204.00	76.83	156.00	152.73	100.00	214.84	149.00	137.33
Lemongrass Extract	121.8	12.60	315.20	132.93	279.20	149.83	259.80	130.41	195.60	36.07	292.80	165.69	271.00	239.16
Swim	115.8	8.70	423.20	140.68	279.20	149.83	433.60	119.00	699.40	861.83	311.60	180.48	145.20	139.57
Intermittent fasting	121.6	13.01	349.80	90.93	355.80	48.15	367.40	254.26	355.00	205.48	420.00	236.35	280.80	259.03

Table 1. The results showed a change in the average fasting blood sugar at each treatment point, with significant increases on days 1 and 4. For no treatment with $p \leq 0.05$.

Table 2. Lipid Profile in DMT2 Mice

Plasma Lipids (mg/dL)										
Subject	Without Treatment		Metformin		Lemongrass Extract		Swim		Intermittent Fasting	
	before	Post	before	Post	before	Post	before	Post	before	Post
1	100	118	101	118	106	126	102	118	112	179
2	106	174	109	156	103	118	101	101	105	132
3	115	156	118	152	101	138	113	110	106	121
4	102	189	105		112		105		109	
5	106		106		113		103		117	
Average	105.8	159.25	107.8	142	107	127.33	104.8	109.67	109.8	144
SD	5.76	30.63	6.38	20.88	5.34	10.07	4.82	8.50	4.87	30.81

Based on Table 2, the results showed no significant changes in the average lipid profile at each measurement point in the groups without treatment, metformin treatment, lemongrass extract treatment, swimming treatment, and intermittent fasting treatment ($p \geq 0.05$).

Table 3. MDA Profile in DMT2 Mice

Plasma Lipids (mg/dL)										
Subject	Without Treatment		Metformin		Lemongrass Extract		Swim		Intermittent Fasting	
	before	Post	before	Post	before	Post	before	Post	before	Post
1	100	118	101	118	106	126	102	118	112	179
2	106	174	109	156	103	118	101	101	105	132
3	115	156	118	152	101	138	113	110	106	121
4	102	189	105		112		105		109	
5	106		106		113		103		117	
Average	105.8	159.25	107.8	142	107a	127.33a	104.8	109.67	109.8	144
SD	5.76	30.63	6.38	20.88	5.34	10.07	4.82	8.50	4.87	30.81

Super cryptic notes with the same letters indicate a significant difference between the two treatments. ($p \leq 0.05$)

Based on Table 3. The results showed a change in the average MDA at each measurement point, with significant increases in Pre and Post for the lemongrass extract treatment (p-value ≤ 0.05).

3.4 Discussion

In this study, fasting blood glucose levels increased significantly on days 1 and 4 in the untreated group ($p < 0.05$). This increase suggests that hyperglycemia in diabetic rats may worsen without intervention. In contrast, the groups receiving metformin, lemongrass extract, swimming, and intermittent fasting showed no significant increase in glucose levels. These results indicate that glucose levels remained statistically stable in the treated groups during the study period, but they do not establish that any treatment significantly reduced blood glucose. Metformin's glucose-lowering action is associated with reduced hepatic glucose production and changes in insulin sensitivity (LaMoia & Shulman, 2020).

The findings for lemongrass should be interpreted in light of studies reporting hypoglycemic and antioxidant activity in Cymbopogon citratus extracts and their phenolic compounds (Wang et al., 2022; Falode et al., 2023). Research on other medicinal plants has also characterized phenolic compounds associated with antioxidant potential, including the total phenolic content of black turmeric rhizome extract (Zulfisa et al., 2024). These studies provide a biological context, but they do not demonstrate that the specific extract used here caused the stable glucose pattern observed in this experiment. Research on other plant extracts in diabetic rat models also reports glucose-related and antioxidant effects, although results from different plants cannot be assumed to apply directly to lemongrass (Hassan et al., 2015).

Intermittent fasting and physical activity may affect glucose and energy metabolism through pathways that include changes in glucose utilization and skeletal muscle adaptation. Experimental research has examined the combined effects of fasting and exercise on energy metabolism (Real-Hohn et al., 2018), while a rat study reported changes in metabolic and oxidative pathways following intermittent fasting and exercise interventions (Chijiokwu et al., 2022). Exercise-related adaptations in skeletal muscle, including autophagy-related pathways, have also been studied in models of type 2 diabetes (Yang et al., 2020). Evidence from exercise and plant-extract research in diabetic rats further suggests that glucose transport and related metabolic outcomes may respond to interventions. However, these studies do not establish the precise mechanism underlying the findings in the present experiment (Olayaki et al., 2023).

The lipid profile changed at each measurement point in all groups, but none of the changes were statistically significant ($p \geq 0.05$). Therefore, this study did not detect a clear lipid effect from any intervention during the study period. A three-week intervention and five rats per group may have limited the ability to detect small differences, while individual variability may also have contributed. Research on intermittent fasting has examined lipid metabolism markers in skeletal muscle, illustrating that lipid outcomes are distinct from blood glucose outcomes and require direct measurement (Liu et al., 2020). Studies combining exercise and metformin have also investigated lipid-related tissue outcomes in animal models, but their findings cannot be used to infer a lipid effect in the present experiment (Zhang et al., 2022; Yu et al., 2023).

The lemongrass extract group showed a significant increase in MDA levels between pre- and post-treatment ($p < 0.05$). This finding does not support an antioxidant improvement in MDA over the study period. Other studies have investigated antioxidant status following lemongrass administration in rats, including changes in antioxidant measures and atherogenic indices (Somparn et al., 2018). A separate study of Cymbopogon citratus phenolic fractions in diabetic rats reported effects on oxidative-stress-related outcomes, but its model and intervention conditions differ from those used here (Falode et al., 2023). Exercise and metformin research has likewise examined oxidative-stress pathways in diabetic animal models (Zhang et al., 2022). These findings provide context, not an explanation, for the increase in MDA observed in this study. The short intervention period is one possible factor, but further research is needed to test that explanation. Since MDA is used as a marker of lipid peroxidation, future studies should continue to monitor oxidative-stress markers when evaluating herbal interventions in diabetic models.

This study has several limitations. The sample size was small (five rats per group), the intervention lasted only three weeks, and the Wilcoxon test evaluates within-group changes rather than differences between groups. The study also examined a limited set of parameters and did not assess other markers of insulin function, antioxidant status, or lipid metabolism. Future studies should use larger samples, longer interventions, and between-group analyses. Researchers may also consider measuring related endpoints, such as muscle glucose and insulin indices, which have been investigated in exercise studies in diabetic rats (Peyravi et al., 2019), as well as liver or muscle outcomes in studies of metformin combined with intermittent fasting (Bastawy et al., 2024). Swimming research in diabetic rats has also examined oxidative stress and liver outcomes, providing a relevant direction for expanded assessment in future work (Ghiasi et al., 2019).

4. CONCLUSION

This study found that fasting blood glucose levels increased significantly on days 1 and 4 in the untreated group, while the groups receiving metformin, lemongrass extract, swimming, and intermittent fasting showed no significant increase. The lipid profile changed at each measurement point in all groups, but none of the changes were statistically significant. MDA levels changed significantly between pre- and post-treatment only in the lemongrass extract group. These findings suggest that the four interventions may help maintain blood glucose stability in type 2 diabetic rats. However, they did not produce significant changes in lipid profile within the study period, and the significant change in MDA was limited to the lemongrass extract group. Future studies should use a longer intervention period, a larger sample size, and between-group comparisons to confirm these effects. They should examine additional markers of insulin, lipid metabolism, and oxidative stress, as well as the optimal dose of lemongrass extract and the swimming and intermittent fasting protocols. Based on these results, lemongrass extract, swimming, and intermittent fasting may be considered as complementary approaches to support blood glucose control in type 2 diabetes, provided that further research confirms their effectiveness and safety.

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