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Systematic Review

Effects of *Helianthus tuberosus*-Derived Products on Glycemic, Lipid, and Anthropometric Outcomes: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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Abstract

Helianthus tuberosus has been investigated for managing dysglycemia, dyslipidemia, and excess body weight, although clinical findings remain inconsistent. This systematic review and meta-analysis evaluated the effects of *H. tuberosus*-derived products on glycemic indices, lipid profiles, and anthropometric outcomes. Randomized controlled trials were identified through PubMed, Scopus, ScienceDirect, ThaiJo, and ThaiLis up to April 2026. Risk of bias was assessed, and weighted mean differences (WMDs) were pooled using random-effects models. Seven trials were included. Significant reductions in postprandial glucose (PPG) were observed at 60 min (WMD: −15.02 mg/dL; 95% CI: −20.94 to −9.10; p = 0.04) and 120 min (WMD: −10.10 mg/dL; 95% CI: −18.25 to −1.96; p = 0.02). Significant reductions were also observed in body weight (BW) (WMD: −3.95 kg; 95% CI: −5.11 to −2.78; $p < 0.001$), body mass index (BMI) (WMD: −0.84 kg/m^2; 95% CI: −1.26 to −0.43; $p < 0.001$), and visceral fat (VF) (WMD: −4.98; 95% CI: −9.80 to −0.16; p = 0.04). Other outcomes showed no consistent significant effects. Despite these findings, substantial heterogeneity and limited evidence certainty warrant cautious interpretation. *H. tuberosus*-derived products may improve postprandial glycemia and selected anthropometric outcomes, whereas effects on fasting glycemic control and lipid profiles remain inconclusive. Larger, high-quality trials are needed to confirm these findings.

Keywords: anthropometry; blood glucose; functional foods; inulin; lipids; Jerusalem artichoke

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1. Introduction

General recommendations for managing blood glucose levels, lipid profiles, and anthropometric parameters include dietary modifications and regular physical exercise. However, lifestyle adherence often necessitates pharmacological interventions to achieve therapeutic targets and reduce associated health risks [1,2].

Dietary modification and physical activity are considered first-line strategies for the management of cardiometabolic disorders [3,4]. However, adherence to lifestyle interventions is often suboptimal, necessitating adjunctive pharmacological or nutraceutical

approaches. *H. tuberosus* L. (known commonly as Jerusalem artichoke (JA)) has gained attention as a functional food due to its high inulin content and potential metabolic benefits [5,6].

H. tuberosus L. is a perennial plant belonging to the family Asteraceae and is native to North America [7,8]. It is characterized by rapid growth, resistance to pests and diseases, and tolerance to adverse environmental conditions [9]. Traditionally cultivated for human and animal consumption [10], *H. tuberosus* has increasingly been utilized as a source of functional food ingredients, particularly inulin, oligofructose, and fructose, because of their potential nutritional and health benefits [11,12].

Functional food benefits at least one specific physiological function beyond its essential nutritional value, contributing to improved well-being and health and/or reducing the risk of disease [10]. The *H. tuberosus* is a natural raw material from which several functional ingredients, including inulin, oligofructose, and fructose, are extracted [10,13]. These bioactive compounds exhibit nutritional and functional properties, making *H. tuberosus* particularly valuable to individuals seeking cardioprotective benefits [14,15].

Preclinical studies suggest that *H. tuberosus* may exert antidiabetic effects, potentially attributable to its inulin content, a dietary fiber resistant to hydrolysis by digestive enzymes in the human small intestine [16,17]. Beyond glycemic regulation, inulin has been investigated for its potential benefits in gastrointestinal health and body weight management [18]. Furthermore, previous studies have suggested that *H. tuberosus* supplementation may influence glycemic indices, lipid profiles, antioxidant status, and inflammatory and immunological markers. However, the clinical relevance and consistency of these effects remain uncertain, warranting further investigation into its potential role in cardiometabolic health management [19].

Although several clinical trials have investigated the metabolic effects of *H. tuberosus*-derived products, their findings remain inconsistent, potentially because of differences in study populations, intervention formulations, dosages, and treatment durations. To our knowledge, no previous meta-analysis has comprehensively synthesized evidence from randomized controlled trials regarding their effects on glycemic indices, lipid profiles, and anthropometric outcomes. Therefore, the present systematic review and meta-analysis aimed to address this evidence gap by quantitatively evaluating the effects of *H. tuberosus*-derived products on these clinically relevant metabolic outcomes.

2. Materials and Methods

2.1. Study Design

This was a systematic review and meta-analysis of randomized controlled trials (RCTs) conducted on human populations to evaluate the effects of *H. tuberosus* supplementation on cardiometabolic outcomes. The study followed the latest version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines [20] (Please see supplementary materials). The study protocol was also registered in the International Prospective Register of Systematic Reviews under the registration number CRD420251001507 (Available from https://www.crd.york.ac.uk/PROSPERO/view/CRD420251001507 (accessed on 1 March 2025)). To ensure a rigorous and structured approach in defining the study design, the Participant, Intervention, Comparison, and Outcome framework was employed [21], as outlined below:

- Participants: Children and/or adults with diabetes mellitus, prediabetes, dyslipidemia, overweight, obesity or healthy volunteer.
- Intervention: *H. tuberosus* or Jerusalem artichoke supplementation
- Comparison: Placebo or no treatment
- Outcome: glycemic indices, lipid profile, and anthropometric parameters.

2.2. Search Strategy

A systematic literature search was conducted across multiple databases, including PubMed, Scopus, ScienceDirect, ThaiJo, and grey literature sources, including ThaiLis, ProQuest Dissertations and Theses, the Thai Digital Collection thesis database, and ClinicalTrials.gov. Citation searching was also performed, and all studies published up to 30 April 2026 were considered for inclusion. The search strategy included Medical Subject Headings and relevant keywords such as "Jerusalem artichoke," "*Helianthus tuberosus*," "diabetes mellitus," "hyperglycemia," "insulin resistance," "dyslipidemia," "hyperlipidemia," "obesity," and "overweight" to ensure comprehensive coverage of relevant studies. No language restrictions were applied, and additional relevant articles were identified through manual searches. Non-English studies were translated into English to facilitate their inclusion in the analyses (Appendix A).

2.3. Selection of Trials

Two reviewers (WP and CT) independently assessed and selected the identified records, and a third reviewer conducted a final eligibility review to resolve any discrepancies. The systematic search results were imported into Rayyan (https://www.rayyan.ai/) to facilitate screening. Two independent researchers (WP and CT) performed initial screening based on titles and abstracts. During this stage, duplicate and irrelevant articles were excluded, and studies that met the predefined eligibility criteria were selected for full-text review and data extraction. To assess the level of agreement between the two primary reviewers, Cohen's kappa coefficient was calculated, yielding a value of 0.92, indicating almost perfect agreement.

Studies were included if they met the following criteria: (1) randomized controlled trials (RCTs) comparing the effects of *Helianthus tuberosus* (*H. tuberosus*) or *H. tuberosus*-derived products with those of placebo or no treatment on cardiometabolic outcomes, and (2) studies reporting outcome measures related to glycemic indices (for example, fasting blood sugar [FBS], hemoglobin A1c [HbA1c], homeostatic Model Assessment of Insulin Resistance [HOMA-IR], postprandial glucose [PPG], insulin resistance, and serum insulin), lipid profiles (including low-density lipoprotein [LDL], high-density lipoprotein [HDL], total cholesterol [TC], and triglycerides [TG]), and anthropometric parameters (for example, body weight [BW], body mass index [BMI], waist circumference [WC], waist to hip ratio [W/H] and visceral fat [VF]). No restrictions were applied regarding sex, publication year, or the presence of underlying health conditions. Reviews or meta-analyses, observational studies, letters to the editor, animal studies, and studies lacking a control group were excluded.

2.4. Data Extraction

Two reviewers independently extracted data, and any discrepancies were resolved by consulting a third reviewer. The following information was extracted from each eligible study: primary author, year of publication, study design, study population characteristics, sample size, study duration, type and dosage of the *H. tuberosus* product, baseline and endpoint values of outcome measures, and details of treatment and comparator interventions.

2.5. Assessment of Risk of Bias

Two reviewers independently assessed the risk of bias of the included randomized controlled trials using the Cochrane Risk of Bias 2 (RoB 2) tool, following the guidelines outlined in the Cochrane Handbook for Systematic Reviews of Interventions [22]. Any disagreements between the reviewers were resolved through discussion with a third reviewer. The assessment covered five domains: (D1) bias arising from the randomization

process, (D2) bias due to deviations from intended interventions, (D3) bias due to missing outcome data, (D4) bias in measurement of the outcome, and (D5) bias in selection of the reported result. Each domain was classified as having a low risk of bias, some concerns, or a high risk of bias. An overall risk-of-bias judgment was subsequently determined for each included study based on the assessments across the five domains.

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach was employed as the final step in quality assessment to enhance the credibility of the study's findings. The GRADE framework evaluates five key domains: (1) risk of bias, which assesses potential biases within the included studies; (2) inconsistency, which examines variations in outcomes across studies; (3) indirectness, which evaluates the applicability of study findings to clinical practice; (4) imprecision, which considers the certainty of the estimated effect size; and (5) other considerations, including publication bias, confounding factors, and the magnitude of the observed effects [23].

According to the GRADE framework, research quality was categorized into four levels: (1) high, indicating strong confidence that the actual effect is close to the estimated effect; (2) moderate, indicating moderate confidence in the estimated effect, with the possibility that the actual effect may differ substantially; (3) low, reflecting limited confidence in the estimated effect, suggesting that the actual effect could be significantly different; and (4) very low, indicating minimal confidence in the estimated effect, with a high likelihood that the actual effect is substantially different from the estimated effect [24].

2.6. Statistical Analysis

Meta-analysis was performed using STATA software (version 15.0; StataCorp LLC, USA). A random-effects model based on the DerSimonian and Laird method was employed to estimate the weighted mean difference (WMD) and the corresponding 95% confidence interval (95% CI). Statistical significance for all analyses was set at $p < 0.05$. Heterogeneity among studies was assessed using Cochran's Q test and the I^2 statistic, with the statistical significance for heterogeneity set at $p < 0.1$

The weighted mean difference (WMD) was employed as the principal effect measure for continuous outcomes to evaluate differences between the *H. tuberosus* intervention and comparator groups. WMD estimates were calculated using outcome measurements obtained at baseline and at the conclusion of the follow-up period for both intervention and control groups. The standard deviations (SDs) of the mean changes were subsequently derived using the following formula, assuming a pre–post correlation coefficient (R) of 0.5 [25].

$$SD = [SDpre^2 + SDpost^2 - (2R \times SDpre \times SDpost)]^{1/2}$$

To assess the robustness of the findings, sensitivity analyses were performed by comparing pooled effect estimates derived from random-effects and fixed-effects models. A leave-one-out analysis was also conducted to evaluate the influence of individual studies on the pooled estimates. Furthermore, the impact of different assumptions regarding the pre–post correlation coefficient (R), used to estimate the standard deviations of change scores, was examined. While R = 0.5 was assumed in the primary analysis, alternative values of R = 0.25 and R = 0.75 were applied to assess the sensitivity of the pooled estimates to these assumptions [26,27].

Furthermore, subgroup analyses were conducted based on formulation type, treatment duration, participants' health status, age categories, and the type of *H. tuberosus* extract administered. In this study, subgroup analyses were prespecified according to the outcomes of interest. For glycemic and lipid profile outcomes, subgroup analyses were conducted based on formulation type, treatment duration, participants' health status, age categories, and the type of *H. tuberosus* extract administered. For anthropometric outcomes, subgroup analyses were performed according to formulation type, participants'

health status, age categories, and the type of JA extract administered. These analyses were performed to investigate potential sources of heterogeneity and to determine the consistency of the intervention effects across different study and participant characteristics.

Publication bias was not formally evaluated in the present study due to the limited number of studies available for each outcome. Consequently, the potential influence of small-study effects and selective reporting bias cannot be definitively ruled out.

3. Results

3.1. Description of Studies

Figure 1 illustrates the study selection process in accordance with the PRISMA 2020 guidelines [20]. A total of 2148 records were identified through electronic database searches, including PubMed (n = 326), Scopus (n = 973), ScienceDirect (n = 831), and ThaiJo (n = 18). After removing 1987 duplicate records, 161 records remained for screening. Of these, 90 records were excluded because they involved non-human studies, leaving 71 reports for retrieval. Subsequently, 63 reports were excluded because they focused on phytochemical analyses (n = 29), animal studies (n = 12), review articles (n = 18), or pre–post study designs (n = 4). Of the five reports assessed for eligibility, three were excluded because they investigated *H. tuberosus* in combination with other products.

Additional searches were conducted through other sources, including the Thai Digital Collection (n = 5), ProQuest (n = 27), ClinicalTrials.gov (n = 3), and citation searching (n = 1), yielding 36 additional records. Of these, 34 reports were excluded because they involved phytochemical studies (n = 12), animal studies (n = 8), review articles (n = 7), pre–post study designs (n = 4), or duplicate records already identified through the primary database searches (n = 3). The remaining two reports were assessed for eligibility, and neither was excluded. Consequently, seven studies met the eligibility criteria and were included in the systematic review and meta-analysis (Figure 1).

Table 1 summarizes the characteristics of the seven included randomized controlled trials, comprising 326 participants, conducted between 2016 and 2025 in Thailand, South Korea, and Japan. The studies included participants with prediabetes, type 2 diabetes mellitus, or obesity, as well as healthy individuals. Intervention durations ranged from 8 to 24 weeks, and sample sizes ranged from 10 to 110 participants. *H. tuberosus* was administered in various formulations, including powder, tablets, capsules, and inulin extracted from Jerusalem artichoke, with placebo preparations serving as comparators. The evaluated outcomes included glycemic parameters, such as FBS, HbA1c, PPG, and HOMA-IR; lipid profiles, including LDL-C, HDL-C, TC, and TG; anthropometric measures, including BW, BMI, WC, W/H ratio and VF; and biochemical safety parameters, including AST, ALT, and serum creatinine.

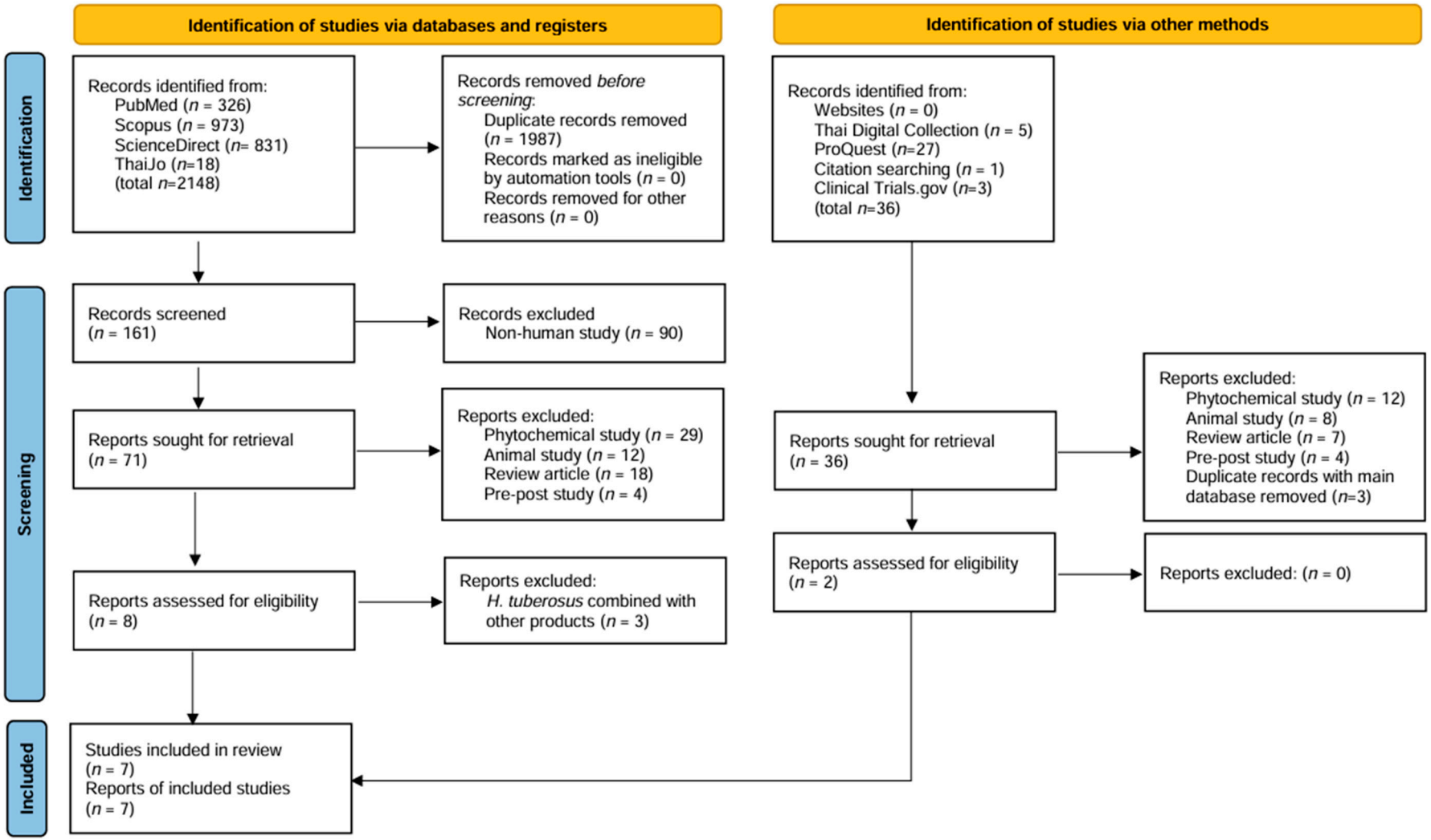

Figure 1. A PRISMA flow diagram describing the selection process for identifying included studies.

Table 1. Characteristics of the included studies in the meta-analysis.

No	Articles	Year	Country	Study Design	Participants	Age Range or Average	Treatment Duration	Groups (*n*)		Outcomes Measurement
								Intervention	Comparators	
1	Thonglim, et al. 2016 [28]	2016	Thailand	RCT	Participants with pre-diabetes	22–55 yrs	8 weeks	JA powder 10 g/day (*n* = 5)	Placebo contained CMC 10 g/day (*n* = 5)	FBS, HbA1C, BMI
2	Ahn, et al. 2018 [19]	2018	Republic of Korea	DRCT	Participants with pre-diabetes and newly diagnosed type 2 diabetes mellitus	55.2 ± 1.30 yrs	12 weeks	JA–fermented soybean mixture (40 g/day; inulin ~6 g/day), administered thrice daily; multi-component intervention (*n* = 22).	Placebo contained 84.71% rice flour and 2.32% cornstarch (*n* = 25)	HbA1C, HOMA-IR, PPG, BW, BMI, W/H, LDL, HDL, TC, TG
3	Inganinanda, et al. 2019 [29]	2019	Thailand	RCT	Participants with obesity	30–50 yrs 43.01 ± 6.22 yrs	8 weeks	JA powder 2.4 g/day (400 mg 2 capsules 3 times/day (*n* = 18)	Placebo contained MC 2.4 g/day (*n* = 18)	BW, BMI, WC, VF
4	Juttupornpong, et al. 2019 [30]	2019	Thailand	RCT	Participants with pre-diabetes	35–65 yrs 49.23 ± 9.73 yrs	8 weeks	JA powder 2.4 g/day (400 mg 2 capsules 3 times/day (*n* = 18)	Placebo contained MC 2.4 g/day (*n* = 18)	FBS, HbA1C
5	Najima, et al. 2018 [31]	2018	Japan	DRCT	Healthy participant	20–59 yrs	12 weeks	JA tablets (1750 mg/day; inulin 750 mg/day), containing 99% artichoke powder (*n* = 14).	Placebo contained lactose 84%, dextrin 10% and MC 5% (*n* = 13)	FBS, PPG, AST, ALT, creatinine
6	Visuthranukul, et al. 2022 [32]	2022	Thailand	DRCT	Participants with obesity	7–15 years 10.50 ± 2.25 yrs	24 weeks	Inulin powder extracted from Thai Jerusalem artichoke (13 g/day), dissolved in 150 mL of warm water and consumed once daily approximately 30 min before dinner for 6 months (*n* = 55).	Isocaloric maltodextrin (11 g/day) (*n* = 55)	FBS, LDL, HDL, TC, TG, WC, VF, ALT
7	Teparak, et al. 2025 [33]	2025	Thailand	DRCT	Type 2 diabetes mellitus	30–50 years 53.50 ± 0.9 yrs	8 weeks	JA extract capsule 1.26 g/day contained inulin 250 mg/day and anthocyanins (0.28 g/day) (*n* = 30)	placebo capsules contained maltodextrin (*n* = 30)	FBS, HbA1C, HOMA-IR, BW, BMI, WC, W/H, LDL, HDL, TC, TG, ALT

Remark: N/A, not available; RCT, randomized controlled trial; DRCT, double-blind randomized controlled trial; JA, Jerusalem artichoke; DM, diabetes mellitus; FBS, fasting blood sugar; HbA1C; HOMA-IR, Hemoglobin A1c; HOMA-IR, Homeostatic Model Assessment of Insulin Resistance; PPG, postprandial glucose; BW, body weight; BMI, body mass index; WC, waist circumference; W/H, waist to hip ratio; VF, visceral fat; LDL, low-density lipoprotein; HDL, high-density lipoprotein; TC, total cholesterol; TG, triglyceride; AST, Aspartate Aminotransferase; ALT, Alanine transaminase.

3.2. Risk of Bias in Included Studies

The risk of bias assessment using the revised Cochrane Risk of Bias 2 (RoB 2) tool revealed variations in methodological quality across the seven included studies. Two studies (28.6%), conducted by Teparak et al. (2025) [33] and Visuthranukul et al. (2022) [32], were classified as having a low overall risk of bias across all five domains. In contrast, Najima et al. (2018) [31] was judged to have a high overall risk of bias (14.3%), primarily due to bias arising from missing outcome data. The remaining four studies (57.1%) were classified as having some concerns, mainly related to deviations from intended interventions, missing outcome data, and selection of the reported result. Among the five domains, bias in selection of the reported result was the most frequently identified concern, affecting three studies (42.9%), followed by bias due to deviations from intended interventions and missing outcome data. Bias in measurement of the outcome was generally assessed as low risk, with only two studies (28.6%) raising some concerns in this domain. Overall, these findings indicate variability in the risk of bias across the included trials, which should be considered when interpreting the pooled effect estimates (Table 2).

Table 2. Summary of authors' judgment about each risk of bias item for included studies.

	D1	D2	D3	D4	D5	Overall
Ahn, et al. 2018 [19]	Low risk	Low risk	Some concerns	Low risk	Some concerns	Some concerns
Inganinanda. 2019 [29]	Low risk	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
Juttuponpong. 2019 [30]	Some concerns	Some concerns	Some concerns	Low risk	Low risk	Some concerns
Najima, et al. 2018 [31]	Low risk	Low risk	High risk	Low risk	Low risk	High risk
Teparak, et al. 2025 [33]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Thonglim. 2016 [28]	Some concerns	Low risk	Low risk	Some concerns	Some concerns	Some concerns
Visuthranukul, et al. 2022 [32]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Domains**:** D1: Bias arising from the randomization process; D2: Bias due to deviations from intend intervention; D3: Bias due to missing outcomes data; D4: Bias due to measurement of the outcome; D5: Bias in selection of the reported results.

The GRADE assessment indicated that the certainty of evidence ranged from very low to low across the 15 evaluated outcomes. Ten outcomes, FBS, HbA1c, PPG at 30 min, HOMA-IR, LDL, HDL, TC, BW, WC, and W/H ratio, were rated as having very low certainty of evidence. The remaining five outcomes, comprising PPG at 60 and 120 min, TG, BMI, and VF, were classified as having low certainty of evidence. No outcomes were rated as having moderate or high certainty. Downgrading was primarily attributable to concerns regarding risk of bias, substantial between-study heterogeneity, and imprecision. Very serious inconsistency was identified for several glycemic and lipid outcomes, particularly FBS, HbA1c, HOMA-IR, LDL, HDL, and TC (I^2 = 90–100%), as well as BW (I^2 = 92%). In contrast, PPG at 60 and 120 min, TG, BMI, and VF exhibited relatively low heterogeneity (I^2 = 0–35%) and were not downgraded for inconsistency. Overall, these findings highlight important limitations in the certainty of the available evidence and underscore the need for cautious interpretation of the pooled effect estimates (Table 3).

Table 3. Certainty of evidence for the effects of *H. tuberosus* supplementation on cardiometabolic outcomes assessed using the GRADE approach.

Outcome	Studies	N	I^2	Risk of Bias	Inconsistency	Imprecision	Certainty
FBS	5	248	95%	Serious	Very serious	Serious	Very low
HbA1c	4	157	96%	Serious	Very serious	Serious	Very low
PPG 30 min	2	74	83%	Serious	Serious	Serious	Very low
PPG 60 min	2	74	0%	Serious	Not serious	Serious	Low
PPG 120 min	2	74	25%	Serious	Not serious	Serious	Low
HOMA-IR	2	104	100%	Serious	Very serious	Serious	Very low
LDL	3	217	97%	Serious	Very serious	Serious	Very low
HDL	3	217	90%	Serious	Very serious	Serious	Very low
TC	3	217	99%	Serious	Very serious	Serious	Very low
TG	3	217	40%	Serious	Not serious	Serious	Low
BW	3	140	92%	Serious	Very serious	Serious	Very low
BMI	4	150	35%	Serious	Not serious	Serious	Low
WC	3	206	75%	Serious	Serious	Serious	Very low
W/H ratio	2	107	85%	Serious	Serious	Serious	Very low
VF	2	146	7%	Serious	Not serious	Serious	Low

Remark**:** FBS, fasting blood sugar; HbA1C, Hemoglobin A1c; PPG, postprandial glucose; BW, body weight; BMI, body mass index; WC, waist circumference; W/H, waist to hip ratio; VF, visceral fat; LDL, low-density lipoprotein; HDL, high-density lipoprotein; TC, total cholesterol; TG, triglyceride; WMD, weight mean difference; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation.

GRADE domain explanations and limitations:

- Risk of bias: Assessed using outcome-specific RoB 2 judgments, considering the direction, magnitude, and contribution of potential biases to pooled estimates.
- Inconsistency: Very serious inconsistency was provisionally assigned to outcomes with substantial heterogeneity (I^2 = 89–99%), assessment of effect direction, confidence interval overlap, and clinical variability.
- Indirectness: Rated as not serious, subject to confirmation of population and intervention applicability, particularly for the synbiotic combination trial.
- Imprecision: Rated as serious based on confidence interval width and limited information size.
- Publication bias: Insufficient evidence was available for definitive assessment; no downgrading was applied.

3.3. Effect of H. tuberosus on Glycemic Biomarkers

Six studies [19,28,30–33] provided data for the meta-analysis, with separate analyses conducted on FBS, HbA1c, PPG and HOMA-IR. The pooled results indicated that the reduction in FBS was not statistically significant, with a WMD of −7.89 mg/dL (95% CI: −18.84, 3.06; p = 0.16; I^2 = 95.0%). Similarly, the effect on HbA1c was also not significant, yielding a WMD of −0.18% (95% CI: −0.85, 0.49; p = 0.59; I^2 = 96.0%) (Table 3).

For PPG at 30 min, the reduction was not statistically significant, with a WMD of −10.33 mg/dL (95% CI: −36.92, 16.27; p = 0.45; I^2 = 83.0%). However, the pooled analysis demonstrated a significant reduction in PPG at 60 and 120 min following *H. tuberosus* treatment, with a WMD of −15.02 mg/dL (95% CI: −20.94, −9.10; p < 0.001; I^2 = 0.0%) and −10.10 mg/dL (95% CI: −18.25, −1.96; p = 0.02; I^2 = 25.0%), respectively. The pooled analysis demonstrated a non-significant reduction in HOMA-IR with *H. tuberosus* compared to controls (−0.64; 95% CI: −1.94, 0.65; p = 0.33; I^2 = 100.0%) (Table 3).

3.4. Effect of H. tuberosus on Lipid Profile

The impact of *H. tuberosus* supplementation on the lipid profile was assessed in three trials [19,32,33], with pooled effect sizes analyzed using a random-effects model. The results indicated no significant effect of *H. tuberosus* supplementation compared with placebo on lipid parameters. Specifically, the WMD were −5.34 mg/dL for LDL (95% CI: −20.07, 9.38; $p = 0.48$; $I^2 = 97.0\%$), 1.34 mg/dL for HDL (95% CI: −1.86, 4.54; $p = 0.41$; $I^2 = 90.0\%$), −31.38 mg/dL for total cholesterol (95% CI: −79.61, 16.85; $p = 0.20$; $I^2 = 99.0\%$), and −4.38 mg/dL for triglycerides (95% CI: −10.98, 2.22; $p = 0.19$; $I^2 = 40.0\%$). These findings suggest that *H. tuberosus* supplementation did not significantly improve lipid profiles compared with the placebo (Table 3).

3.5. Effect of H. tuberosus on Anthropometric Parameters

The pooled analysis of three studies [19,29,33] indicated that *H. tuberosus* supplementation resulted in a significant reduction in BW, with a WMD of −3.95 kg (95% CI: −5.11, −2.78; $p < 0.001$; $I^2 = 92.0\%$). In addition, four studies [19,28,29,33] showed *H. tuberosus* supplementation significantly decreased BMI, with a WMD of −0.84 kg/m^2 (95% CI: −1.26, −0.43; $p < 0.001$; $I^2 = 35.0\%$). These findings suggest a potential role for *H. tuberosus* in weight management (Table 4). However, the pooled analysis demonstrated that *H. tuberosus*-derived products reduced WC by 2.13 cm (95% CI: −6.99, 2.73; $p = 0.39$; $I^2 = 75.0\%$) however, this reduction was not statistically significant ($p = 0.39$). Similarly, no statistically significant difference in W/H ratio was observed between the intervention and control groups (WMD: 0.00; 95% CI: −0.01 to 0.00; $p = 0.29$). In contrast, *H. tuberosus*-derived products significantly reduced visceral fat compared with the control group (WMD: −4.98; 95% CI: −9.80 to −0.16; $p = 0.04$).

Table 4. Results of the main and sensitivity analyses.

Outcomes	Main Analysis WMD (95% CI; *p*-Value); I^2	Sensitivity Analysis WMD (95% CI; *p*-Value); I^2	References
FBS	−7.89 mg/dL (−18.84, 3.06; $p = 0.16$); 95.0%	−1.04 mg/dL (−2.85, 0.77; $p = 0.26$); 95.0%	[28,30–33]
HbA1C	−0.18% (−0.85, 0.49; $p = 0.59$); 96.0%	−0.30% (−0.42, −0.18; $p < 0.001$); 97.0% *	[19,28,30,33]
PPG 30 min	−10.33 mg/dL (−36.92, 16.27; $p = 0.45$); 83.0%	0.21 mg/dL (−3.99, 4.40; $p = 0.92$); 83.0% *	[19,31]
PPG 60 min	−15.02 mg/dL (−20.94, −9.10 $p < 0.001$); 0.0% *	−14.64 mg/dL (−20.67, −8.61; $p < 0.001$); 0.0% *	[19,31]
PPG 120 min	−10.10 mg/dL (−18.25, −1.96; $p = 0.02$); 25.0% *	−10.89 mg/dL (−16.99, −4.80; $p < 0.001$); 25.0% *	[19,31]
HOMA-IR	−0.64 (−1.94, 0.65; $p = 0.33$); 100.0%	−1.13 (−1.18, −1.08; $p < 0.001$); 100.0% *	[19,33]
LDL	−5.34 mg/dL (−20.07, 9.38; $p = 0.48$); 97.0%	−9.22 mg/dL (−11.41, −7.03; $p < 0.001$); 97.0% *	[19,32,33]
HDL	1.34 mg/dL (−1.86, 4.54; $p = 0.41$); 90.0%	1.98 mg/dL (1.10, 2.87; $p < 0.001$); 90.0% *	[19,32,33]
TC	−31.38 mg/dL (−79.61, 16.85; $p = 0.20$); 99.0%	−11.59 mg/dL (−15.44, −7.74; $p < 0.001$); 98.0% *	[19,32,33]
TG	−4.38 mg/dL (−10.98, 2.22; $p = 0.19$); 40.0%	−6.11 mg/dL (−10.56, −1.66; $p = 0.007$); 25.0% *	[19,32,33]
BW	−3.95 kg (−5.11, −2.78; $p < 0.001$); 92%	−3.95 kg (−5.11, −2.78; $p < 0.001$); 90.0% *	[19,29,33]
BMI	−0.84 kg/m^2 (−1.26, −0.43; $p < 0.001$); 35.0% *	−0.86 kg/m^2 (−1.11, −0.61; $p < 0.001$); 35.0% *	[19,28,29,33]
WC	−2.13 cm (−6.99, 2.73; $p = 0.39$); 75.0%	−0.36 cm (−1.93, 1.20; $p = 0.65$); 75.0%	[29,32,33]
W/H ratio	0.00 (−0.01, 0.00; $p = 0.33$); 85.0%	−0.02 (−0.03, −0.01; $p = 0.02$); 85.0% *	[19,33]
VF	−4.98 (−9.80, −0.16; $p = 0.04$); 7.0% *	−5.25 (−9.04, −1.45; $p = 0.007$); 7.0% *	[29,32]

Remark**:** BW, body weight; BMI, body mass index; WMD, weighted mean difference; PPG, postprandial glucose; LDL, low density lipoprotein; HDL, high density lipoprotein; TG, triglycerides; TC, total cholesterol; WC, waist circumference; W/H, waist to hip ratio; VF, visceral fat; * Statistically significant; $p \leq 0.05$.

3.6. Safety

Only two studies, Najima et al. (2018) [31] and Teparak et al. (2025) [33], reported safety-related outcomes following *H. tuberosus* supplementation. These studies assessed

selected hepatic and renal biomarkers, including liver enzymes, blood urea nitrogen (BUN), serum creatinine, and estimated glomerular filtration rate (eGFR). Najima et al. (2018) [31] reported no significant changes in BUN or serum creatinine after 12 weeks of supplementation. Similarly, Teparak et al. (2025) [33] observed no significant changes in serum creatinine following 60 days of supplementation. Although eGFR increased significantly within the intervention group (p = 0.01), the between-group interaction was not statistically significant (p = 0.28). Neither study reported serious adverse events or clinically apparent renal impairment. Nevertheless, the limited safety data, small sample sizes, and short follow-up periods preclude definitive conclusions regarding the long-term safety of *H. tuberosus* supplementation.

3.7. Sensitivity Analysis

Sensitivity analyses were performed using a fixed-effects model to evaluate the robustness of the findings obtained from the primary random-effects analysis. Of the 15 outcomes assessed, eight retained the same statistical significance status across both models. However, seven outcomes, including HbA1c, HOMA-IR, LDL, HDL, TC, TG, and W/H ratio, changed from statistically non-significant under the random-effects model to statistically significant under the fixed-effects model (Table 4). These findings indicate that the pooled estimates for these outcomes were sensitive to the choice of statistical model. Given the substantial heterogeneity observed for several outcomes, the results obtained using the fixed-effects model should be interpreted with caution. Accordingly, the random-effects model was retained as the primary analytical approach.

Leave-one-out sensitivity analyses revealed that several pooled effect estimates were influenced by the exclusion of individual studies, whereas the statistical significance of the findings for FBS, HbA1c, LDL, HDL, TG, and WC remained unchanged. For HOMA-IR and PPG at 30 min, exclusion of Ahn et al. (2018) [19] changed the pooled effects from non-significant to statistically significant. Conversely, exclusion of Ahn et al. (2018) [19] changed the statistically significant reductions in PPG at 60 and 120 min to non-significant findings. Regarding lipid outcomes, omission of Teparak et al. (2025) [33] resulted in a statistically significant reduction in total cholesterol, whereas the findings for LDL, HDL, and TG remained non-significant regardless of the study omitted. For anthropometric outcomes, exclusion of Ahn et al. (2018) [19] changed the statistically significant reduction in BW to a non-significant finding. Similarly, exclusion of either Ahn et al. (2018) [19] or Teparak et al. (2025) [33] changed the statistically significant reduction in BMI to a non-significant finding. Furthermore, exclusion of Teparak et al. (2025) [33] resulted in a statistically significant reduction in the waist-to-hip ratio, whereas omission of Inganinanda et al. (2019) [29] changed the significant reduction in visceral fat to a non-significant result. These findings indicate that several pooled estimates, particularly those based on a limited number of studies, were sensitive to the influence of individual trials (Appendix B).

Additional sensitivity analyses were performed by varying the assumed pre–post correlation coefficient (R) from 0.50 in the primary analysis to 0.25 and 0.75. The results demonstrated varying degrees of sensitivity across outcomes. For PPG at 60 min, statistically significant reductions were reported across all three correlation coefficients, although the magnitude of the pooled estimates varied. In contrast, the statistically significant reduction in PPG at 120 min observed in the primary analysis was no longer significant at R = 0.25 but remained significant at R = 0.75. Similarly, the significant reduction in BW observed in the primary analysis (R = 0.50; WMD = −3.95 kg, 95% CI −5.11 to −2.78; I^2 = 92.0%) was no longer statistically significant when R was adjusted to 0.25 or 0.75. For BMI, reductions remained statistically significant across all three correlation coefficients according to the reported results, although between-study heterogeneity varied substantially (I^2 = 0–79%). The pooled estimates for visceral fat also remained statistically

significant across the evaluated correlation coefficients, although heterogeneity increased markedly at $R = 0.25$ and 0.75. Conversely, FBS, HbA1c, PPG at 30 min, HOMA-IR, LDL, HDL, TC, TG, WC, and waist-to-hip ratio remained statistically non-significant across all three correlation coefficients. Overall, these findings suggest that the robustness of certain pooled estimates, particularly those related to postprandial glucose and anthropometric outcomes, was influenced by individual studies and assumptions regarding the pre–post correlation coefficient, warranting cautious interpretation of the pooled results. Further details are presented in Appendix C.

3.8. Subgroup Analysis

Subgroup analyses were conducted according to formulation type, intervention duration, participants' health status, age group, and the use of *H. tuberosus* extracts. For glycemic outcomes, a statistically significant reduction in PPG at 30 min was observed among healthy participants (WMD = −26.30 mg/dL; 95% CI −48.39 to −4.21), whereas no significant effect was observed among participants with prediabetes or type 2 diabetes mellitus. At 60 min, a significant reduction in PPG was observed among participants with prediabetes or type 2 diabetes mellitus (WMD = −14.50 mg/dL; 95% CI −20.75 to −8.25), while the effect among healthy participants was not statistically significant. At 120 min, significant reductions in PPG were observed in prediabetes or type 2 diabetes mellitus (WMD = −12.50 mg/dL; 95% CI −19.18 to −5.82) but no significant reduction were observed in healthy individuals (WMD = −2.90 mg/dL; 95% CI −17.79 to 11.99). No statistically significant effects were identified across the evaluated subgroups for fasting blood sugar (FBS), HbA1c, or lipid parameters, including LDL, HDL, total cholesterol, and triglycerides.

Regarding anthropometric outcomes, *H. tuberosus* extracts were associated with statistically significant reductions in body weight (WMD = −3.94 kg; 95% CI −5.14 to −2.75) and body mass index (BMI; WMD = −0.80 kg/m^2; 95% CI −1.13 to −0.47). A significant reduction in BMI was also observed among participants with obesity (WMD = −1.00 kg/m^2; 95% CI −1.40 to −0.60). In contrast, non-extract preparations were associated with significant reductions in waist circumference (WMD = −10.35 cm; 95% CI −17.52 to −3.18) and waist-to-hip ratio (WMD = −0.01; 95% CI −0.02 to −0.00). For visceral fat, significant reductions were observed in subgroups receiving interventions for ≤12 weeks, among children, and with non-extract preparations (WMD = −5.73; 95% CI −9.63 to −1.83). Nevertheless, most statistically significant subgroup findings were derived from individual studies, and formal tests for subgroup differences were not reported. Therefore, these findings should be interpreted as exploratory rather than definitive evidence of differential treatment effects across subgroups (Appendix D).

3.9. Publication Bias

Publication bias was not formally assessed because most outcomes included fewer than 10 studies, which is considered insufficient for reliable interpretation of funnel plot asymmetry according to Cochrane recommendations. Therefore, the possibility of publication bias or small-study effects cannot be excluded.

4. Discussion

In this systematic review and meta-analysis, *H. tuberosus*-derived interventions were associated with reductions in PPG at 60 and 120 min and with modest improvements in BW and BMI. However, consistent benefits were not demonstrated for fasting glycemic indices or lipid parameters, and the certainty of these findings was limited by heterogeneity, small sample sizes, short intervention durations, and the inclusion of combination products.

Our findings indicate that *H. tuberosus* supplementation was associated with a significant reduction in PPG levels at 60 and 120 min, whereas no significant effect was observed at 30 min. Moreover, supplementation with *H. tuberosus* did not result in substantial differences in FBS or glycated hemoglobin (HbA1c) levels compared with controls. Notably, three studies enrolled participants who were pre-diabetic, potentially with baseline blood glucose levels close to the normal range. These results may be attributable to short intervention durations, small sample sizes, or the inclusion of participants without diabetes. Although *H. tuberosus* showed a greater glucose-lowering effect than placebo, this difference did not reach statistical significance. In addition, the pooled estimates for FBS and HbA1c revealed considerable heterogeneity among the included studies; therefore, caution should be exercised when interpreting these findings. Furthermore, it remains challenging to determine whether the observed effects on blood glucose levels can be solely attributed to the bioactive properties of *H. tuberosus*, given the potential influence of other metabolic and physiological factors.

Notably, no heterogeneity was detected among the included studies regarding the efficacy of *H. tuberosus* supplementation on PPG levels at 60 and 120 min. The analysis revealed minimal variations in the data presentation, dosage, frequency, and duration of *H. tuberosus* supplementation. The findings of this meta-analysis suggest that *H. tuberosus* tend to reduce PPG levels between 60 and 120 min after ingestion. Previous studies have demonstrated that *H. tuberosus* extracts enhance α-glucosidase inhibitory activity (enzymes that break down carbohydrates), particularly against sucrase and lactase enzymes, in in-vitro models and ameliorate blood glucose levels in db/db mice [34].

Notably, *H. tuberosus* has been reported to partially inhibit intestinal α-glucosidase activity, particularly sucrase activity in the distal intestine and lactase activity throughout the intestine, potentially delaying carbohydrate digestion and absorption and attenuating postprandial hyperglycemia [34]. This mechanism may contribute to its observed glucose-lowering effects. Evidence from pharmacological α-glucosidase inhibitors provides additional clinical context, with previous studies reporting a reduction in the hazard ratio for cardiovascular disease (CVD) associated with longer treatment duration, from 1.19 for less than 12 months to 0.38 for more than 24 months [35]. However, these findings concern pharmacological agents and cannot be directly extrapolated to *H. tuberosus* supplementation. Importantly, cardiovascular outcomes were not assessed in the included trials; therefore, any potential cardiovascular benefits of *H. tuberosus* remain hypothetical and require confirmation in appropriately designed clinical studies.

Elevated blood PPG levels trigger oxidative stress, which plays a significant role in the progression of diabetes and its complications [36,37]. Given its potential to reduce PPG levels, *H. tuberosus* may also mitigate oxidative stress, thereby delaying diabetes progression and reducing the risk of associated complications. However, no clinical trials have specifically evaluated the association between the *H. tuberosus*-induced reduction in PPG levels and clinical outcomes, including complication risk reduction.

Elevated PPG levels contribute to oxidative stress, which is implicated in the progression of diabetes and its associated complications [36,37]. The findings of the present meta-analysis suggest that *H. tuberosus* supplementation may improve PPG regulation, potentially through α-glucosidase inhibition, which delays carbohydrate digestion and glucose absorption. However, this proposed mechanism requires further clinical investigation. Although reductions in PPG may have implications for glycemic management, no clinical trials have directly established whether *H. tuberosus*-induced improvements in PPG translate into reduced oxidative stress, delayed disease progression, or a lower risk of cardiovascular and other diabetes-related complications [38,39]. Given the limited number of studies, small sample sizes, and methodological heterogeneity, these findings should be interpreted cautiously [40]. Further adequately powered, high-quality randomized

controlled trials are warranted to confirm the glycemic effects of *H. tuberosus* and establish their long-term clinical significance.

Significant improvements in anthropometric parameters, specifically body weight and BMI, were also observed. This effect may be attributed to the high inulin content in *H. tuberosus*, as inulin supplementation enhances gut microbiota composition and microbial function [41]. Recent evidence suggests that gut microbiota play a crucial role in energy homeostasis and inflammatory regulation [42]. Dysbiosis, or an imbalance in the gut microbiota, is increasingly recognized as an environmental factor that influences the pathophysiology of obesity [43]. Notably, obesity-induced gut dysbiosis has been well documented [44,45], and research indicates that inulin supplementation may help restore microbial balance by increasing microbial diversity. Several studies have identified inulin-induced bacterial strains as short-chain fatty acid-producing bacteria that exert protective effects against obesity [41].

The potential mechanisms underlying the anthropometric effects of *H. tuberosus* remain incompletely understood. Its inulin content may influence metabolic regulation through alterations in gut microbiota composition, short-chain fatty acid production, and incretin hormone secretion; however, these pathways remain hypothetical in the context of the anthropometric outcomes observed in this review. Glucagon-like peptide-1 (GLP-1) and glucose-dependent insulinotropic polypeptide (GIP), secreted by intestinal L-cells and K-cells, respectively, contribute to glucose homeostasis and pancreatic β-cell function [46]. Previous studies have reported that phytosterol- and inulin-enriched soymilk increased GLP-1 secretion in healthy men [47], whereas *H. tuberosus* consumption reduced active GIP concentrations following carbohydrate- or fat-rich meals without significantly affecting GLP-1 concentrations. Conversely, several human studies have reported no significant increase in circulating GLP-1 following purified inulin supplementation. Experimental studies have also suggested a potential role for GIP signaling in adipose tissue metabolism and obesity, although the clinical relevance of these findings remains uncertain [48]. Takahashi et al. [6] further reported alterations in active GIP concentrations following *H. tuberosus* consumption in individuals with prediabetes; however, the small sample size limits the strength of these findings. Collectively, these observations suggest potential metabolic pathways through which *H. tuberosus* supplementation might influence body composition, but they do not establish that changes in incretin signaling or gut microbiota mediate its anthropometric effects. Future adequately powered mechanistic clinical trials should evaluate GLP-1 and GIP responses, insulin secretion, gastric emptying, gut microbiota composition, and short-chain fatty acid production alongside anthropometric outcomes to clarify these proposed mechanisms.

Regarding lipid-lowering effects, the comparison between *H. tuberosus* supplementation and control groups demonstrated no significant differences across multiple lipid parameters. This lack of efficacy contributed to the observed heterogeneity. In addition, heterogeneity was evident in the findings of the lipid profile trials, further highlighting the variability in response to *H. tuberosus* supplementation across studies.

Given the substantial heterogeneity observed across several outcomes, subgroup analyses were conducted according to participant characteristics, dosage, formulation type, and intervention duration, alongside sensitivity analyses using alternative statistical models, the leave-one-out approach, and varying correlation coefficients. Several outcomes, including HbA1c, PPG at 30 min, HOMA-IR, and lipid parameters, became statistically significant under the fixed-effect model despite non-significant findings in the primary random-effects analyses, indicating sensitivity to model selection. Furthermore, the exclusion of individual studies and variations in the assumed correlation coefficient (R = 0.25 and 0.75) altered the statistical significance of certain outcomes, including body weight. These findings highlight the limited robustness of some pooled estimates and

underscore the need for cautious interpretation, particularly in the presence of substantial heterogeneity. Further well-designed randomized controlled trials are warranted to establish more reliable estimates of the cardiometabolic effects of *H. tuberosus* supplementation.

Although this systematic review and meta-analysis found no reports of severe adverse effects associated with *H. tuberosus* supplementation, the potential for infrequent adverse effects was also examined, particularly concerning renal and hepatic functions. Previous studies reported no statistically significant changes in blood urea nitrogen (BUN) or serum creatinine following *H. tuberosus* supplementation. Although a significant increase in estimated glomerular filtration rate (eGFR) was observed within the intervention group in one study, the between-group difference was not statistically significant. No serious adverse events or clinically apparent renal impairment were reported [31].

Regarding adverse events, the findings of the present systematic review indicate that some included studies reported no significant gastrointestinal adverse events, whereas several others lacked systematic safety reporting, particularly concerning gastrointestinal adverse events. Gastrointestinal tolerability is crucial for the clinical application of *H. tuberosus* supplementation. Visuthranukul et al. (2022) [32] reported no significant adverse effects, although approximately 10% of participants complained about the supplement's taste but completed treatment. Similarly, Teparak et al. (2025) [33] reported no adverse effects. However, adverse event reporting across the included studies was inconsistent, with limited data on gastrointestinal symptoms, including bloating, flatulence, and abdominal discomfort. Therefore, the absence of reported adverse events does not establish safety. Future randomized controlled trials should systematically evaluate gastrointestinal adverse events, treatment adherence, and tolerability to establish the long-term safety and clinical feasibility of supplementation.

Several limitations should be acknowledged. First, small sample sizes and the limited number of trials contributed to imprecise and potentially unstable pooled estimates. Second, substantial heterogeneity across several outcomes may reflect differences in study populations, intervention characteristics, and methodologies. Some estimates were also sensitive to statistical model selection and assumptions regarding baseline–follow-up correlations. To assess robustness, sensitivity analyses were performed using correlation coefficients (R) of 0.25, 0.50, and 0.75, alongside leave-one-out analyses. Nevertheless, these analyses could not fully address uncertainties arising from heterogeneity and model dependence. Second, although the majority of participants had prediabetes and/or diabetes, five trials included individuals with prediabetes, three studies were conducted in obese participants, and two studies involved healthy individuals and/or patients with diabetes. In addition, variability in participant characteristics, geographical settings, intervention durations, dosages (e.g., 150 mg vs. 750 mg of inulin daily), and formulations of *H. tuberosus* products (e.g., powder vs. extract or pure of *H. tuberosus* vs. mixed formulations) may have confounded the effects attributable specifically *H. tuberosus* on glycemic outcomes, potentially influencing the overall findings. Furthermore, several subgroup analyses were based on a limited number of studies, which may have reduced the precision and reliability of the estimates. Therefore, findings from these analyses should be considered exploratory and interpreted with caution, particularly when extrapolating the results to clinical practice.

Subgroup analyses were conducted to explore potential sources of heterogeneity; however, several estimates were based on only one or two studies, limiting their precision and reliability. Furthermore, differences in statistical significance between subgroups do not necessarily indicate genuine differences in treatment effects, particularly in the absence of formal interaction tests. Therefore, these findings should be considered exploratory and hypothesis-generating rather than confirmatory. The limited number of studies and

substantial heterogeneity further warrant cautious interpretation, and additional well-designed randomized controlled trials are needed to investigate potential effect modifiers.

Furthermore, although this study included searches of three international databases and grey literature sources, the Web of Science database was not searched because access to this database was unavailable. Future studies should consider including searches of this database to enhance the comprehensiveness of the literature review.

Future research should focus on well-designed, adequately powered randomized controlled trials to clarify the efficacy and safety of *H. tuberosus*-derived products. In particular, multicenter, double-blind, placebo-controlled trials investigating standardized *H. tuberosus* -derived inulin alone in adults with prediabetes or type 2 diabetes are warranted, with prespecified outcomes including HbA1c, FBS, continuous glucose monitoring (CGM)-derived postprandial glycemic parameters, lipid profiles, body weight, gastrointestinal tolerability, and hepatic and renal safety markers over a follow-up period of at least 12–24 weeks. In addition, acute randomized crossover meal-challenge studies comparing whole *H. tuberosus*, purified inulin, and placebo should be conducted to better isolate and determine the specific bioactive components responsible for the observed metabolic effects.

5. Conclusions

Current evidence from randomized controlled trials suggests that *H. tuberosus*-derived products may attenuate postprandial glycemic excursions and improve selected anthropometric outcomes, including BW, BMI, and VF. However, evidence regarding their effects on fasting glycemic control and lipid profiles remains inconclusive. Future well-designed randomized controlled trials with standardized *H. tuberosus* preparations, adequate sample sizes, longer follow-up periods, and clearly defined metabolic endpoints are warranted to confirm these findings.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/life16122039/s1, Table S1: PRISMA 2020 item checklist.

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Abbreviations

The following abbreviations are used in this manuscript:

ALT	alanine aminotransferase
AST	aspartate aminotransferase

BMI	body mass index
BW	body weight
CI	confidence interval
FBS	fasting blood sugar
HbA1c	glycated hemoglobin
HDL	high-density lipoprotein
HOMA-IR	homeostatic model assessment of insulin resistance
JA	Jerusalem artichoke
LDL	low-density lipoprotein
PPG	postprandial glucose
RCT	randomized controlled trial
TC	total cholesterol
TG	triglycerides
WMD	weighted mean difference

Appendix A

Table A1. Search Strategies.

Database	Step	Search Algorithm	Items Found
PubMed	#1	"Jerusalem artichoke"[tiab]	618
	#2	"Helianthus tuberosus"[tiab]	388
	#3	"Diabetes Mellitus"[MeSH Terms] OR "diabetes mellitus"[tiab]	706,243
	#4	"Hyperglycemia"[MeSH Terms] OR hyperglycemia[tiab]	91,291
	#5	"Insulin Resistance"[MeSH Terms] OR "insulin resistance"[tiab]	172,818
	#6	"Dyslipidemias"[MeSH Terms] OR dyslipidemia[tiab]	128,113
	#7	"Hyperlipidemias"[MeSH Terms] OR hyperlipidemia[tiab]	97,138
	#8	"Obesity"[MeSH Terms] OR obesity[tiab]	496,891
	#9	"Overweight"[MeSH Terms] OR overweight[tiab]	358,113
	#10	"Randomized Controlled Trial"[Publication Type] OR random*[tiab] OR placebo[tiab] OR trial[tiab]	2,450,995
	#11	"Inulin"[MeSH Terms] OR inulin[tiab] OR "Blood Glucose"[MeSH Terms] OR "Lipids"[MeSH Terms] OR "Body Weight"[MeSH Terms] OR glycem*[tiab] OR glucose[tiab] OR lipid*[tiab] OR obes*[tiab]	3,013,982
	#12	("Jerusalem artichoke"[tiab] OR "Helianthus tuberosus"[tiab]) AND ("Inulin"[MeSH Terms] OR inulin[tiab] OR "Blood Glucose"[MeSH Terms] OR "Lipids"[MeSH Terms] OR "Body Weight"[MeSH Terms] OR glycem*[tiab] OR glucose[tiab] OR lipid*[tiab] OR obes*[tiab] OR "Overweight"[MeSH Terms] OR overweight[tiab])	326
Scopus	#1	"Jerusalem artichoke"	2221
	#2	"Helianthus tuberosus"	1567
	#3	"Diabetes Mellitus" OR "diabetes mellitus"	2003
	#4	"Hyperglycemia" OR hyperglycemia	161,582
	#5	"Insulin Resistance" OR "insulin resistance"	198,910
	#6	"Dyslipidemias" OR dyslipidemia	132,142
	#7	"Hyperlipidemias" OR hyperlipidemia	121,726
	#8	"Obesity" OR obesity	755,858
	#9	"Overweight" OR overweight	755,859

	#10	"Randomized Controlled Trial" OR random* OR placebo OR trial	6,146,169
		"Inulin" OR inulin OR "Blood Glucose" OR "Lipids" OR "Body Weight" OR glycem* OR glucose OR lipid* OR obes*	3,562,641
	#11	("Jerusalem artichoke" OR "Helianthus tuberosus") AND ("Inulin" OR inulin OR "Blood Glucose" OR "Lipids" OR "Body Weight" OR glycem* OR glucose OR lipid* OR obes* OR "Overweight" OR overweight)	973
ScienceDirect	#1	"Jerusalem artichoke"	4443
	#2	"Helianthus tuberosus"	2353
	#3	"diabetes mellitus"	592,380
	#4	"hyperglycemia"	188,301
	#5	"insulin resistance"	209,827
	#6	"dyslipidemia"	165,830
	#7	"hyperlipidemia"	158,660
	#8	"obesity"	820,356
	#9	"overweight"	215,553
	#10	("Helianthus tuberosus" OR "Jerusalem artichoke") AND ("diabetes mellitus" OR "hyperglycemia" OR "dyslipidemia" OR "hyperlipidemia" OR "obesity" OR "overweight")	831
ThaiJo	#1	"Jerusalem artichoke"	78
	#2	"Helianthus tuberosus"	77
	#3	"diabetes mellitus"	5816
	#4	"hyperglycemia"	245
	#5	"insulin resistance"	568
	#6	"dyslipidemia"	444
	#7	"hyperlipidemia"	242
	#8	"obesity"	1287
	#9	"overweight"	1674
	#10	("Jerusalem artichoke" OR "Helianthus tuberosus") AND ("diabetes mellitus" OR "hyperglycemia" OR "insulin resistance" OR "dyslipidemia" OR "hyperlipidemia" OR "obesity" OR "overweight")	18
Thai Digital Collection (TDC)	#1	"Jerusalem artichoke"	52
	#2	"Helianthus tuberosus"	35
	#3	"diabetes mellitus"	509
	#4	"hyperglycemia"	5
	#5	"insulin resistance"	29
	#6	"dyslipidemia"	43
	#7	"hyperlipidemia"	22
	#8	"obesity"	121
	#9	"overweight"	163
	#10	("Jerusalem artichoke" OR "Helianthus tu-berosus") AND ("diabetes mellitus" OR "hy-perglycemia" OR "insulin resistance" OR "dyslipidemia" OR "hyperlipidemia" OR "obesity" OR "overweight")	5
ProQuest	#1	("Jerusalem artichoke") OR ("Jerusalem artichoke")	40,887
	#2	("Helianthus tuberosus") OR ("Helianthus tuberosus")	6435
	#3	("diabetes mellitus") OR ("diabetes mellitus")	937,788
	#4	("hyperglycemia") OR ("hyperglycemia")	257,426

	#5	(“insulin resistance”) OR (“insulin resistance”)	655,517
	#6	(“dyslipidemia”) OR (“dyslipidemia”)	230,250
	#7	(“hyperlipidemia”) OR (“hyperlipidemia”)	212,896
	#8	(“obesity”) OR (“obesity”)	2,504,204
	#9	(“overweight”) OR (“overweight”)	12,134,597
	#10	(“Jerusalem artichoke” OR “*Helianthus tuberosus*”) AND (“diabetes mellitus” OR “hyperglycemia” OR “insulin resistance” OR “dyslipidemia” OR “ hyperlipidemia” OR “ obesity” OR “overweight”)	27
ClinicalTrials.gov	#1	“Jerusalem artichoke”	3
	#2	“Helianthus tuberosus”	3
	#3	(“Jerusalem artichoke”) OR (*“Helianthus tuberosus”*)	3

Appendix B

Table A2. Leave-One-Out Sensitivity Analysis of the Pooled Effect Estimates.

Outcome/Omitted Study	No. of Studies Included	Pooled Effect Size (WMD, 95% CI)	*p*-Value	I^2 (%)	Interpretation
FBS					
None (overall analysis)	5	−7.89 mg/dL (−18.84, 3.06)	0.16	95.0%	Reference model
Juttupornpong, et al. 2019 [30]	4	−9.28 mg/dL (−26.35, 7.79)	0.29	96.0%	Stable findings
Najima, et al. 2018 [31]	4	−9.50 mg/dL (−21.68, 2.68)	0.13	96.0%	Stable findings
Teparak, et al., 2025 [33]	4	−0.82 mg/dL (−4.69, 3.05)	0.68	49.0%	Stable findings
Thonglin, 2016 [28]	4	−8.31 mg/dL (−21.74, 5.12)	0.23	96.0%	Stable findings
Visuthranukul, et al. 2022 [32]	4	−10.55 mg/dL (−25.99, 4.88)	0.18	93.0%	Stable findings
HbA1C					
None (overall analysis)	4	−0.18% (−0.85, 0.49)	0.60	96.0%	Reference model
Ahn, et al. 2018 [19]	3	−0.24% (−1.06, 0.59)	0.57	98.0%	Stable findings
Juttupornpong, et al. 2019 [30]	3	−0.36% (−0.99, 0.27)	0.26	92.0%	Stable findings
Teparak, et al., 2025 [33]	3	0.09% (−0.21, 0.40)	0.56	66.0%	Stable findings
Thonglin, 2016 [28]	3	−0.20 (−1.08, 0.68)	0.66	98.0%	Stable findings
HOMA-IR					
None (overall analysis)	2	−0.64 (−1.94, 0.65)	0.33	100.0%	Reference model
Ahn, et al. 2018 [19]	1	−1.30 (−1.35, −1.25)	<0.001	N/A	Effect changes *
Teparak, et al., 2025 [33]	1	0.02 (−0.11, 0.15)	0.76	N/A	Stable findings
PPG 30 min					
None (overall analysis)	2	−10.33 mg/dL (−36.92, 16.27)	0.45	83.0%	Reference model
Ahn, et al. 2018 [19]	1	−26.30 mg/dL (−48.39, −4.21)	0.02	N/A	Effect changes *
Najima, et al. 2018 [33]	1	1.20 mg/dL (−3.07, 5.47)	0.58	N/A	Stable findings
PPG 60 min					
None (overall analysis)	2	−15.02 mg/dL (−20.94, −9.10)	<0.001	0.0%	Reference model
Ahn, et al. 2018 [19]	1	−16.00 mg/dL (−39.62, 6.42)	0.17	N/A	Effect changes *
Najima, et al. 2018 [33]	1	−14.50 mg/dL (−20.75, −8.25)	<0.001	N/A	Stable findings
PPG 120 min					
None (overall analysis)	2	−10.10 mg/dL (−18.25, −1.96)	0.02	25.0%	Reference model
Ahn, et al. 2018 [19]	1	−2.90 mg/dL (−17.79, 11.99)	0.70	N/A	Effect changes *
Najima, et al. 2018 [33]	1	−12.50 mg/dL (−19.18, −5.82)	<0.001	N/A	Stable findings
LDL					
None (overall analysis)	3	−5.34 mg/dL (−20.07, 9.38)	0.48	97.0%	Reference model
Ahn, et al. 2018 [19]	2	−6.03 mg/dL (−34.62, 22.56)	0.68	95.0%	Stable findings
Teparak et al. 2025 [33]	2	1.73 mg/dL (−9.29, 12.75)	0.76	69.0%	Stable findings
Visuthranukul et al. 2022 [32]	2	−11.23 mg/dL (−28.37, 5.92)	0.20	98.0%	Stable findings

HDL					
None (overall analysis)	3	1.34 mg/dL (−1.86, 4.54)	0.41	90.0%	Reference model
Ahn, et al. 2018 [19]	2	−0.30 mg/dL (−3.54, 2.94)	0.86	71.0%	Stable findings
Teparak et al. 2025 [33]	2	1.23 mg/dL (−5.52, 7.98)	0.72	92.0%	Stable findings
Visuthranukul et al. 2022 [32]	2	2.72 mg/dL (−0.71, 6.14)	0.12	92.0%	Stable findings
TC					
None (overall analysis)	3	−31.38 mg/dL (−79.61, 16.85)	0.20	99.0%	Reference model
Ahn, et al. 2018 [19]	2	19.64 mg/dL (−29.76, 69.04)	0.44	99.0%	Stable findings
Teparak et al. 2025 [33]	2	−77.79 mg/dL (−145.97, −9.60)	0.03	97.0%	Effect changes *
Visuthranukul et al. 2022 [32]	2	62.55 mg/dL (−33.37, 158.47)	0.20	99.0%	Stable findings
TG					
None (overall analysis)	3	−4.38 mg/dL (−10.98, 2.22)	0.19	40.0	Reference model
Ahn, et al. 2018 [19]	2	−3.32 mg/dL (−15.64, 8.99)	0.60	48.0%	Stable findings
Teparak, et al. 2025 [33]	2	−1.55 mg/dL (−7.37, 4.27)	0.60	0.0%	Stable findings
Visuthranukul, et al. 2022 [32]	2	−4.33 mg/dL (−12.12, 3.45)	0.28	58.0%	Stable findings
BW					
None (overall analysis)	3	−3.95 kg (−5.11, −2.78)	<0.001	92.0%	Reference model
Ahn, et al. 2018 [19]	2	−0.02 (−1.02, 0.98)	0.97	90.0%	Effect changes *
Inganinanda, et al. 2019 [29]	2	−3.92 (−5.91, −1.93)	<0.001	90.0%	Stable findings
Teparak, et al., 2025 [33]	2	−3.94 (−5.14, −2.75)	<0.001	91.0%	Stable findings
BMI					
None (overall analysis)	4	−0.84 kg/m2 (−1.26, −0.43)	<0.001	35.0%	Reference model
Ahn, et al. 2018 [19]	3	−0.05 kg/m^2 (−2.18, 2.09)	0.96	31.0%	Effect changes *
Inganinanda, et al. 2019 [29]	3	−0.85 kg/m^2 (−1.32, −0.38)	<0.001	54.0%	Stable findings
Teparak, et al. 2025 [33]	3	−0.02 kg/m^2 (−1.99, 1.96)	0.99	49.0%	Effect changes *
Thonglin. 2016 [28]	3	−0.87 kg/m^2 (−1.13, −0.62)	<0.001	0.0%	Stable findings
WC					
None (overall analysis)	3	−2.13 cm (−6.99, 2.73)	0.39	75.0%	Reference model
Inganinanda, et al. 2019 [29]	2	0.14 (−1.47, 1.75)	0.86	0.0%	Stable findings
Teparak, et al. 2025 [33]	2	−4.30 (−15.39, 6.80)	0.45	86.0%	Stable findings
Visuthranukul, et al. 2022 [32]	2	−4.57 (−14.64, 5.51)	0.37	87.0%	Stable findings
W/H					
None (overall analysis)	2	0.00 (−0.01, 0.00)	0.33	85.0%	Reference model
Ahn, et al. 2018 [19]	1	0.00 (−0.01, 0.01)	1.00	N/A	Stable findings
Teparak, et al. 2025 [33]	1	−0.01 (−0.02, −0.00)	0.006	0.0%	Effect changes *
VF					
None (overall analysis)	2	−4.98 (−9.80, −0.16)	0.04	7.0%	Reference model
Inganinanda, et al. 2019 [29]	1	3.10 (−13.15, 19.35)	0.71	N/A	Effect changes *
Visuthranukul, et al. 2022 [32]	1	−5.73 (−9.63, −1.83)	0.004	N/A	Stable findings

Remark**:** BW, body weight; BMI, body mass index; WMD, weighted mean difference; PPG, postprandial glucose; LDL, low density lipoprotein; HDL, high density lipoprotein; TG, triglycerides; TC, total cholesterol; WC, waist circumference; W/H, waist to hip ratio; VF, visceral fat; * Statistically significant; $p \leq 0.05$.

Appendix C

Table A3. Sensitivity analysis conducted using R values of 0.25 and 0.75, compared with the R value of 0.50 used in the primary analysis.

Outcomes	R = 0.5 (Primary Analysis) WMD (95% CI; *p*-Value); I^2	R = 0.25 WMD (95% CI; *p*-Value); I^2	R = 0.75 WMD (95% CI; *p*-Value); I^2
FBS	−7.89 mg/dL (−18.84, 3.06; $p = 0.16$); 95.0%	0.55 mg/dL (−3.79, 4.89; $p = 0.80$); 12.0%	3.05 mg/dL (−3.79, 9.89; $p = 0.38$); 44.0%

HbA1C	−0.18% (−0.85, 0.49; $p = 0.59$); 96.0%	−0.18% (−0.84, 0.48; $p = 0.59$); 98.0%	−0.18% (−0.84, 0.48; $p = 0.59$); 98.0%
PPG 30 min	−10.33 mg/dL (−36.92, 16.27; $p = 0.45$); 83.0%	−21.00 mg/dL (−53.44, 11.44; $p = 0.20$); 99.0%	−27.76 mg/dL (−69.52, 14.00; $p = 0.19$); 94.0%
PPG 60 min	−15.02 mg/dL (−20.94, −9.10; $p < 0.001$); 0.0% *	−29.64 mg/dL (−47.68, −11.59; $p < 0.001$); 6.0% *	−32.80 mg/dL (−64.86, −0.74; $p = 0.04$); 9.0% *
PPG 120 min	−10.10 mg/dL (−18.25, −1.96; $p = 0.02$); 25.0% *	−3.16 mg/dL (−11.74, 5.42; $p = 0.47$); 27.0%	−25.17 mg/dL (−39.78, −10.55; $p < 0.001$); 22.0% *
HOMA-IR	−0.64 (−1.94, 0.65; $p = 0.33$); 100.0%	−0.39 (−1.50, 0.71; $p = 0.49$); 99.0%	−0.39 (−1.50, 0.72; $p = 0.49$); 99.0%
LDL	−5.34 mg/dL (−20.07, 9.38; $p = 0.48$); 97.0%	−3.67 mg/dL (−20.74, 13.40; $p = 0.67$); 99.0%	−9.52 mg/dL (−23.99, 4.95; $p = 0.20$); 68.0%
HDL	1.34 mg/dL (−1.86, 4.54; $p = 0.41$); 90.0%	−0.12 mg/dL (−3.13, 2.90; $p = 0.94$); 97.0%	1.74 mg/dL (−1.42, 4.90; $p = 0.28$); 76.0%
TC	−31.38 mg/dL (−79.61, 16.85; $p = 0.20$); 99.0%	45.62 mg/dL (−1.06, 92.30; $p = 0.06$); 100.0%	57.19 mg/dL (−35.93, 150.31; $p = 0.23$); 91.0%
TG	−4.38 mg/dL (−10.98, 2.22; $p = 0.19$); 40.0%	−1.05 mg/dL (−10.10, 8.00; $p = 0.82$); 97.0%	−3.48 mg/dL (−15.76, 8.81; $p = 0.58$); 0.0%
BW	−3.95 kg (−5.11, −2.78; $p < 0.001$); 92.0% *	−1.80 kg (−4.88, 1.28; $p = 0.25$); 97.0%	−1.26 kg (−4.24, 1.72; $p = 0.41$); 37.0%
BMI	−0.84 kg/m² (−1.26, −0.43; $p < 0.001$); 35.0% *	−0.74 kg/m² (−1.18, −0.29 $p = 0.001$); 79.0% *	−0.92 kg/m² (−1.31, −0.52; $p < 0.0001$); 0.0% *
WC	−2.13 cm (−6.99, 2.73; $p = 0.39$); 75.0%	−0.70 cm (−1.47, 0.08; $p = 0.08$); 97.0%	−0.15 cm (−3.47, 3.18; $p = 0.93$); 0.0%
W/H ratio	0.00 (−0.01, 0.00; $p = 0.33$); 85.0%	0.00 (−0.01, 0.00; $p = 0.20$); 70.0%	0.00 (−0.01, 0.00; $p = 1.00$); 0.0%
VF	−4.98 (−9.80, −0.16; $p = 0.04$); 7.0% *	−3.13 (−4.47, −1.79; $p < 0.0001$); 97.0% *	−2.91 (−4.20, −1.61; $p < 0.0001$); 74.0% *

Remark: BW, body weight; BMI, body mass index; WMD, weighted mean difference; PPG, postprandial glucose; LDL, low density lipoprotein; HDL, high density lipoprotein; TG, triglycerides; TC, total cholesterol; WC, waist circumference; W/H, waist to hip ratio; VF, visceral fat; * Statistically significant; $p \leq 0.05$.

Appendix D

Table A4. Subgroup analysis of RCTs evaluating effects on clinical outcomes of *H. tuberosus.*

Outcomes	No. of Trials	WMD	95% CI	I^2 (%)	p [a]	p [b]
FBS						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	3	−13.68	−31.80, 4.43	95.0	0.14	<0.001
Obesity, and healthy populations	2	−2.04	−3.14, 3.22	0.0	0.21	0.95
Age-based subgroup						
Children	1	1.90	−0.21, 4.01	N/A	0.08	N/A
Adult	4	−10.55	−25.99, 4.88	93.0	0.18	<0.001
Extract						
Non-extract	3	−3.16	−7.10, 0.78	0.0	0.12	0.63
H. tuberosus extract	2	−15.29	−49.39, 18.81	99.0	0.38	<0.001
HbA1C						
Extract						
Non-extract	2	0.12	−0.31, 0.55	80.0	0.58	0.03
H. tuberosus extract	2	−0.48	−1.35, 0.39	93.0	0.28	<0.001
PPG 30 min						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	1	1.20	−3.07, 5.47	N/A	0.58	N/A

Healthy populations	1	−26.30	−48.39, −4.21	N/A	0.02	N/A
PPG 60 min						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	1	−14.50	−20.75, −8.25	N/A	<0.001	N/A
Healthy populations	1	−16.60	−39.62, 6.42	N/A	0.16	N/A
PPG 120 min						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	1	−12.50	−19.18, −5.82	N/A	<0.001	N/A
Healthy populations	1	−2.90	−17.79, 11.99	N/A	0.70	N/A
LDL						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	2	−11.23	−28.37, 5.92	98.0	0.20	<0.001
Obesity populations	1	9.20	−3.20, 21.60	N/A	0.15	N/A
Age-based subgroup						
Children	1	9.20	−3.20, 21.60	N/A	0.15	N/A
Adult	2	−11.23	−28.37, 5.92	98.0	0.20	<0.001
Extract						
Non-extract	1	9.20	−3.20, 21.60	N/A	0.15	N/A
H. tuberosus extract	2	−11.23	−28.37, 5.92	98.0	0.20	<0.001
HDL						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	2	2.72	−0.71, 6.14	92.0	0.12	<0.001
Obesity populations	1	−2.40	−5.83, 1.03	N/A	0.17	N/A
Age-based subgroup						
Children	1	−2.40	−5.83, 1.03	N/A	0.17	N/A
Adult	2	2.72	−0.71, 6.14	92.0	0.12	<0.001
Extract						
Non-extract	1	−2.40	−5.83, 1.03	N/A	0.17	N/A
H. tuberosus extract	2	2.72	−0.71, 6.14	92.0	0.12	<0.001
Total cholesterol						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	2	−78.93	−279.53, 121.66	97.0	0.20	<0.001
Obesity populations	1	−4.00	−16.18, 8.18	N/A	0.52	N/A
Age-based subgroup						
Children	1	−4.00	−16.18, 8.18	N/A	0.52	N/A
Adult	2	−78.93	−279.53, 121.66	97.0	0.20	<0.001
Extract						
Non-extract	1	−4.00	−16.18, 8.18	N/A	0.52	N/A
H. tuberosus extract	2	−78.93	−279.53, 121.66	97.0	0.20	<0.001
Triglyceride						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	2	−6.36	−13.42, 0.69	59.0	0.08	0.12
Obesity populations	1	−0.40	−24.60, 23.80	N/A	0.97	N/A
Age-based subgroup						
Children	1	−0.40	−24.60, 23.80	N/A	0.97	N/A
Adult	2	−6.36	−13.42, 0.69	59.0	0.08	0.12
Extract						
Non-extract	1	−0.40	−24.60, 23.80	N/A	0.97	N/A
H. tuberosus extract	2	−6.36	−13.42, 0.69	59.0	0.08	0.12
Body weight						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	2	−1.99	−5.91, 1.93	96.0	0.32	<0.001
Obesity populations	1	−1.33	−9.47, 6.81	N/A	0.75	N/A

Extract						
Non-extract	2	0.00	−1.01, 1.01	0.0	1.00	0.52
H. tuberosus extract	1	−3.94	−5.14, −2.75	N/A	<0.001	N/A
Body mass index						
Participants health condition						
Prediabetes, type 2 diabetes mellitus	3	−0.02	−1.99, 1.96	49.0	0.98	0.99
Obesity populations	1	−1.00	−1.40, −0.60	N/A	<0.001	N/A
Extract						
Non-extract	3	−0.05	−2.18, 2.09	54.0	0.96	0.12
H. tuberosus extract	1	−0.80	−1.13, −0.47	N/A	<0.001	N/A
WC						
Duration						
≤12 weeks	2	−4.57	−14.64, 5.51	87.0	0.37	0.006
>12 weeks	1	1.00	−3.27, 5.27	N/A	0.65	N/A
Participants health condition						
Prediabetes, type 2 diabetes mellitus	1	0.00	−1.73, 1.73	N/A	1.00	N/A
Obesity, and healthy populations	2	−4.30	−15.39, 6.80	86.0	0.45	0.008
Age-based subgroup						
Children	1	0.00	−1.73, 1.73	N/A	1.00	N/A
Adult	2	−4.30	−15.39, 6.80	86.0	0.45	0.008
Extract						
Non-extract	1	−10.35	−17.52, −3.18	N/A	0.005	N/A
H. tuberosus extract	2	0.14	−1.47, 1.75	0.0	0.86	067
W/H						
Extract						
Non-extract	1	−0.01	−0.02, −0.001	N/A	0.04	N/A
H. tuberosus extract	1	−0.00	−0.01, 0.01	N/A	1.00	N/A
VF						
Duration						
≤12 weeks	1	−5.73	−9.63, −1.83	N/A	0.004	N/A
>12 weeks	1	3.10	−13.15, 19.35	N/A	0.71	N/A
Age-based subgroup						
Children	1	−5.73	−9.63, −1.83	N/A	0.004	N/A
Adult	1	3.10	−13.15, 19.35	N/A	0.71	N/A
Extract						
Non-extract	1	−5.73	−9.63, −1.83	N/A	0.004	N/A
H. tuberosus extract	1	3.10	−13.15, 19.35	N/A	0.71	N/A

Remark: BW, body weight; BMI, body mass index; WMD, weighted mean difference; PPG, postprandial glucose; LDL, low density lipoprotein; HDL, high density lipoprotein; TG, triglycerides; TC, total cholesterol; WC, waist circumference; W/H, waist to hip ratio; VF, visceral fat; *Statistically significant; $p \leq 0.05$.

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