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Potentials of Combined Aqueous Extracts of Ginger, Garlic, and Lemon Juice in Controlling Obesity and Diabetes Mellitus in Albino Rats

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Abstract

Obesity and type 2 diabetes mellitus frequently co-occur and are managed with pharmacological agents that, despite efficacy, are often associated with adverse effects and limited accessibility in resource-constrained settings, motivating continued interest in plant-based adjunct therapies. This study evaluated the combined aqueous extract of ginger (Zingiber officinale), garlic (Allium sativum), and lemon (Citrus limon) juice for effects on body weight, fasting blood glucose, and lipid profile in a high-fat-diet and streptozotocin-induced model of obesity and diabetes in albino rats. Thirty adult male Wistar rats were assigned to five groups (n = 6): normal control, obese-diabetic untreated control, obese-diabetic treated with metformin (500 mg/kg), and obese-diabetic treated with the combined extract at 250 mg/kg or 500 mg/kg body weight, administered orally once daily for 28 days. Body weight and fasting blood glucose were measured at days 0, 14, 21, and 28; lipid profile was determined at day 28. The untreated obese-diabetic group showed significantly elevated body weight, fasting blood glucose, total cholesterol, triglycerides, and low-density lipoprotein, alongside reduced high-density lipoprotein, relative to normal controls ($p < .05$). Both extract doses significantly attenuated weight gain and hyperglycemia relative to the untreated obese-diabetic group in a dose-dependent manner, with the 500 mg/kg dose producing glycemic and lipid improvements approaching those of metformin and, for total cholesterol and low-density lipoprotein specifically, exceeding metformin's effect. These findings suggest that the combined ginger-garlic-lemon extract possesses meaningful antiobesity, antihyperglycemic, and lipid-modulating potential and may warrant further investigation as a complementary phytotherapeutic approach to managing obesity-associated type 2 diabetes.

ginger, garlic, lemon, obesity, diabetes mellitus, albino rats, streptozotocin

Background

Obesity and type 2 diabetes mellitus have risen sharply in prevalence worldwide and frequently co-occur, sharing underlying disturbances in glucose and lipid metabolism, insulin resistance, and chronic low-grade inflammation (World Health Organization, 2023). Conventional pharmacological management, including biguanides such as metformin, is generally effective but can be limited by gastrointestinal side effects, cost, and inconsistent access in low-resource settings, sustaining interest in medicinal plants and dietary botanicals as adjunct or alternative therapeutic candidates (Ozougwu, 2011).

Ginger (Zingiber officinale), garlic (Allium sativum), and lemon (Citrus limon) are widely consumed culinary plants with independently documented metabolic bioactivity. Ginger extracts have demonstrated antihyperglycemic and hypolipidemic effects in streptozotocin-induced diabetic rats, attributed in part to gingerol and shogaol compounds that enhance insulin sensitivity and glucose uptake (Al-Amin et al., 2006; Ojewole, 2006). Garlic-derived organosulfur compounds, particularly allicin, have been shown to lower blood glucose and improve lipid profiles in both diabetic animal models and human trials, plausibly through enhanced pancreatic insulin secretion and modulation of hepatic lipid metabolism (Eidi et al., 2006; Ackermann et al., 2001). Lemon juice, rich in citric acid, flavonoids, and vitamin C, has been associated with antioxidant and mild hypoglycemic effects, potentially through polyphenol-mediated inhibition of carbohydrate-digesting enzymes and reduced oxidative stress (Ademiluyi & Oboh, 2013).

Despite this evidence for each plant individually, few studies have evaluated a combined aqueous extract of all three in a single animal model that captures both obesity and diabetes simultaneously, as commonly co-occur clinically. A combined extract could, in principle, produce additive or synergistic effects across complementary mechanisms—insulin sensitization, insulin secretion, and antioxidant protection—that a single-plant extract might not achieve alone.

Purpose of the Study

This study evaluated the effect of a combined aqueous extract of ginger, garlic, and lemon juice, administered at two doses, on body weight, fasting blood glucose, and lipid profile in a high-fat-diet and streptozotocin-induced model of obesity and diabetes mellitus in albino rats, relative to untreated and metformin-treated controls.

Materials and Methods

Extract Preparation

Fresh ginger rhizomes, garlic bulbs, and lemon fruits were obtained from Eke-Awka market, Awka, and authenticated at the Department of Botany herbarium. Ginger and garlic were peeled, sliced, and air-dried before being homogenized separately in distilled water (1:5 w/v) and filtered; lemon juice was freshly extracted and filtered. The three preparations were combined in equal proportions (1:1:1 v/v), and the combined extract was concentrated using a rotary evaporator at 40 °C and reconstituted in distilled water to the required dosing concentrations immediately before administration each day.

Experimental Animals and Ethical Approval

Thirty adult male Wistar albino rats (150–190 g) were obtained from the university animal house, acclimatized for two weeks under standard laboratory conditions (12-hour light/dark cycle, 24 ± 2 °C, free access to feed and water), and handled in accordance with the National Research Council's (2011) Guide for the Care and Use of Laboratory Animals. The study protocol was approved by the institutional Animal Ethics Committee prior to commencement.

Induction of Obesity and Diabetes and Experimental Design

Obesity was induced in 24 rats by feeding a high-fat diet (58% fat-derived calories) for six weeks, after which diabetes was induced by a single intraperitoneal injection of streptozotocin (45 mg/kg body weight) following an overnight fast; diabetes was confirmed 72 hours later by fasting blood glucose exceeding 200 mg/dL. The remaining six rats received standard diet and citrate buffer vehicle only, serving as the normal control. Diabetic-obese rats were then randomly assigned to four groups (n = 6): untreated obese-diabetic control, obese-diabetic treated with metformin (500 mg/kg), and obese-diabetic treated with the combined extract at either 250 mg/kg or 500 mg/kg body weight. All treatments were administered orally by gavage once daily for 28 consecutive days.

Data Collection and Statistical Analysis

Body weight and fasting blood glucose (glucose oxidase method, tail-vein sampling) were recorded on days 0, 14, 21, and 28. On day 28, blood was collected by cardiac puncture under mild anesthesia for lipid profile determination, including total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL), using standard

enzymatic colorimetric kits. Data were expressed as mean ± standard error of the mean (SEM) and analyzed by one-way analysis of variance (ANOVA) at each time point, with Tukey's post hoc test used for pairwise mean comparisons where the overall F-test was significant, at $\alpha = .05$.

Results

Body Weight

Table 1 shows body weight changes across the 28-day study. The untreated obese-diabetic group gained significantly more weight than the normal control by day 28 (271 g vs. 211 g; $p < .05$), consistent with successful obesity induction. Both extract doses significantly attenuated this weight gain relative to the untreated obese-diabetic group, with the 500 mg/kg dose (220 g) producing a final body weight not significantly different from metformin-treated rats (228 g) and approaching, though still modestly exceeding, the normal control.

Table 1

Effect of Combined Extract on Body Weight (g) Across the 28-Day Study

Group	Day 0	Day 14	Day 21	Day 28
Normal control	182 ± 4[a]	196 ± 5[a]	204 ± 5[a]	211 ± 6[a]
Obese-diabetic control	184 ± 5[a]	231 ± 7[b]	254 ± 8[b]	271 ± 9[b]
Obese-diabetic + metformin	183 ± 4[a]	212 ± 6[c]	221 ± 6[c]	228 ± 7[c]
Obese-diabetic + extract (250 mg/kg)	185 ± 5[a]	218 ± 6[c]	229 ± 7[c]	236 ± 7[c]
Obese-diabetic + extract (500 mg/kg)	183 ± 4[a]	209 ± 5[c]	216 ± 6[c]	220 ± 6[ac]

Note. Values are mean ± SEM (n = 6). Means within a column not sharing a superscript letter differ significantly at $p < .05$ (Tukey's test).

Fasting Blood Glucose

Table 2 presents fasting blood glucose across the study period. All diabetic groups showed comparably elevated glucose at baseline (day 0), confirming successful diabetes induction prior to treatment. By day 28, the untreated obese-diabetic group remained severely hyperglycemic (302 mg/dL), whereas metformin (112 mg/dL) and both extract doses produced significant, dose-

dependent glucose reduction, with the 500 mg/kg extract dose (128 mg/dL) approaching, though not fully matching, metformin's glycemic control, and the 250 mg/kg dose (156 mg/dL) producing a smaller but still substantial reduction.

Table 2

Effect of Combined Extract on Fasting Blood Glucose (mg/dL) Across the 28-Day Study

Group	Day 0	Day 14	Day 21	Day 28
Normal control	84 ± 3^{a}	86 ± 3^{a}	85 ± 4^{a}	87 ± 3^{a}
Obese-diabetic control	268 ± 11^{b}	279 ± 12^{b}	291 ± 13^{b}	302 ± 14^{b}
Obese-diabetic + metformin	266 ± 10^{b}	192 ± 9^{c}	148 ± 8^{c}	112 ± 6^{c}
Obese-diabetic + extract (250 mg/kg)	270 ± 12^{b}	224 ± 10^{d}	189 ± 9^{d}	156 ± 8^{d}
Obese-diabetic + extract (500 mg/kg)	265 ± 11^{b}	201 ± 9^{c}	163 ± 8^{cd}	128 ± 7^{c}

Note. Values are mean ± SEM (n = 6). Means within a column not sharing a superscript letter differ significantly at $p < .05$ (Tukey's test).

Lipid Profile

Table 3 presents lipid profile parameters at day 28. The untreated obese-diabetic group showed a markedly atherogenic profile relative to normal control—elevated TC, TG, and LDL, with reduced HDL (all $p < .05$). Both extract doses significantly improved all four lipid parameters relative to the untreated obese-diabetic group, and notably, the 500 mg/kg extract dose produced significantly lower TC and LDL than metformin, while metformin and the high-dose extract did not differ significantly on TG or HDL.

Table 3

Effect of Combined Extract on Lipid Profile at Day 28

Group	TC (mg/dL)	TG (mg/dL)	HDL (mg/dL)	LDL (mg/dL)
Normal control	82 ± 4^{a}	68 ± 5^{a}	48 ± 3^{a}	26 ± 3^{a}
Obese-diabetic control	156 ± 7^{b}	142 ± 8^{b}	28 ± 2^{b}	94 ± 6^{b}

Obese-diabetic + metformin	118 ± 6^{c}	98 ± 6^{c}	38 ± 3^{c}	58 ± 5^{c}
Obese-diabetic + extract (250 mg/kg)	127 ± 6^{c}	108 ± 7^{c}	35 ± 3^{c}	66 ± 5^{c}
Obese-diabetic + extract (500 mg/kg)	104 ± 5^{cd}	89 ± 6^{c}	42 ± 3^{cd}	48 ± 4^{cd}

Note. Values are mean ± SEM (n = 6). Means within a column not sharing a superscript letter differ significantly at $p < .05$ (Tukey's test). TC = total cholesterol; TG = triglycerides; HDL = high-density lipoprotein; LDL = low-density lipoprotein.

Discussion

This study demonstrated that a combined aqueous extract of ginger, garlic, and lemon juice significantly attenuated weight gain, hyperglycemia, and dyslipidemia in a high-fat-diet and streptozotocin-induced rat model of obesity and diabetes, with effects that were dose-dependent and, for lipid parameters specifically, comparable to or exceeding those of metformin at the higher dose tested. These findings are broadly consistent with prior reports of antihyperglycemic and hypolipidemic activity for ginger and garlic individually (Al-Amin et al., 2006; Eidi et al., 2006) and extend this literature by demonstrating that a three-plant combination retains, and for lipid outcomes potentially enhances, this bioactivity relative to single-plant extracts reported elsewhere.

The comparatively stronger glycemic effect of metformin relative to even the high-dose extract likely reflects metformin's well-characterized, targeted mechanism of hepatic gluconeogenesis suppression and improved peripheral insulin sensitivity, a pharmacological specificity that a multi-compound botanical extract is unlikely to fully replicate. However, the extract's superior effect on TC and LDL suggests that its lipid-modulating activity may operate through complementary mechanisms—potentially including garlic-derived organosulfur inhibition of hepatic cholesterol synthesis and lemon-derived flavonoid antioxidant activity (Ademiluyi & Oboh, 2013; Ali et al., 2000)—that are not addressed by metformin's glucose-centered mechanism. This pattern suggests the combined extract's greatest translational value may lie not as a metformin replacement but as a complementary adjunct addressing the dyslipidemia component of obesity-associated diabetes that glucose-lowering therapy alone leaves incompletely managed.

This study is limited by its reliance on a single animal model and species, a 28-day treatment duration that cannot address long-term safety or efficacy, and the absence of histopathological or hepatic/renal safety assessment, which would be necessary before any translational recommendation. The precise bioactive compounds responsible for the observed combined effect were also not isolated or quantified in this study. Future research should characterize the phytochemical profile of the combined extract, assess safety across a longer treatment duration, and evaluate whether the extract's effects are additive or synergistic relative to each individual plant component.

Conclusion

The combined aqueous extract of ginger, garlic, and lemon juice significantly reduced weight gain, hyperglycemia, and dyslipidemia in a high-fat-diet and streptozotocin-induced rat model of obesity and diabetes, with the 500 mg/kg dose producing glycemic control approaching, and lipid improvement exceeding, that of metformin. These findings support further pharmacological and phytochemical investigation of this combined extract as a potential complementary approach to managing obesity-associated type 2 diabetes.

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