World Nutrition, September 2026;17(3): 33-39
DOI: https://doi.org/10.26596/wn.202617333-39

WORLD NUTRITION
The Official Journal of the World Public Health Nutrition Association
Journal homepage: https://www.worldnutritionjournal.org
ISSN: 2041-9775

Research Article

Acute effects of apple cider vinegar on postprandial glycemia following a high-carbohydrate meal in healthy adults: A randomized placebo-controlled trial

Muhammed Kadir Süzen*, Sedef Duran[2]

[1]Department of Nutrition and Dietetics, Tekirdag Dr. I. Fehmi Cumalıoğlu City Hospital, Tekirdag, Türkiye; [2]Department of Family Medicine, Faculty of Medicine, Trakya University, Edirne, Türkiye

OPEN ACCESS

***Corresponding Author**
Süzen M.K.
kdrsuzen@gmail.com
ORCID: 0000-0003-4528-3772

Article History
Received: June 06, 2026
Reviewed: June 21, 2026
Revised: June 24, 2026
Accepted: July 05, 2026
Published: September 30, 2026

Citation
Süzen M.K. & Duran S. (2026). Acute effects of apple cider vinegar on postprandial glycemia following a high-carbohydrate meal in healthy adults: A randomized placebo-controlled trial. *World Nutrition*, 17(3), September, 33–39. https://doi.org/10.26596/wn.202617333-39

Academic Editor
Ted Greiner, PhD

Copyright © 2026 Süzen & Duran S. Published by WPHNA. This is an open-access article distributed under the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Highlights/Key Messages

- Apple cider vinegar significantly reduced blood glucose concentration at 60 min after a high-carbohydrate meal in healthy adults.
- Net iAUC was approximately 25% lower in the vinegar group but this was not significant after adjustment for baseline fasting glucose.
- Apple cider vinegar may influence specific phases of postprandial glycemia despite no significant effect on overall postprandial glycemic response.

Background
Vinegar may attenuate postprandial glycemic responses, but evidence from highcarbohydrate meals in healthy adults is limited.

Objective
This study evaluated the acute effects of apple cider vinegar taken with a highcarbohydrate meal on postprandial glycemia (PPG) and the net incremental area under the curve (net iAUC) in healthy adults.

Methods
In this single-blind, randomized, parallel-group, placebo-controlled trial, 36 healthy adults aged 18–50 years were randomized to intervention (n = 18) or control (n = 18) groups. All consumed a standardized test meal providing approximately 93 g carbohydrate. The intervention group received a beverage containing 20 mL apple cider vinegar; controls received placebo. Capillary glucose was measured at fasting and 30, 45, 60, and 120 min postprandially. Net iAUC was calculated by the trapezoidal method. Glucose was analyzed with a linear mixed model (Bonferroni-adjusted pairwise comparisons) and net iAUC with ANCOVA adjusted for baseline fasting glucose.

Results
Baseline characteristics, including age and body mass index, did not differ between groups ($p > 0.05$). Fasting, 30-, 45-, and 120-min glucose also did not differ ($p > 0.05$). At 60 min, glucose was significantly lower in the intervention group (109.94 ± 20.43 vs 123.83 ± 19.92 mg/dL; adjusted $p = 0.045$). Net iAUC was approximately 25% lower with vinegar (2841.67 ± 1703.84 vs 3804.58 ± 1806.49 mg × min/dL), a difference that was not statistically significant after adjustment for baseline fasting glucose ($p = 0.108$). The group × time interaction was not significant ($p = 0.288$).

Conclusions
Apple cider vinegar may lower blood glucose during the early postprandial period after a high-carbohydrate meal, but not net iAUC or the overall two-hour response. Larger, methodologically robust studies, or those administering vinegar before the meal, are needed to clarify its acute effects on PPG.

Keywords: apple cider vinegar, acetic acid, postprandial glycemia, randomized controlled trial

Introduction

Postprandial glycemia (PPG) refers to blood glucose levels after a meal and is an important indicator of metabolic health in both healthy individuals and those with diabetes. High-glucose peaks and glycemic fluctuations during the postprandial period have been associated with several adverse health outcomes, even in healthy individuals. Fluctuations in PPG activate oxidative stress mechanisms, increase cellular damage, and adversely affect endothelial function. Over time, these processes may contribute to the development of cardiometabolic risk factors, including inflammation, insulin resistance, and atherosclerotic changes (Avner & Robbins, 2025). Therefore, maintaining PPG within target ranges is considered a nutritional strategy for preserving metabolic health. It has been reported that choosing low-glycemic-index foods, increasing dietary fiber intake, and reconsidering the carbohydrate load of meals may contribute to reducing cardiometabolic risk by attenuating the PPG response (Vlachos et al., 2020). Nevertheless, many individuals seek complementary and alternative approaches to support glycemic control. A study conducted in Türkiye reported that approximately 22% of individuals with type 2 diabetes used herbal products for glycemic control (Pınar et al., 2017).

Vinegar is a fermented food product obtained through the conversion of carbohydrates first into ethanol by yeasts and subsequently into acetic acid (AA) by acetic acid bacteria. With a history dating back to 2000 BC, vinegar has long been used as a food preservative, flavoring agent, and for various health-related purposes. AA, which gives vinegar its characteristic sour taste, generally constitutes 4–7% of the vinegar's composition and is considered the primary contributor to the metabolic effects of vinegar (Garcia-Parrilla et al., 2017).

In recent years, increasing attention has been directed toward the effects of AA and vinegar consumption on PPG. Systematic evaluations of studies conducted in different populations and with different meal compositions have shown that vinegar may reduce postprandial glucose and insulin responses, particularly after carbohydrate-rich meals. It has been suggested that these effects may be associated with several mechanisms, including delayed gastric emptying, slower carbohydrate digestion, and increased glucose utilization in peripheral tissues (Launholt et al., 2020; Santos et al., 2019).

However, important methodological differences exist in the current literature. Considerable variation is observed among studies in the types of vinegar used, AA concentrations, administered doses, carbohydrate content of the test meals, and other variables. Furthermore, the generalizability of findings is limited by the small sample sizes of many studies, the lack of detailed reporting of randomization and blinding procedures, and the risk of bias in some investigations (Launholt et al., 2020). Systematic reviews have found that the available evidence is of moderate quality and have called for more standardized human studies (Launholt et al., 2020; Santos et al., 2019). In addition, most previous studies have used test meals containing approximately 50 g of carbohydrates (Östman et al., 2005; Leeman et al., 2005; Johnston & Buller, 2005; Liatis et al., 2010; Liljeberg & Björck, 1998), whereas evidence regarding the effects of vinegar after meals with a higher glycemic load remains limited. Therefore, controlled studies using meals with varying carbohydrate loads may contribute to a better understanding of vinegar's role in PPG regulation. The meals consumed in everyday settings are not limited to a standardized carbohydrate load and may differ substantially in both composition and glycemic impact. Therefore, evaluating vinegar supplementation in the context of a higher-carbohydrate mixed meal may provide a more practical understanding of its potential role in postprandial glycemic regulation. In addition, examining glucose responses at different postprandial time points may help identify when the effects of vinegar are most pronounced. In light of these considerations, the present study evaluated the effects of apple cider vinegar consumed with a standardized meal containing approximately 93 g of carbohydrate in healthy adults.

The aim of this randomized controlled trial was to evaluate the acute effects of 20 mL of apple cider vinegar consumed with a standardized high-carbohydrate test meal on postprandial blood glucose concentrations and the net incremental area under the glucose curve (net iAUC) in healthy adults.

Materials and Methods

This single-blind, randomized, parallel-group, placebo-controlled trial evaluated the acute effects of apple cider vinegar on postprandial glycemia (PPG) in healthy adults aged 18–50 years who volunteered to participate in the study. Inclusion criteria were age between 18 and 50 years and willingness to participate. Exclusion criteria included chronic disease, diabetes, prediabetes, reactive hypoglycemia, gastrointestinal disorders, pregnancy, and the use of medications known to affect glucose metabolism. Sample size calculation indicated a minimum of 34 participants was needed (80% power, $\alpha = 0.05$). Following stratification according to BMI and smoking status, participants were allocated to the intervention or control group using a computer-generated block randomization sequence generated through random.org.

Thirty-eight participants were recruited; one withdrew, and one was excluded because fasting blood glucose exceeded 100 mg/dL; therefore, analyses were conducted with 36 participants. Participant flow throughout the study is summarized in the CONSORT 2010 flow diagram (Figure 1). The study was approved by the Scientific Research Ethics Committee of Thrace University (Decision No. 04/15, February 15, 2021), and written informed consent was obtained from all participants.

After an overnight fast (8–12 h), participants consumed a standardized test meal consisting of toasted bread (135 g), processed cheese (36 g), and peach nectar (150 mL), providing approximately 508 kcal and 93 g carbohydrate. The intervention group received 20 mL of apple cider vinegar (5–6% acidity) diluted in water and mixed with peach nectar, whereas the control group received water mixed with peach nectar. Participants were blinded to group allocation throughout the study. The intervention and placebo beverages were served in closed cups.

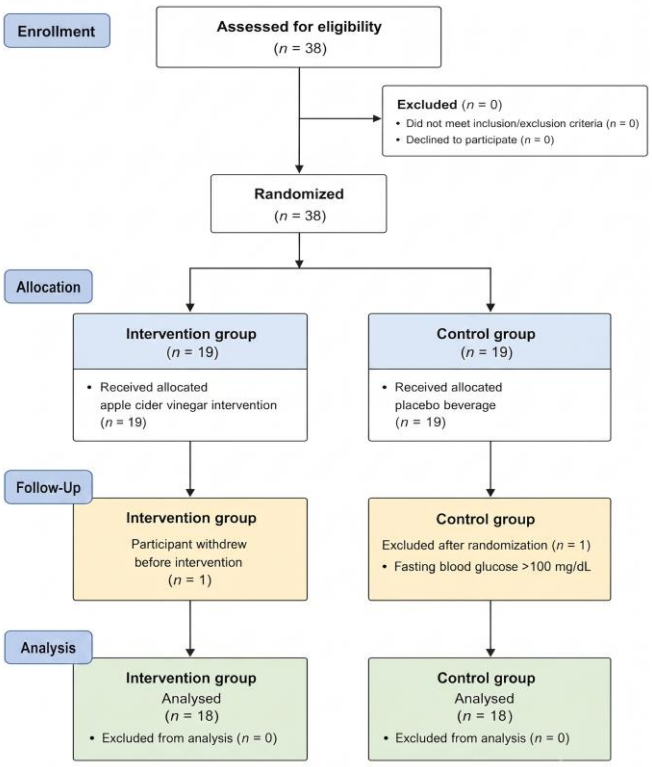


Figure 1. CONSORT 2010 flow diagram of participant enrollment, randomization, follow-up, and analysis

During protocol development, preliminary testing was conducted to minimize perceptible differences between beverages, and the beverages were formulated to provide similar appearance, taste, and odor characteristics. The investigator, who prepared the beverages, was not blinded. All food and beverages were consumed within 10 min. During the study period, participants were instructed to avoid moderate-to-vigorous physical activity and not to consume any other food until all glucose measurements were completed.

Capillary blood glucose concentrations were measured at baseline and at 30, 45, 60, and 120 min after meal consumption. Capillary blood glucose concentrations were measured using a calibrated blood glucose monitoring system (Rheamed, model SC-126-AA; Sand County Biotechnology Inc., Taiwan). Calibration was verified prior to the study, and the same device was used for all participants throughout the study. A new lancet and test strip (Rheamed test strip; Sand County Biotechnology Inc., Taiwan) were used for each measurement.

Height was measured without shoes using a stadiometer (Tartı Medikal, Türkiye) and recorded to the nearest 0.01 m. Body weight and body fat percentage were assessed under fasting conditions using a bioelectrical impedance analyzer (TANITA Corporation of America, Inc., USA). Participants were instructed to refrain from exercise and caffeine consumption for at least 12 h prior to body composition assessment and to remove all jewelry and metallic objects before measurement.

Statistical analyses were performed using IBM SPSS Statistics 27.0. Data are presented as mean ± SD. The normality of continuous variables was assessed using the Shapiro–Wilk test prior to statistical analyses. Between-group comparisons were performed using independent-samples t-tests for normally distributed variables and Mann–Whitney U tests for non-normally distributed variables. Sex distribution between groups was compared using Fisher's exact test. Postprandial glucose concentrations were analyzed using a linear mixed model, including group, time, baseline fasting glucose, and the group × time interaction as fixed effects and participant as a random effect. Pairwise comparisons were adjusted using the Bonferroni method. Net incremental area under the curve (net iAUC) was calculated using the trapezoidal method and compared between groups using analysis of covariance (ANCOVA), with baseline fasting glucose included as a covariate. Effect sizes were expressed as Cohen's d with 95% confidence intervals. Statistical significance was set at $p < 0.05$.

Results

Baseline Characteristics

Data from 36 participants (19 women and 17 men) were included in the final analyses. The intervention group comprised 10 women and 8 men, whereas the control group comprised 9 women and 9 men.

No statistically significant differences were observed between groups regarding age, BMI, body fat percentage, waist circumference, or other baseline characteristics (Table 1).

Table 1. Baseline characteristics of the participants (mean ± SD)

Variable	Intervention (n = 18)	Control (n = 18)	p-value
Sex (M/F)	8/10	9/9	1
Age (years)	28.00 ± 5.12	27.06 ± 5.22	0.286
BMI (kg/m²)	23.22 ± 2.17	24.29 ± 2.74	0.171
Body fat (%)	24.80 ± 6.56	25.16 ± 6.70	0.752
Waist circumference (cm)	84.77 ± 9.29	86.38 ± 8.72	0.458

Note. BMI: body mass index; M: male; F: female.

Postprandial Blood Glucose Response

As shown in Table 2, fasting capillary blood glucose concentrations were 84.61 ± 5.10 mg/dL in the intervention group and 84.72 ± 4.90 mg/dL in the control group ($p = 0.947$).

Pairwise comparisons derived from the linear mixed model (LMM) with Bonferroni adjustment showed no significant between-group differences at 30 min ($p = 0.230$), 45 min ($p = 0.177$), or 120 min ($p = 0.501$). At 60 min, blood glucose concentration was significantly lower in the intervention group than in the control group (109.94 ± 20.43 vs. 123.83 ± 19.92 mg/dL; mean difference = −13.89 mg/dL, 95% CI: −27.52 to −0.26 mg/dL; adjusted $p = 0.045$). The overall group × time interaction in the LMM was not statistically significant ($F(3,102) = 1.27$, $p = 0.288$).

The temporal changes in blood glucose concentrations for both groups are presented in Figure 2.

Table 2. Postprandial blood glucose concentrations and net iAUC values (mean ± SD)

Parameter	Control Group (n = 18)	Intervention Group (n = 18)	Mean Difference (95% CI)	P-value	Cohen's *d*
Fasting (0 min) (mg/dL)	84.72 ± 4.90	84.61 ± 5.10	−0.11 (−3.50 to 3.28)	0.947†	0.02
30 min (mg/dL)	136.17 ± 18.24	127.39 ± 22.06	−8.78 (−22.51 to 4.95)	0.230‡	0.43
45 min (mg/dL)	132.33 ± 21.84	121.22 ± 23.94	−11.11 (−26.63 to 4.41)	0.177‡	0.48
60 min (mg/dL)	123.83 ± 19.92	109.94 ± 20.43	−13.89 (−27.52 to −0.26)	*0.045*‡*	0.69
120 min (mg/dL)	103.89 ± 18.28	99.89 ± 11.23	−4.00 (−14.21 to 6.21)	0.501‡	0.26
Net iAUC (mg × min/dL)	3804.58 ± 1806.49	2841.67 ± 1703.84	−962.92 (−2110.11 to 184.28)	0.108§	0.55

Note. Values are expressed as mean ± standard deviation (SD). CI: confidence interval; iAUC: incremental area under the curve. Mean differences were calculated as intervention minus control values.

† P-value derived from an independent-samples t-test for baseline descriptive comparison.

‡ P-values for postprandial time points (30, 45, 60, and 120 min) were obtained from pairwise comparisons within the Linear Mixed Model (LMM) framework using Bonferroni adjustment for multiple comparisons. Group, time, baseline fasting glucose (G0), and the group × time interaction were included as fixed effects, whereas subject identity was included as a random effect to account for within-subject correlation arising from repeated measurements.

§ P-value for net iAUC was obtained from an Analysis of Covariance (ANCOVA) with baseline fasting glucose included as a covariate.

* P < 0.05 indicates a statistically significant difference between groups.

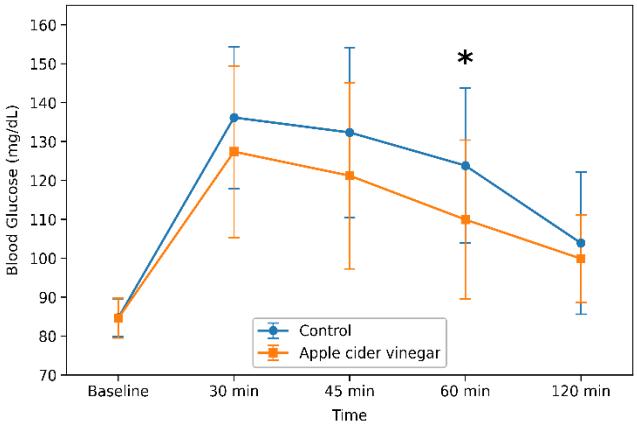


Figure 2. Blood glucose concentrations before and after consumption of the test meal in the control and apple cider vinegar groups

Net iAUC was 3804.58 ± 1806.49 mg·min/dL in the control group and 2841.67 ± 1703.84 mg·min/dL in the intervention group. ANCOVA adjusted for baseline fasting glucose showed no significant difference between groups (p = 0.108). The effect size was moderate (Cohen's d = 0.55).

Discussion

In this study, the acute effects of consuming 20 mL of apple cider vinegar with a high-carbohydrate meal on PPG were evaluated in healthy adults. Lower postprandial glucose concentrations were observed at 60 min in the vinegar group. Although net iAUC values were approximately 25% lower in the intervention group than in the control group, this difference did not reach statistical significance. Similarly, no significant difference was observed between the groups in the overall pattern of the two-hour glucose response. These findings suggest that apple cider vinegar may affect certain components of the PPG response.

Our findings are consistent with previous evidence suggesting that vinegar consumption may suppress PPG. Östman et al. (2005) reported that vinegar added to a white bread-based meal reduced glucose and insulin responses, whereas Leeman et al. (2005) observed lower glycemic and insulinemic responses following potato meals containing vinegar. Similarly, the addition of vinegar to meals with a high glycemic load suppressed the postprandial glucose response (Johnston et al., 2004; Johnston & Buller, 2005; Johnston et al., 2010; Liatis et al., 2010). However, substantial variation exists among studies in the amount of vinegar administered (generally similar to that used in the present study), the composition and carbohydrate content of the test meal, the study design, and participant characteristics. Although these studies indicate that vinegar may exert beneficial effects on glucose metabolism, the certainty of the available evidence remains debatable because of methodological heterogeneity and limited sample sizes (Launholt et al., 2020).

The 60-min finding of the present study is consistent with the early postprandial glycemic suppression reported by Östman et al. (2005) and Liatis et al. (2010), particularly during the 30–60 min postprandial period. Johnston et al. (2010) reported that 10 g of vinegar reduced PPG by 23–28%, but noted that this effect was not observed with meals containing monosaccharides. Liatis et al. (2010) demonstrated that vinegar significantly suppressed glycemic response in patients with type 2 diabetes only when added to meals with a high glycemic index. The high-carbohydrate meal used in the present study, containing both starch and simple sugars, may have contributed to a more pronounced glycemic rise than seen in most studies. The observed effect size at 60 min was in the moderate range (Cohen's d = 0.69), suggesting that the intervention effect was not only statistically significant but also potentially meaningful from a physiological perspective.

The lack of statistical significance despite an approximately one-quarter reduction in net iAUC values may be related to several methodological factors. Although baseline fasting glucose was accounted for in the statistical analyses using a linear mixed model and analysis of covariance, residual physiological differences among participants inherent to the parallel-group design may still have contributed to variability in net iAUC. Crossover designs are generally considered to provide greater statistical sensitivity by reducing interindividual variability. In addition, the test meal used in the present study contained

approximately 93 g of carbohydrate, representing a higher glycemic load than the 50 g carbohydrate test meals frequently used in the literature (Östman et al., 2005; Leeman et al., 2005; Johnston & Buller, 2005; Liatis et al., 2010; Liljeberg & Björck, 1998). The considerable interindividual variability in postprandial glucose responses may have limited the ability to detect a statistically significant difference in net iAUC between groups. Notably, the observed effect size for net iAUC was in the moderate range, suggesting that the magnitude of the intervention effect warrants further investigation in larger studies.

In addition to its potential benefits on PPG, the safety profile of apple cider vinegar consumption should also be considered. In a systematic review, Launholt et al. reported that apple cider vinegar, when consumed at recommended amounts and appropriately diluted, was not associated with serious adverse effects. Nevertheless, dental erosion, esophageal irritation, and various gastrointestinal complaints may occur when consumed in excessive amounts or inappropriately (Launholt et al., 2020). In this respect, the 20 mL of diluted apple cider vinegar intervention used in the present study is consistent with the range considered safe in the literature.

The strengths of this study include its randomized, placebo-controlled design, the absence of significant baseline differences between groups, and the use of a high-carbohydrate mixed meal that may better reflect real-world eating conditions than the standardized meals used in many previous studies. In addition, the sample size was larger than that of several previously published acute vinegar intervention studies. The application of a linear mixed model for repeated glucose measurements and analysis of covariance for net iAUC further strengthened the statistical evaluation by accounting for repeated measurements and baseline fasting glucose.

Several limitations should also be acknowledged. First, the parallel-group design may have increased interindividual variability in postprandial glucose responses, whereas a crossover design could have provided greater statistical efficiency for detecting treatment effects. Menstrual cycle phase was not standardized or recorded and may have contributed to interindividual variability in postprandial glucose responses among female participants. Although baseline fasting glucose was included as a covariate in the statistical analyses, residual physiological differences between participants may still have contributed to variability in postprandial glucose responses and net iAUC values.

Furthermore, glycemic responses were assessed solely through capillary blood glucose measurements. Although this method is widely used in postprandial glycemic studies and allows repeated measurements under practical conditions, it may provide less precise estimates than laboratory-based venous plasma glucose analyses. The absence of insulin, incretin hormone, gastric emptying, and continuous glucose monitoring measurements limits insight into the physiological mechanisms underlying the observed effects. Finally, the study evaluated only the acute effects of a single apple cider vinegar intervention. Therefore, whether similar effects would be observed with regular long-term consumption remains to be established.

Conclusions

In conclusion, our findings suggest that apple cider vinegar may have beneficial effects on PPG in healthy adults. However, well-designed studies with larger sample sizes and crossover designs are required to further clarify this relationship. Further research in individuals with impaired glucose regulation, across different vinegar doses and meal compositions, may help clarify its clinical relevance to postprandial glycemic control. Future studies that include insulin, GLP-1, and gastric emptying parameters may contribute to a better understanding of the biological basis of vinegar's glycemic effects.

Author Contributions

Conceptualization: MKS, SD; Data curation: MKS; Formal analysis: MKS; Investigation: MKS; Methodology: MKS, SD; Project administration: MKS; Supervision: SD; Validation: SD; Visualization: MKS; Writing – original draft: MKS; Writing – review & editing: MKS, SD. All authors have read and approved the final version of the paper and its submission and have given consent for publication.

Declaration of Generative AI and AI-Assisted Technologies in Scientific Writing

Generative AI was used solely for language editing and translation support during the preparation of the manuscript from Turkish to English. All scientific content, data analysis, interpretation of results, and final manuscript revisions were performed and verified by the authors, who takes full responsibility for the content of this publication.

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Scientific Research Ethics Committee of Trakya University (Decision No. 04/15, February 15, 2021).

Acknowledgements

The authors would like to thank all participants who voluntarily took part in this study. The authors would like to thank İ.S.S. for assistance with blood glucose measurements during data collection.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Publisher's Note: *All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher. The publisher remains neutral with regard to jurisdictional claims.*

REFERENCES

Avner, S., & Robbins, T. (2025). A scoping review of glucose spikes in people without diabetes: Comparing insights from grey literature and medical research. Clinical Medicine Insights: *Endocrinology and Diabetes*, 18, 11795514251381409. https://doi.org/10.1177/11795514251381409

Garcia-Parrilla, M.C., Torija, M.J., Mas, A., Cerezo, A.B., & Troncoso, A.M. (2017). Vinegars and other fermented condiments. In J. Frias, C. Martinez-Villaluenga, & E. Peñas (Eds.), Fermented foods in health and disease prevention (pp. 577–591). Elsevier.

Johnston, C.S., & Buller, A.J. (2005). Vinegar and peanut products as complementary foods to reduce postprandial glycemia. *Journal of the American Dietetic Association,* 105(12), 1939–1942. https://doi.org/10.1016/j.jada.2005.09.006

Johnston, C.S., Kim, C.M., & Buller, A.J. (2004). Vinegar improves insulin sensitivity to a high-carbohydrate meal in subjects with insulin resistance or type 2 diabetes. *Diabetes Care*, 27(1), 281–282. https://doi.org/10.2337/diacare.27.1.281

Johnston, C.S., Steplewska, I., Long, C.A., Harris, L.N., & Ryals, R.H. (2010). Examination of the antiglycemic properties of vinegar in healthy adults. *Annals of Nutrition and Metabolism*, 56(1), 74–79. https://doi.org/10.1159/000272133

Launholt, T.L., Kristiansen, C.B., & Hjorth, P. (2020). Safety and side effects of apple vinegar intake and its effect on metabolic parameters and body weight: A systematic review. *European Journal of Nutrition*, 59(6), 2273–2289. https://doi.org/10.1007/s00394-020-02214-3

Leeman, M., Östman, E., & Björck, I. (2005). Vinegar dressing and cold storage of potatoes lowers postprandial glycaemic and insulinaemic responses in healthy subjects. *European Journal of Clinical Nutrition*, 59, 1266–1271. Full text here

Liatis, S., Grammatikou, S., Poulia, K. A., Perrea, D., Makrilakis, K., Diakoumopoulou, E., & Katsilambros, N. (2010). Vinegar reduces postprandial hyperglycaemia in patients with type II diabetes when added to a high, but not to a low, glycaemic index meal. *European Journal of Clinical Nutrition,* 64(7), 727–732. https://doi.org/10.1038/ejcn.2010.89

Liljeberg, H., & Björck, I. (1998). Delayed gastric emptying rate may explain improved glycaemia in healthy subjects to a starchy meal with added vinegar. *European Journal of Clinical Nutrition*, 52(5), 368–371. https://doi.org/10.1038/sj.ejcn.1600572

Östman, E., Granfeldt, Y., Persson, L., & Björck, I. (2005). Vinegar supplementation lowers glucose and insulin responses and increases satiety after a bread meal in healthy subjects. *European Journal of Clinical Nutrition*, 59(9), 983–988. https://doi.org/10.1038/sj.ejcn.1602197

Pınar, N., Topaloğlu, M., Özsan, M., Özer, C., & Alp, H. (2017). Hatay ilinde üniversite hastanesi endokrin polikliniğine başvuran diyabet hastalarının bitkisel ürün kullanımı. *Konuralp Medical Journal*, 9(3), 202–206.

Santos, H.O., de Moraes, W.M.A.M., da Silva, G.A.R., Prestes, J., & Schoenfeld, B.J. (2019). Vinegar (acetic acid) intake on glucose metabolism: A narrative review. *Clinical Nutrition ESPEN*, 32, 1–7. https://doi.org/10.1016/j.clnesp.2019.05.008

Vlachos, D., Malisova, S., Lindberg, F.A., & Karaniki, G. (2020). Glycemic index (GI) or glycemic load (GL) and dietary interventions for optimizing postprandial hyperglycemia in patients with T2 diabetes: A review. *Nutrients*, 12, 1561. https://doi.org/10.3390/nu12061561