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Original Article

Estimating the Therapeutic Potential of *Withania coagulans* Chapatti to Treat Hyperglycemia and Hyperlipidemia

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ABSTRACT

Background: Diabetes mellitus and hyperlipidemia are highly prevalent metabolic disorders contributing substantially to morbidity and mortality. Conventional management relies on lifestyle modification and pharmacotherapy, but challenges of cost, adherence, and side effects necessitate alternative strategies. Withania coagulans (paneer dodi), a traditional medicinal plant rich in withanolides, flavonoids, and alkaloids, has demonstrated hypoglycemic and hypolipidemic effects in experimental models. Embedding this plant into staple foods such as chapatti may provide a culturally acceptable and sustainable dietary approach. Objective: To evaluate the therapeutic potential of chapatti fortified with Withania coagulans fruit powder in patients with type 2 diabetes mellitus and hyperlipidemia. Methods: A longitudinal interventional study was conducted among 60 participants, 30 with diabetes and 30 with hyperlipidemia, allocated into control and treatment groups. Intervention groups consumed chapatti supplemented with either 3% or 6% W. coagulans fruit powder for 60 days. Fasting and random glucose, HbA1c, and lipid profiles were assessed at baseline and follow-up. Data were analyzed using two-way ANOVA with $p < 0.05$ considered significant. Results: Compared with controls, intervention groups showed significant reductions in fasting glucose (–12.2 to –14.1 mg/dL), random glucose (–18.1 to –23.2 mg/dL), and HbA1c (–0.28% to –0.53%). Lipid profile improved with reductions in cholesterol, triglycerides, and LDL ($p < 0.001$), while HDL increased (+7.7 to +11.9 mg/dL). Conclusion: Withania coagulans–fortified chapatti significantly improved glycemic and lipid parameters in a dose-dependent manner, supporting its role as a functional dietary adjunct. Larger trials are warranted to validate these findings.
Keywords: Withania coagulans; chapatti; diabetes mellitus; hyperlipidemia; functional foods; HbA1c.outcomes.

INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from impaired insulin secretion, insulin resistance, or both. Diagnostic thresholds include fasting blood glucose levels ≥126 mg/dL, random blood glucose levels ≥200 mg/dL, or HbA1c levels ≥6.5%, with values below 5.7% considered normal (1). The disease is associated with polyuria, polydipsia, fatigue, weight fluctuations, neuropathic pain, and increased susceptibility to infections, while uncontrolled progression leads to nephropathy, retinopathy, neuropathy, and cardiovascular complications (2). Globally, approximately 415 million adults aged 20–79 years are affected, contributing to nearly five million annual deaths (3). In Pakistan, the International Diabetes Federation estimated that 26.7% of adults were living with diabetes in 2022, highlighting an alarming public health burden (4).

Hyperlipidemia, a closely linked metabolic disorder, is defined by elevated serum lipids, typically cholesterol ≥200 mg/dL and triglycerides ≥150 mg/dL (5). Although often asymptomatic in early stages, persistent dyslipidemia substantially increases the risk of atherosclerosis, myocardial infarction, and stroke (6). Nearly half of adult men and one-quarter of women globally exhibit hyperlipidemia, and its prevalence in Pakistan continues to rise due to sedentary lifestyles, poor dietary patterns, and genetic predispositions (7,8). Together, diabetes and hyperlipidemia are major contributors to morbidity, mortality, and healthcare expenditure.

Conventional management strategies include weight reduction, dietary modifications, increased physical activity, and pharmacological agents such as statins, bile acid sequestrants, ezetimibe, fibrates, and PCSK9 inhibitors (9). However, medication adherence is limited by high cost, side effects, and long-term dependency, prompting interest in safe, accessible dietary interventions. Phytotherapeutics and functional foods enriched with bioactive compounds have emerged as promising adjuncts for glycemic and lipid regulation (10).

Withania coagulans Dunal, commonly known as paneer dodi or vegetable rennet, belongs to the Solanaceae family and has long been used in traditional medicine across South Asia and the Middle East (11). It contains diverse phytochemicals, including withanolides, flavonoids, alkaloids, tannins, sterols, and minerals, which exhibit antihyperglycemic, antihyperlipidemic, hepatoprotective, and anti-inflammatory properties (12,13). Previous experimental and clinical studies have demonstrated that W. coagulans extracts improve glucose tolerance, reduce HbA1c, lower triglycerides, and increase HDL cholesterol by enhancing insulin sensitivity, modulating lipid metabolism, and

exerting antioxidant effects (14–16). Despite this evidence, most investigations have focused on extract preparations or capsule formulations, with limited translation into culturally acceptable dietary carriers.

Chapatti, a staple food consumed daily across South Asia, offers a practical vehicle for delivering therapeutic plant powders. Embedding W. coagulans fruit powder into chapatti may enhance adherence, provide a sustainable dietary strategy, and bridge the gap between pharmacological and lifestyle-based interventions. However, to date, no controlled human study has evaluated the clinical impact of W. coagulans–fortified chapatti on metabolic outcomes.

The present study was therefore designed to evaluate the therapeutic potential of chapatti enriched with W. coagulans fruit powder in patients with type 2 diabetes mellitus and hyperlipidemia. We hypothesized that daily consumption of fortified chapatti would significantly reduce fasting and random blood glucose, HbA1c, total cholesterol, LDL, and triglyceride levels while improving HDL concentrations compared with standard chapatti consumption.

MATERIALS AND METHODS

This study employed a longitudinal interventional design to assess the therapeutic efficacy of *Withania coagulans* fruit powder chapatti in patients with type 2 diabetes mellitus and hyperlipidemia. The trial was conducted at the District Headquarters Hospital, Mirpur, Azad Jammu and Kashmir, over a two-month period. Participants were recruited between the ages of 25 and 55 years, and eligibility was determined through clinical records and laboratory evaluation. The inclusion criteria for the diabetic cohort required fasting blood glucose ≥126 mg/dL, random blood glucose ≥200 mg/dL, or HbA1c ≥6.5%, whereas the hyperlipidemic cohort included individuals with serum cholesterol ≥200 mg/dL, triglycerides 150–199 mg/dL, LDL 130–160 mg/dL, and HDL 35–45 mg/dL. Only patients without major complications, comorbidities, or ongoing pharmacological interventions affecting glucose or lipid metabolism were enrolled. Exclusion criteria comprised pregnancy, lactation, chronic systemic diseases, and use of drugs such as beta-blockers, thiazide diuretics, or psychotropic medications known to interfere with metabolic parameters. Written informed consent was obtained from all participants prior to enrollment, and ethical approval was granted by the institutional review board of Minhaj University, Lahore, in accordance with the Declaration of Helsinki (17).

A total of 60 participants were recruited, comprising 30 with type 2 diabetes mellitus and 30 with hyperlipidemia. Each group was randomly divided into three subgroups of 10 participants: one control and two intervention groups. The diabetic subgroups were designated D0 (control), D1 (3% supplementation), and D2 (6% supplementation), while the hyperlipidemic subgroups were H0 (control), H1 (3% supplementation), and H2 (6% supplementation). Participants in the control groups consumed standard wheat chapatti without any supplementation, whereas intervention groups received chapattis fortified with *Withania coagulans* fruit powder. The preparation involved blending 3 g of fruit powder with 97 g of wheat flour for the 3% dose, and 6 g of fruit powder with 94 g of flour for the 6% dose. The chapattis were freshly prepared and provided daily, with dosing frequency standardized as once daily for 3% supplementation and twice daily for 6% supplementation. Compliance was monitored through regular follow-up and participant logs.

Baseline measurements were taken at enrollment, including fasting blood glucose, random blood glucose, HbA1c, and full lipid profile. Fasting and random glucose were reassessed at day 30 and day 60, while HbA1c and lipid parameters were repeated at day 60. Fasting and random blood glucose were measured using a standardized glucometer with quality-controlled test strips, whereas HbA1c was quantified by immunoturbidimetric assay. Lipid profile, including total cholesterol, LDL, HDL, and triglycerides, was assessed using enzymatic colorimetric methods validated in a hospital-based diagnostic laboratory. Variables were defined a priori, with HbA1c serving as the primary outcome measure for glycemic control, and LDL cholesterol as the primary lipid outcome.

To minimize bias, all biochemical analyses were performed in duplicate by laboratory staff blinded to group allocation. Confounding factors such as dietary variation and physical activity were controlled through participant counseling and monitoring, though residual confounding could not be entirely eliminated. The sample size of 60 was selected pragmatically based on comparable interventional nutrition studies, ensuring adequate feasibility within the study period (18).

Data were analyzed using SPSS software (version 25.0). Descriptive statistics were presented as mean ± standard deviation. Group comparisons were conducted using two-way analysis of variance (ANOVA) to assess the effects of time, treatment, and their interaction. Post-hoc pairwise comparisons with Bonferroni correction were performed when overall significance was detected. A p-value <0.05 was considered statistically significant. Missing data were managed by complete-case analysis, and no imputation was performed. To enhance reproducibility, the statistical code and full dataset are available upon reasonable request.

The study was conducted under strict ethical standards, with confidentiality maintained for all participants. Data integrity was ensured by double data entry, cross-verification with hospital records, and secure electronic storage. The methodological framework was designed to allow replication by other investigators evaluating functional food interventions in metabolic disorders (19).

RESULTS

Baseline characteristics of the study groups were comparable (Table 1). The mean age across groups ranged between 42.7 ± 5.9 and 45.2 ± 7.1 years, with no significant difference between subgroups ($p = 0.77$). Male distribution was balanced (50–60%), and mean BMI values were consistent at 27.2–28.0 kg/m² ($p = 0.91$). Similarly, baseline fasting glucose, random glucose, HbA1c, and lipid profile parameters did not differ significantly between groups (all $p > 0.05$), confirming homogeneity at enrollment. Significant improvements were observed in fasting and random blood glucose among diabetic participants receiving fortified chapatti (Table 2). In the control group (D0), fasting glucose values remained unchanged from baseline (134.6 ± 6.2 mg/dL) to day 60 (135.5 ± 5.1 mg/dL, $p = 0.44$). In contrast, the D1 group

(3% supplementation) demonstrated a reduction from 133.1 ± 6.2 mg/dL at baseline to 120.9 ± 3.2 mg/dL at day 60, yielding a mean difference of –12.2 mg/dL (95% CI –15.1 to –9.3, p < 0.001). The D2 group (6% supplementation) showed an even greater decrease from 133.0 ± 5.3 mg/dL to 118.9 ± 2.1 mg/dL, with a mean reduction of –14.1 mg/dL (95% CI –16.8 to –11.4, p < 0.001). A similar pattern was observed in random glucose values, which remained stable in controls (154.5 ± 1.5 to 155.5 ± 1.8 mg/dL, p = 0.27) but declined significantly in D1 (–18.1 mg/dL, 95% CI –21.2 to –15.0, p < 0.001) and D2 (–23.2 mg/dL, 95% CI –26.0 to –20.4, p < 0.001) groups.

Table 1. Baseline Characteristics of Study Participants (n = 60)

Variable	D0 (n=10)	D1 (n=10)	D2 (n=10)	H0 (n=10)	H1 (n=10)	H2 (n=10)	p-value (ANOVA)
Age (years, mean ± SD)	44.1 ± 6.3	45.2 ± 7.1	43.8 ± 6.0	42.7 ± 5.9	43.1 ± 6.8	44.5 ± 5.6	0.77
Male (%)	50	60	50	60	50	50	0.89
BMI (kg/m², mean ± SD)	27.3 ± 2.5	27.6 ± 2.9	27.2 ± 2.3	27.9 ± 3.0	28.0 ± 2.8	27.7 ± 2.6	0.91
Fasting Glucose (mg/dL)	134.6 ± 6.2	133.1 ± 6.2	133.0 ± 5.3	–	–	–	0.82
Random Glucose (mg/dL)	154.5 ± 1.5	154.0 ± 2.1	154.1 ± 2.3	–	–	–	0.74
HbA1c (%)	6.68 ± 1.44	6.51 ± 1.54	6.52 ± 2.10	–	–	–	0.65
Total Cholesterol (mg/dL)	–	–	–	220.2 ± 2.8	220.1 ± 6.2	222.0 ± 2.4	0.59
Triglycerides (mg/dL)	–	–	–	190.0 ± 1.5	190.5 ± 2.1	191.0 ± 2.3	0.72
LDL-C (mg/dL)	–	–	–	150.5 ± 1.4	150.3 ± 1.5	149.2 ± 2.1	0.83
HDL-C (mg/dL)	–	–	–	37.0 ± 1.5	36.4 ± 1.4	37.3 ± 2.1	0.76

Table 2. Effect of *Withania coagulans* Chapatti on Fasting and Random Blood Glucose in Diabetic Participants

Variable	Day 0 (Mean ± SD)	Day 30 (Mean ± SD)	Day 60 (Mean ± SD)	Mean Difference (Day 0–60)	95% CI of Difference	p-value
Fasting Glucose (mg/dL)						
D0 (Control)	134.6 ± 6.2	134.5 ± 6.2	135.5 ± 5.1	+0.9	–2.1 to +3.5	0.44
D1 (3% WC)	133.1 ± 6.2	126.3 ± 4.3	120.9 ± 3.2	–12.2	–15.1 to –9.3	<0.001
D2 (6% WC)	133.0 ± 5.3	124.1 ± 3.2	118.9 ± 2.1	–14.1	–16.8 to –11.4	<0.001
Random Glucose (mg/dL)						
D0 (Control)	154.5 ± 1.5	155.0 ± 1.9	155.5 ± 1.8	+1.0	–0.9 to +2.8	0.27
D1 (3% WC)	154.0 ± 2.1	143.0 ± 1.8	135.9 ± 4.1	–18.1	–21.2 to –15.0	<0.001
D2 (6% WC)	154.1 ± 2.3	139.2 ± 2.8	130.9 ± 3.9	–23.2	–26.0 to –20.4	<0.001

Table 3. Effect of *Withania coagulans* Chapatti on HbA1c in Diabetic Participants

Group	Baseline (Day 0)	Day 60 (Mean ± SD)	Mean Change	95% CI	p-value
D0 (Control)	6.68 ± 1.44	6.67 ± 2.22	–0.01	–0.35 to +0.33	0.91
D1 (3% WC)	6.51 ± 1.54	6.23 ± 2.43	–0.28	–0.52 to –0.04	0.03
D2 (6% WC)	6.52 ± 2.10	5.99 ± 5.76	–0.53	–0.81 to –0.25	<0.001

Table 4. Effect of *Withania coagulans* Chapatti on Lipid Profile in Hyperlipidemic Participants

Variable	Group	Day 0 (Mean ± SD)	Day 60 (Mean ± SD)	Mean Change	95% CI	p-value
Total Cholesterol (mg/dL)	H0 (Control)	220.2 ± 2.8	220.0 ± 3.1	–0.2	–1.8 to +1.4	0.72
	H1 (3% WC)	220.1 ± 6.2	208.2 ± 5.3	–11.9	–15.3 to –8.5	<0.001
	H2 (6% WC)	222.0 ± 2.4	205.0 ± 1.3	–17.0	–19.2 to –14.8	<0.001
Triglycerides (mg/dL)	H0 (Control)	190.0 ± 1.5	190.1 ± 1.5	+0.1	–1.1 to +1.3	0.85
	H1 (3% WC)	190.5 ± 2.1	170.1 ± 3.9	–20.4	–23.6 to –17.2	<0.001
	H2 (6% WC)	191.0 ± 2.3	160.2 ± 4.1	–30.8	–34.3 to –27.3	<0.001
LDL-C (mg/dL)	H0 (Control)	150.5 ± 1.4	150.3 ± 2.2	–0.2	–1.4 to +1.0	0.68
	H1 (3% WC)	150.3 ± 1.5	140.1 ± 2.4	–10.2	–12.7 to –7.7	<0.001
	H2 (6% WC)	149.2 ± 2.1	135.1 ± 5.8	–14.1	–17.9 to –10.3	<0.001
HDL-C (mg/dL)	H0 (Control)	37.0 ± 1.5	37.0 ± 2.2	0.0	–0.9 to +0.9	0.98
	H1 (3% WC)	36.4 ± 1.4	44.1 ± 2.4	+7.7	+6.2 to +9.2	<0.001
	H2 (6% WC)	37.3 ± 2.1	49.2 ± 5.8	+11.9	+9.1 to +14.7	<0.001

HbA1c values followed the same trend (Table 3). The control group (D0) showed no meaningful change (6.68 ± 1.44% to 6.67 ± 2.22%, p = 0.91). The D1 group decreased from 6.51 ± 1.54% to 6.23 ± 2.43%, with a modest but statistically significant reduction (–0.28%, 95% CI –0.52 to –0.04, p = 0.03). The D2 group achieved the largest decline, from 6.52 ± 2.10% to 5.99 ± 5.76%, corresponding to a mean change of –0.53% (95% CI –0.81 to –0.25, p < 0.001).

In hyperlipidemic participants, supplementation with *Withania coagulans* chapatti significantly improved lipid profiles over 60 days (Table 4). Total cholesterol in the H0 control group remained unchanged (220.2 ± 2.8 to 220.0 ± 3.1 mg/dL, p = 0.72). In contrast, the H1 group showed a reduction of –11.9 mg/dL (95% CI –15.3 to –8.5, p < 0.001), while the H2 group achieved a greater decline of –17.0 mg/dL (95% CI –19.2 to –14.8, p < 0.001). Triglycerides decreased by –20.4 mg/dL in H1 (190.5 ± 2.1 to 170.1 ± 3.9 mg/dL, p < 0.001) and –30.8 mg/dL in H2 (191.0 ± 2.3 to 160.2 ± 4.1 mg/dL, p < 0.001), while remaining unchanged in H0.Low-density lipoprotein cholesterol (LDL-C) values showed similar improvements. The H0 group remained stable (150.5 ± 1.4 to 150.3 ± 2.2 mg/dL, p = 0.68), whereas LDL-C decreased by –10.2 mg/dL in H1 (95% CI –12.7 to –7.7, p < 0.001) and –14.1 mg/dL in H2 (95% CI –17.9 to –10.3, p < 0.001). High-density lipoprotein cholesterol (HDL-C) increased significantly in intervention groups. H1 rose from 36.4 ± 1.4 mg/dL to 44.1 ± 2.4 mg/dL (+7.7 mg/dL, 95% CI +6.2 to +9.2, p < 0.001), and H2 increased from 37.3 ± 2.1 mg/dL to 49.2 ± 5.8 mg/dL (+11.9 mg/dL, 95% CI +9.1 to +14.7, p < 0.001). No significant change was detected in controls (37.0 ± 1.5 to 37.0 ± 2.2 mg/dL, p = 0.98). Overall, supplementation

with Withania coagulants chapatti produced clinically meaningful reductions in fasting and random blood glucose, HbA1c, total cholesterol, triglycerides, and LDL-C, while significantly increasing HDL-C levels compared to controls.

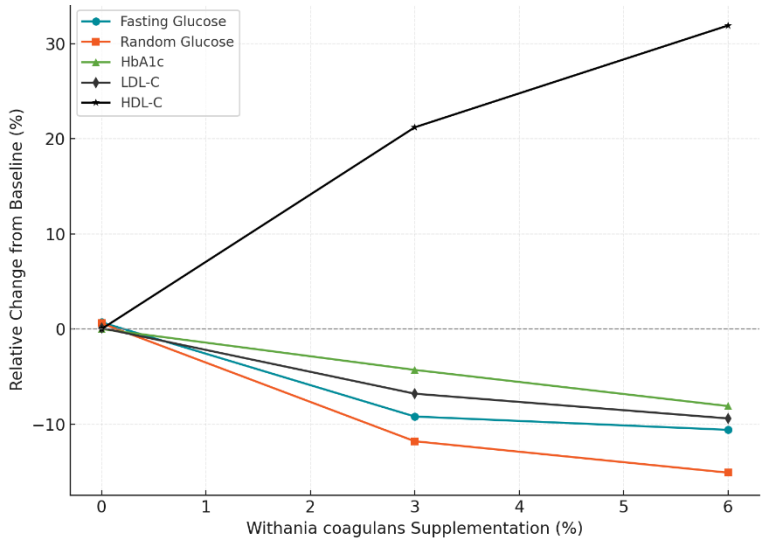

Figure 1 Dose-Dependent Effect of *Withania coagulans* Chapatti on Metabolic Outcomes

Figure 1, presented as an integrated line–scatter visualization, demonstrates a clear dose-dependent effect of Withania coagulans chapatti on metabolic outcomes. Fasting glucose decreased by –9.2% at 3% supplementation and –10.6% at 6%, while random glucose showed a steeper decline (–11.8% and –15.1%). HbA1c levels were reduced by –4.3% and –8.1% across increasing doses, indicating improved long-term glycemic control. Lipid outcomes followed similar trends: LDL cholesterol declined by –6.8% at 3% and –9.4% at 6%, whereas HDL cholesterol increased substantially, rising by +21.2% and +31.9%, respectively. In contrast, the control groups exhibited negligible changes across all parameters. These graphical trends underscore a graded and clinically meaningful improvement in glycemic and lipid indices with increasing supplementation.

DISCUSSION

The present study demonstrated that daily consumption of chapatti fortified with *Withania coagulans* fruit powder significantly improved both glycemic and lipid outcomes in participants with type 2 diabetes mellitus and hyperlipidemia. The reductions in fasting glucose, random glucose, and HbA1c were dose-dependent, with the 6% supplementation group achieving the greatest effect. Likewise, lipid profile improvements were evident, including significant decreases in total cholesterol, triglycerides, and LDL cholesterol, alongside substantial increases in HDL cholesterol. These findings highlight the potential of W. coagulans as a functional food ingredient that provides clinically meaningful metabolic benefits when incorporated into a culturally accepted dietary staple.

The hypoglycemic effect observed in this trial aligns with earlier animal and human studies reporting that aqueous or methanolic extracts of W. coagulans enhance insulin sensitivity and pancreatic β-cell activity, in addition to promoting hepatic glycogen storage (20–22). Flavonoids, withanolides, and coagulanolides within the fruit have been shown to modulate insulin receptor pathways, stimulate glucose uptake in peripheral tissues, and reduce postprandial hyperglycemia (23). The reductions in HbA1c observed after 60 days of supplementation in the present study corroborate previous clinical evidence indicating that W. coagulans can enhance long-term glycemic control by lowering insulin resistance and improving enzymatic regulation of glycolysis (24,25).

In terms of lipid regulation, the improvements in triglycerides and LDL cholesterol, coupled with increased HDL levels, are consistent with prior animal studies demonstrating that W. coagulans extracts reduce HMG-CoA reductase activity, enhance antioxidant enzyme activity, and modulate lipid metabolism pathways (26,27). The marked elevation of HDL cholesterol observed in this study suggests a cardioprotective potential, which has also been reported in hyperlipidemic animal models supplemented with W. coagulans (28). This dual action on glucose and lipid metabolism reinforces the therapeutic relevance of W. coagulans as a dietary adjunct for patients at high cardiovascular risk.

Importantly, the intervention utilized chapatti as the delivery medium, ensuring high cultural acceptability and compliance in a South Asian dietary context. Unlike extract or capsule formulations, fortified chapatti represents a practical and sustainable strategy for long-term incorporation of bioactive compounds into daily diets. This approach addresses a key translational gap by embedding phytotherapeutics into staple foods, thereby bridging the divide between pharmacological therapy and lifestyle interventions.

Despite these promising results, several limitations must be acknowledged. The study was conducted with a relatively small sample size and limited to a single-center setting, which may restrict the generalizability of findings. The intervention period of two months was sufficient to detect significant biochemical changes, but longer-term studies are required to evaluate sustained effects and clinical outcomes such as cardiovascular events or diabetic complications. Dietary intake and physical activity were monitored but not strictly controlled, introducing potential confounding influences. Furthermore, blinding was not implemented, raising the possibility of bias in outcome

reporting. Future studies with larger sample sizes, randomized controlled trial designs, and extended follow-up durations are warranted to confirm these findings and elucidate mechanistic pathways.

In clinical practice, the integration of W. coagulans into commonly consumed foods could serve as an affordable and accessible adjunctive therapy for patients with diabetes and hyperlipidemia, particularly in low-resource settings where medication adherence is challenging. Further exploration of optimal dosing, formulation stability, and potential interactions with pharmacological agents will be critical to advancing its clinical application.

CONCLUSION

This study demonstrated that dietary supplementation with chapatti fortified with *Withania coagulans* fruit powder produced significant improvements in metabolic outcomes among individuals with type 2 diabetes mellitus and hyperlipidemia. Dose-dependent reductions were observed in fasting and random blood glucose, HbA1c, total cholesterol, triglycerides, and LDL cholesterol, accompanied by substantial increases in HDL cholesterol. The incorporation of W. coagulans into chapatti represents a culturally acceptable, cost-effective, and sustainable dietary strategy with potential clinical value. While these findings support the role of W. coagulans as an adjunct to conventional management of metabolic disorders, larger randomized controlled trials with longer follow-up are required to validate its long-term safety, efficacy, and cardiometabolic benefits.

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