Croatian Journal of Food Science and Technology
www.ptfos.unios.hr/cjfst/
since 2009

Health benefits of fruit vinegars

Tomislav Soldo[1*], Sunčana Včelik[2], Jurislav Babić[2], Borislav Miličević[1], Tihomir Kovač[2]

[1]Josip Juraj Strossmayer University of Osijek, Faculty of Tourism and Rural Development in Požega, Požega, Croatia
[2]Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology, Osijek, Croatia

ARTICLE INFO

TYPE: Review
https://doi.org/10.17508/CJFST.2026.18.1.05

*CORRESPONDENCE
Tomislav Soldo
tsoldo@ftrr.hr

ARTICLE HISTORY
Received: December 12, 2025
Accepted: March 30, 2026

CITATION
Soldo T, Včelik S, Babić J, Miličević B, Kovač T. Health benefits of fruit vinegars. Croatian Journal of Food Science and Technology (2026) 18 (1) 70—78

KEYWORDS
fruit vinegar; bioactive compounds; functional food; antioxidant activity; human health

KEY CONTRIBUTION
Provides a concise overview of the health-promoting mechanisms and evidence-based benefits of fruit vinegars.

ABSTRACT

Fruit vinegars, which are produced through the alcoholic and acetic fermentation of fruit substrates, are increasingly recognised as functional foods with potential health benefits. Their biological value results from the presence of organic acids (especially acetic acid), polyphenols, flavonoids, vitamins, minerals and other bioactive compounds derived from the fruit and microbial metabolism during fermentation. Numerous studies, including selected experimental studies and limited clinical trials, have reported antioxidant, antimicrobial, hypolipidaemic and hypoglycaemic effects of fruit vinegars, particularly those produced from apple, plum and grape. These findings suggest potential benefits in body weight regulation, glucose metabolism and cholesterol levels, possible roles in supporting intestinal microbiota health; however, the evidence remains heterogeneous and dependent on study design and population. In addition, the presence of specific phenolic compounds may contribute to the prevention of oxidative stress and chronic non-communicable diseases. The biological activity of fruit vinegars is strongly influenced by the type of fruit used, production methods, microbial dynamics and the duration of fermentation. Despite the growing body of evidence, further clinical studies are needed to confirm their efficacy, safety and optimal dosage for human consumption. The aim of this review is to consolidate current knowledge on the composition, mechanisms of action and potential applications of fruit vinegars in promoting human health, with a focus on evidence-based findings and future research perspectives.

Introduction

Fermented products, including vinegar, have long played a crucial role in human nutrition and health, dating back to the earliest civilizations, such as those of the Babylonians, Egyptians and Greeks, where vinegar was used as a condiment, preservative and medicinal aid. According to historical sources, Hippocrates used it to clean wounds (Johnston and Gaas, 2006) and the Babylonians used it in cooking to enrich their diet (Conner and Allgeier, 1976). Scientific literature suggests that vinegar has evolved from a basic fermented product into a functional food with proven health benefits over time. Vinegar is a rich source of polyphenols, vitamins, melanoidins and organic acids, which together promote antioxidant, anti-inflammatory, antitumour, hypolipidaemic and hepatoprotective effects (Xia et al., 2020; Budak et al., 2014). According to Olas (2024), the multidirectional effects of fruit vinegars result from the synergy of various chemical compounds, including organic acids, phenolic compounds, vitamins, minerals and fermentation-derived products. Today, vinegar is increasingly recognized as a functional fermented food that may contribute to the prevention of metabolic disorders, diabetes and cardiovascular diseases. Recent studies suggest that apple cider vinegar may offer benefits in the treatment of insulin resistance, osteoporosis and neurological diseases such as Alzheimer's disease and may also support weight loss (Olas, 2025). Zhang et al. (2020) state that the main topics that occupy scientists in vinegar research, according to the content of the research, are: microorganisms, substances, health functions, production technologies, auxiliary agents and vinegar residues. Fruit vinegar today serves as a model for research on the connection between fermented foods and human health, particularly in the development of functional nutrition and personalised dietary therapy.

Literature review

Antioxidant and Antimicrobial Activity of Fruit Vinegars

Recent scientific research confirms that fruit vinegars are a very rich source of bioactive compounds with pronounced positive properties, among which antioxidant and antimicrobial properties stand out in particular. It has been confirmed that the content of phenolic and flavonoid compounds, as well as the total antioxidant capacity, depend on the technological production process, the type of fruit used and the influence of added sugars during fermentation. In their research on vinegars obtained from grape varieties (Antoniewicz et al., 2021) found that vinegars from the above varieties to which sugar was added, had the highest antioxidant capacity and antimicrobial activity, while Benedek et al. (2022) reported that balsamic vinegars with the addition of sea buckthorn, rosehip and raspberry showed significant antioxidant properties and weaker, but still present antimicrobial activity. Bakir et al. (2017) show in their research that balsamic vinegar, in addition to containing the highest amounts of total phenols and flavonoids, also exhibits strong antibacterial activity against *Salmonella Typhimurium*. In his study, Budak (2022) showed that the content of organic acids, phenols and antioxidant capacity are positively correlated with antimicrobial activity. In this study, apple cider vinegar and rosehip vinegar showed the highest activity against gram-positive and gram-negative bacteria. Fruit vinegars from different geographical areas also show similar bioactive potential. Ousaaid et al. (2021) reported that apple cider vinegar samples from several apple varieties showed antimicrobial activity against different microbial strains studied, while Sengun et al. (2020) indicated the high potential of different fruit vinegars as antioxidants and antimicrobial agents. Yildiz (2023) points out that red fruit vinegars, especially raspberry, pomegranate and guelder-rose, stand out in terms of their bioactive content and potential compared to apple cider and grape vinegar. Rosehip vinegar, according to Özdemir et al.

(2022), shows pronounced antioxidant activity, is rich in phenolic compounds and its vitamin C content increases during fermentation. Jia et al. (2024) in their research on hawthorn vinegar state that it has extremely strong antimicrobial and antioxidant properties. In terms of new approaches to the valorization of by-products and biomass, Silva et al. (2024) showed that vinegars produced from unused fruits (grapes, figs, apricots, raspberries, plums) retain high levels of phenolic compounds and minerals, with pronounced antimicrobial activity, especially against *Pseudomonas aeruginosa*. A similar potential has been noted in traditional Tunisian grape, fig and date vinegars, which show strong antioxidant capacity and greater inhibition of bacterial than fungal strains (Mouna et al., 2021). Melkis and Jakubczyk (2024) noted that the so-called "live" fruit vinegars, which are not filtered or pasteurised, contain significant amounts of vitamin C, polyphenols and flavonoids, with apple cider vinegar being the most promising functional product. Furthermore, vinegars produced from blueberry wine and honey have demonstrated high antioxidant capacity, as indicated by DPPH, ABTS and FRAP tests and effective antimicrobial activity against *Bacillus subtilis* and *Salmonella enterica Typhimurium* (da Silva Fonseca et al., 2018). Overall, the results of the aforementioned studies confirm that fruit vinegars, regardless of their origin and type of raw material, possess significant antioxidant and antimicrobial properties, which are associated with a high content of phenolic compounds, organic acids and vitamin C. These products demonstrate significant potential for use in functional foods, food preservation and health promotion through their natural, biologically active components.

Effects of Fruit Vinegars on Lipid and Glycemic Regulation

Numerous studies have shown that fruit vinegars, rich in organic acids and phenolic compounds, exhibit significant hypolipidaemic and hypoglycaemic effects. Randomized clinical trials conducted in adults with type 2 diabetes have reported that daily consumption of apple cider vinegar (typically 15–30 mL, diluted in water) over intervention periods of eight weeks or longer may lead to reductions in total cholesterol, triglycerides and fasting glucose levels, as well as improve HbA1c levels. Research also shows reductions in weight, body mass index, waist circumference and body fat, as well as lower glucose, triglyceride and cholesterol levels, after apple cider vinegar consumption in obese individuals. Evidence further suggests that vinegar enhances insulin sensitivity in individuals with diabetes, reducing postprandial blood sugar and fat levels without affecting fat breakdown. Studies in animal models have yielded consistent results, confirming the metabolic benefits of different types of fruit vinegars. Apple cider and grape vinegar significantly reduced LDL, triglyceride and total cholesterol levels, while increasing HDL in albino rats (Hamed and Matar, 2014; Jafarirad et al., 2023; Gheflati et al., 2019; Hadi et al., 2021). Date vinegar improved lipid and inflammatory biomarker concentrations, reducing total cholesterol (TC), low-density lipoprotein (LDL), triglycerides (TG), high-density lipoprotein (HDL) and inflammatory biomarkers (C-reactive protein (CRP) (Ali et al., 2019; Ali et al., 2025). In a study on rats, Ok et al. (2013), indicated that supplementation with pomegranate vinegar reduced fat through the coordinated control of AMPK, which leads to stimulation of lipolysis in adipose tissue and stimulation of fatty acid oxidation in the liver, while persimmon vinegar in an experiment with mice significantly reduced the concentrations of triglycerides (TG) and total cholesterol (TC) in both serum and liver tissue, indicating that persimmon vinegar has anti-obesity properties (Moon et al., 2010). Mulberry vinegar improved antioxidant defence, glucose regulation and lipid status in diabetic rats (Kim et al., 2010). Similarly, vinegars produced from the fruit of salaka (*Salacca zalacca*) have been shown to reduce blood glucose, LDL and total cholesterol levels, while promoting pancreatic cell regeneration. Notably, the Swaru salacca variety exhibits the strongest hypoglycaemic and hypolipidaemic effects (Zubaidah, et al., 2017). Collectively, these findings suggest that regular consumption of fruit vinegars may contribute to improved lipid and glycaemic homeostasis through multiple interrelated mechanisms—including increased insulin sensitivity, stimulation of fatty acid oxidation and reduction of oxidative and inflammatory stress. Therefore, fruit vinegars may be considered valuable functional foods with potential applications in the prevention and dietary management of metabolic disorders such as diabetes and dyslipidaemia.

Effects of Fruit Vinegars on Gut Microbiota and Immune Modulation

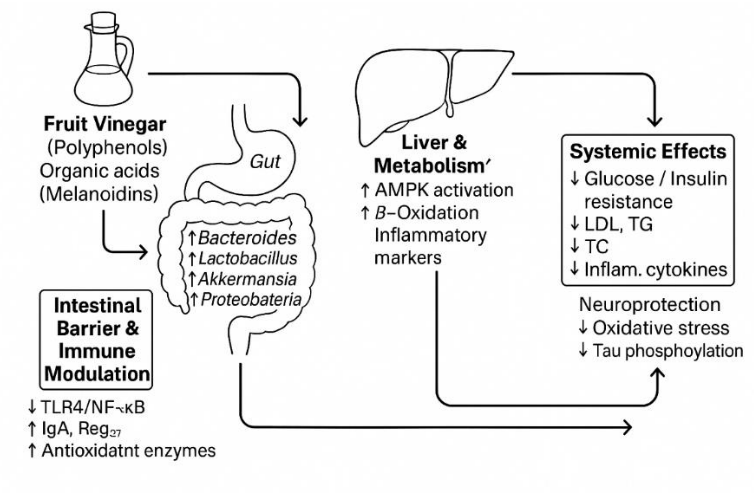

Figure 1. Mechanistic pathways of fruit vinegar action through the gut–microbiota–immune–metabolic axis. (Author's illustration based on Budak (2022); Li et al. (2022); Xia et al. (2022)

Recent studies have highlighted the central role of gut microbiota modulation and immune system regulation as key mechanisms underlying the health-promoting effects of fruit vinegars (Figure 1.). Several *in vivo* investigations have demonstrated that polyphenol-rich vinegars exhibit prebiotic and immunomodulatory properties, primarily mediated by alterations in microbial composition, improvements in intestinal barrier function, and modulation of inflammatory signalling pathways. In a study of the effect of supplementation with vinegar obtained from the fruits of *Rosa roxburghii Tratt* (RFV) in obese mice, it was found to significantly reduce fat accumulation and dyslipidaemia, while simultaneously restoring the balance of the intestinal microbiota - by reducing the *Firmicutes/Bacteroidetes* ratio and increasing the proportion of beneficial bacteria such as *Lactobacillaceae, Bacteroides* and *Akkermansia,* and the two main bacteria that could trigger dyslipidaemia in obese mice were *Actinobacteria* and *Firmicutes* (Li et al., 2022). Similar results were reported by Duan and Li (2023) in a mouse experiment using jujube vinegar, which reduced hyperlipidaemia by controlling the gut microbiome and increasing antioxidant capacity. An increase in the number of gut microbes by 13.46% was also recorded and the F/B (*Firmicutes/Bacteroidota*) ratio increased by 2.08 times. The abundance of aerobic and facultatively aerobic bacteria also increased by 2.84 times, while the abundance of potential pathogens decreased by 44.72%. The polyphenol-rich vinegar extract (VE) studied by Xia et al. (2022) demonstrated anti-diabetic activity by suppressing the TLR4/NF-κB inflammatory pathway and restoring gut microbial diversity. Treatment increased *Bacteroidetes*, *Lactobacillus*, *Bifidobacterium* and *Bacteroides* populations, while decreasing proinflammatory *Firmicutes* and *Proteobacteria*, leading to elevated SCFA levels and improved glucose and lipid regulation. A similar effect was observed by Ding et al. (2025) when experimental mice were fed apple cider vinegar powder. They found that liver damage was alleviated after administering apple cider vinegar powder (ACVP), through the remodelling of the gut microbiota, restoration of microbial metabolites and improvement of gut and liver function. In addition to microbial modulation, certain vinegars have been shown to directly enhance intestinal immunity. Polysaccharides isolated from Korean persimmon vinegar (KPV-0) were shown to activate mucosal immune responses by stimulating Peyer's patch cells to produce immunoglobulin A (IgA) and cytokines such as IL-6, GM-CSF and TGF-β, both *in vitro* and *in vivo* (Lee et al., 2015). Similarly, polyphenol-rich extracts from Zhenjiang aromatic vinegar (ZAV) alleviated ethanol-induced liver damage by reducing levels of oxidative stress biomarkers, regulating gut microbiota composition and immune factors and improving antimicrobial peptides (Reg3b and Reg3g) and intestinal homeostasis in ethanol-treated mice (Xia et al., 2021). Based on the above-cited studies, we conclude that fruit vinegars and their bioactive components act through the gut–microbiota–immune axis, strengthening intestinal immunity and inhibiting inflammatory processes. Studies have often reported an increase in the proportion of *Akkermansia*, *Lactobacillus* and *Bacteroides*, accompanied by a decrease in *Firmicutes* and *Proteobacteria*, which appears to be a common mechanism contributing to the anti-inflammatory and antidiabetic effects of fruit vinegars. This confirms that fruit vinegars are functional foods that maintain metabolic and immunological homeostasis by regulating the intestinal microbiota.

Inflammation Modulation, Metabolic Regulation and Neuroprotection

Fruit vinegars represent a multifunctional group of fermented products rich in bioactive compounds, including organic acids, polyphenols, vitamins, minerals and fermentation metabolites, whose synergistic effects contribute to their broad therapeutic properties. A growing body of research confirms that fruit vinegars may play an important role in modulating inflammatory processes, enhancing metabolic balance, promoting neuroprotection and slowing down the ageing process. In their work, Ousaaid et al. (2024) conclude that the organic acids abundant in fruit vinegar are transformed in the digestive system into compounds that have an anti-inflammatory effect by controlling the intestinal microbiota and promoting the production of anti-inflammatory cytokines. Vinegars contain melanoidins and tetramethylpyrazine, which play a crucial role in antioxidant activity, liver protection and the regulation of lipid metabolism (Xia et al., 2020). In experiments with vinegar extract, Xia et al., (2022) found a reduction in inflammation by inhibiting the TLR4/NF-κB signaling pathway, restoration of intestinal microbiota dysbiosis and an increase in the content of short-chain fatty acids in diabetic mice, all of which indicate that VE could be a candidate for intervention in type 2 diabetes by regulating intestinal microbiota and inflammation (Xia et al., 2022). Several authors have investigated the effectiveness of different types of fruit vinegars in regulating lipid and glycaemic metabolism and apple cider vinegar has proven to be extremely effective in several ways, especially in reducing glucose levels, HbA1c, total cholesterol, triglycerides and LDL (Jafarirad et al., 2023; Arjmandfard et al., 2025), and regular consumption of ACV for 12 weeks led to improvements in anthropometric and metabolic indicators (Abou-Khalil et al., 2024). Many authors have conducted research on other fruit vinegars, such as date, persimmon and pomegranate vinegars. These vinegars have also demonstrated hypolipidaemic and hypoglycaemic properties, reducing LDL, total cholesterol, HbA1c and improving insulin sensitivity and antioxidant status (Ali et al., 2019; Moon et al., 2010; Ok et al., 2013; Laurindo et al., 2022). Activation of the AMPK signalling pathway, increased by fatty acid oxidation and modulation of intestinal microbiota, contributes to better regulation of lipid and glycaemic metabolism (Ok et al., 2013; Ding et al., 2025; Duan and Li, 2023; Li et al., 2022). In addition to their metabolic effects, fruit vinegars also exhibit significant neuroprotective and anti-ageing properties. Tripathi et al. (2020) in their research on mice confirm that apple cider vinegar reduces tau protein phosphorylation, amyloid aggregation, reduces memory impairment and protects hippocampal cholinergic neurons from degeneration. The authors conclude that the existence of inhibitory enzyme activity and higher antioxidant potential indicates that apple cider vinegar, as a nutritional beverage, could be effective against neurological complications such as Alzheimer's disease. In their research, Barrong et al. (2024) report that regular consumption of vinegar for four weeks improved self-reported depressive symptomatology in healthy, overweight adults and improvements in niacin metabolism may be a contributing factor to this improvement. Scientific evidence clearly indicates that regular consumption of fruit vinegars may have anti-inflammatory, cardiometabolic and neuroprotective effects, acting through antioxidant mechanisms, modulation of the gut microbiota and regulation of key metabolic pathways. Further research is needed to elucidate these effects and optimise the use of fruit vinegars in the prevention and treatment of chronic metabolic and neurodegenerative diseases.

Conclusion

Fruit vinegars are multifunctional fermented products rich in organic acids, polyphenols and bioactive compounds that collectively contribute to human health. Their antioxidant, anti-inflammatory and antimicrobial properties, along with their ability to regulate lipid and glucose metabolism, contribute to maintaining metabolic balance and preventing chronic diseases such as diabetes, obesity and cardiovascular disorders. Recent evidence also suggests that fruit vinegars have neuroprotective and anti-ageing effects, indicating a broader systemic role in health and longevity. Overall, fruit vinegars can be considered valuable functional foods and nutraceuticals; however, additional clinical research is needed to determine the optimal consumption, clarify their mechanisms of action and confirm their long-term efficacy in disease prevention and health promotion.

Author Contributions: TS, SV, JB and BM – Conceptualization, TS, SV- Writing- Original Draft. TS, SV, TK-Visualization. JB, BM, TK - Writing- Reviewing and Editing.

Funding: This study was supported by the project "Studies of Bioactive Food Components with New Possibilities of Use for Healthy Nutrition and Nutritional Supplements" (BioActFood, NPOO 581-UNIOS-93), funded by the European Union -NextGenerationEU through the Recovery and Resilience Mechanism.

Acknowledgements: None.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abou-Khalil, R. Andary, J., El-Hayek, E. (2024): Apple cider vinegar for weight management in Lebanese adolescents and young adults with overweight and obesity: a randomized, double-blind, placebo-controlled study. *BMJ Nutrition, Prevention and Health, 7(1)* 61–67. https://doi.org/10.1136/bmjnph-2023-000823

Ali, Z., Ma, H., Wali, A., Ayim, I., Sharif, M. N. (2019): Daily date vinegar consumption improves hyperlipidemia, β-carotenoid and inflammatory biomarkers in mildly hypercholesterolemic adults. *Journal of Herbal Medicine,* 17–18, 100265. https://doi.org/10.1016/j.hermed.2019.100265

Ali, Z., Rafique, H., Tahir, R. A., Saeed, T., Rasheed, M. A., Khan, I., Alsulami, T., Shahzadi, M., Amir, M. L., Althawab, S. A., Cui, F. (2025): Clinical and computational exploration of red date fruit vinegar: synergistic effects on cardiovascular and type 2 diabetes pathways. *Frontiers in Nutrition,* 12, 1557733. https://doi.org/10.3389/fnut.2025.1557733

Antoniewicz, J., Jakubczyk, K., Kwiatkowski, P., Maciejewska-Markiewicz, D., Kochman, J., Rębacz-Maron, E., Janda-Milczarek, K. (2021): Analysis of antioxidant capacity and antimicrobial properties of selected Polish grape vinegars obtained by spontaneous fermentation. *Molecules,* 26(16), 4727. https://doi.org/10.3390/molecules26164727

Arjmandfard, D., Behzadi, M., Sohrabi, Z., Sartang, M. M. (2025): Effects of apple cider vinegar on glycemic control and insulin sensitivity in patients with type 2 diabetes: A GRADE-assessed systematic review and dose-response meta-analysis of controlled clinical trials. *Frontiers in Nutrition,* 12, 1528383. https://doi.org/10.3389/fnut.2025.1528383

Bakir, S., Devecioglu, D., Kayacan, S., Toydemir, G., Karbancioglu-Guler, F., Capanoglu, E. (2017): Investigating the antioxidant and antimicrobial activities of different vinegars. *European Food Research and Technology,* 243(12), 2083–2094. https://doi.org/10.1007/s00217-017-2908-0

Barrong, H., Coven, H., Lish, A., Fessler, S. N., Jasbi, P., Johnston, C. S. (2024): Daily vinegar ingestion improves depression and enhances niacin metabolism in overweight adults: a randomized controlled trial. *Nutrients,* 16(14), 2305. https://doi.org/10.3390/nu16142305

Benedek, C., Szakolczi, O., Makai, G., Kiskó, G., Kókai, Z. (2022): Evaluation of physicochemical, sensory and antimicrobial properties of small-scale produced fruit vinegars. *Acta Alimentaria,* 51(1), 1–10. https://doi.org/10.1556/066.2021.00077

Budak, N. H., Filiz, B. E., Çetin, E. S., Gökirmakli, Ç. (2022): Antimicrobial activity of different kinds of traditional vinegar and its relationship with antioxidant properties. *Annals of the University Dunarea De Jos of Galati, Fascicle Vi-Food Technology, 46(1), 140-154.* https://doi.org/10.35219/FOODTECHNOLOGY.2022.1.11

Budak, N. H., Aykin, E., Seydim, A. C., Greene, A. K., Guzel-Seydim, Z. B. (2014): Functional properties of vinegar. *Journal of Food Science,* 79(5), R757–R764. https://doi.org/10.1111/1750-3841.12434

Conner, H. A. and Allgeier, R. J. (1976). Vinegar: its history and development. In *Advances in applied microbiology,* D. Perlman (Ed.), London: Elsevier,20, 81–133. https://doi.org/10.1016/S0065-2164(08)70110-2

da Silva Fonseca, M. , Santos, V. A. Q., Calegari, G. C., Dekker, R. F. H., Barbosa-Dekker, A. de M., da Cunha, M. A. A. (2018): Blueberry and honey vinegar: successive batch production, antioxidant potential and antimicrobial ability. *Brazilian Journal of Food Technology,* 21, e2017101. https://doi.org/10.1590/1981-6723.10117

Ding, Q., Xue, D., Ren, Y., Xue, Y., Shi, J., Xu, Z., Geng, Y. (2025): Apple cider vinegar powder mitigates liver injury in high-fat-diet mice via gut microbiota and metabolome remodeling. *Nutrients,* 17(13), 2157. https://doi.org/10.3390/nu17132157

Duan, G. and Li, L. (2023): Deciphering the mechanism of jujube vinegar on hyperlipoidemia through gut microbiome based on 16S rRNA, BugBase analysis and the stamp analysis of KEGG. *Frontiers in Nutrition,* 10, 1160069. https://doi.org/10.3389/fnut.2023.1160069

Gheflati, A., Bashiri, R., Ghadiri-Anari, A., Reza, J. Z., Kord, M. T., Nadjarzadeh, A. (2019): The effect of apple vinegar consumption on glycemic indices, blood pressure, oxidative stress, and homocysteine in patients with type 2 diabetes and dyslipidemia: a randomized controlled clinical trial. *Clinical nutrition ESPEN*, 33, 132–138. https://doi.org/10.1016/j.clnesp.2019.06.006

Hadi, A., Pourmasoumi, M., Najafgholizadeh, A., Clark, C. C. T. and Esmaillzadeh, A. (2021): The effect of apple cider vinegar on lipid profiles and glycemic parameters: a systematic review and meta-analysis of randomized clinical trials. *BMC Complementary Medicine and Therapies*, 21(1), 179. https://doi.org/10.1186/s12906-021-03351-w

Hamed, A. T. and Matar, R. A. (2014): The effect of apple cider vinegar and grape vinegar on lipid profile in Albino white rats. *Jordan Journal of Pharmaceutical Sciences,* 7(3), 163–170. https://doi.org/10.12816/0027040

Jafarirad, S., Elahi, M.-R., Mansoori, A., Khanzadeh, A., Haghighizadeh, M.-H. (2023): The improvement effect of apple cider vinegar as a functional food on anthropometric indices, blood glucose and lipid profile in diabetic patients: a randomized controlled clinical trial. *Frontiers in clinical diabetes and healthcare*, 4, 1288786. https://doi.org/10.3389/fcdhc.2023.1288786

Jia, K., Xue, S., Du, Y., Peng, L., Chen, W., Yu, X., Cao, X., Fang, R., Li, Z. (2024): Antimicrobial and antioxidant properties of hawthorn vinegar. *Microbiology Research,* 15(4), 2048–2055. https://doi.org/10.3390/microbiolres15040137

Johnston, C. S. and Gaas, C. A. (2006): Vinegar: medicinal uses and antiglycemic effect. *MedGenMed : Medscape general medicine*, 8(2), 61, 16926800.

Kim HJ, Choi SW, Cho SH. (2010): Effects of Various Mulberry Products on the Blood Glucose and Lipid Status of Streptozotocin-induced Diabetic Rats. *Korean Journal of Nutrition*, 43(6):551-560. https://doi.org/10.4163/kjn.2010.43.6.551

Laurindo, L. F., Barbalho, S. M., Marquess, A. R., de Souza Grecco, A. I.., de Alvares Goulart, R., Tofano, R. J., Bishayee, A. (2022): Pomegranate (*Punica granatum* L.) and metabolic syndrome risk factors and outcomes: a systematic review of clinical studies. *Nutrients,* 14(8), 1665. https://doi.org/10.3390/nu14081665

Lee, M. Y., Kim, H., Shin, K. S. (2015): *In vitro* and *in vivo* effects of polysaccharides isolated from Korean persimmon vinegar on intestinal immunity. *Journal of the Korean Society for Applied Biological Chemistry,* 58(6), 867–876. https://doi.org/10.1007/s13765-015-0117-8

Li, J., Zhang, J., Zhang, Y., Shi, Y., Feng, D., Zuo, Y., Hu, P. (2022): Effect and correlation of Rosa roxburghii Tratt fruit vinegar on obesity, dyslipidemia and intestinal microbiota disorder in high-fat diet mice. *Foods,* 11(24), 4108. https://doi.org/10.3390/foods11244108

Melkis, K. and Jakubczyk, K. (2024): The chemical profiles and antioxidant properties of live fruit or vegetable vinegars available on the Polish food market. *Foods,* 13(10), 1488. https://doi.org/10.3390/foods13101488

Moon, Y.-J., Choi, D.-S., Oh, S.-H., Song, Y.-S., Cha, Y.-S. (2010): Effects of persimmon-vinegar on lipid and carnitine profiles in mice. *Food Science and Biotechnologyn,* 19(2), 343–348. https://doi.org/10.1007/s10068-010-0049-3

Mouna, B. H., Mahfoudhi, A., Gharsallah, H., El Hatmi, H., Attia, H., Azabou, S. (2021): Traditional homemade Tunisian vinegars: phytochemical profile, biological, physicochemical and microbiological properties. *LWT-Food Science and Technology,* 152, 112293. https://doi.org/10.1016/j.lwt.2021.112293

Ok, E., Do, G.-M., Lim, Y., Park, J.-E., Park, Y.-J., Kwon, O. (2013): Pomegranate vinegar attenuates adiposity in obese rats through coordinated control of AMPK signaling in the liver and adipose tissue. *Lipids in Health and Disease,* 12, 163. https://doi.org/10.1186/1476-511X-12-163

Olas, B. (2024): Pro-health potential of fruit vinegars and oxymels in various experimental models. *International Journal of Molecular Sciences*, 26(1), 7. https://doi.org/10.3390/ijms26010007

Ousaaid, D., Bakour, M., Laaroussi, H., El Ghouizi, A., Lyoussi, B., El Arabi, I. (2024): Fruit vinegar as a promising source of natural anti-inflammatory agents: an up-to-date review. *DARU-Journal of Pharmaceutical Sciences,* 32(1), 307–317. https://doi.org/10.1007/s40199-023-00493-9

Ousaaid, D., Laaroussi, H., Bakour, M., Ennaji, H., Lyoussi, B., El Arabi, I. (2021): Antifungal and antibacterial activities of apple vinegar of different cultivars. *International Journal of Microbiology, 2021,* 6087671. https://doi.org/10.1155/2021/6087671

Özdemir, N., Pashazadeh, H., Zannou, O., Koca, I. (2022): Phytochemical content, antioxidant activity and volatile compounds associated with the aromatic property of vinegar produced from rosehip fruit (*Rosa canina* L.). *LWT-Food Science and Technology,* 154, 112716. https://doi.org/10.1016/j.lwt.2021.112716

Sengun, I. Y., Kilic, G., Ozturk, B. (2020): Screening physicochemical, microbiological and bioactive properties of fruit vinegars produced from various raw materials. *Food Science and Biotechnology,* 29(3), 401–408. https://doi.org/10.1007/s10068-019-00678-6

Silva, V., Mehrpour, G., Soares, V., Santo, D., Nunes, P., Quintas, C. (2024): Quality and biological properties of vinegar processed from non-valorized fruits in Southern Portugal. *Future Foods,* 9, 100337. https://doi.org/10.1016/j.fufo.2024.100337

Tripathi, S., Kumari, U., Mitra Mazumder, P. (2020): Ameliorative effects of apple cider vinegar on neurological complications via regulation of oxidative stress markers. *Journal of Food Biochemistry,* 44(12), e13504. https://doi.org/10.1111/jfbc.13504

Xia, T., Duan, W., Zhang, Z., Li, S., Zhao, Y., Geng, B., Zheng, Y., Yu, J., Wang, M. (2021): Polyphenol-rich vinegar extract regulates intestinal microbiota and immunity and prevents alcohol-induced inflammation in mice. *Food Research International,* 140, 110064. https://doi.org/10.1016/j.foodres.2020.110064

Xia, T., Zhang, B., Duan, W., Zhang, J., Wang, M. (2020): Nutrients and bioactive components from vinegar: a fermented and functional food. *Journal of Functional Foods,* 64, 103681. https://doi.org/10.1016/j.jff.2019.103681

Xia, T., Zhang, Z., Zhao, Y., Kang, C., Zhang, X., Tian, Y., Yu, J., Cao, H., Wang, M. (2022): The anti-diabetic activity of polyphenols-rich vinegar extract in mice via regulating gut microbiota and liver inflammation. *Food Chemistry,* 393, 133443. https://doi.org/10.1016/j.foodchem.2022.133443

Yildiz, E. (2023): Characterization of fruit vinegars via bioactive and organic acid profile using chemometrics. *Foods,* 12(20), 3769. https://doi.org/10.3390/foods12203769

Zhang, X.-L., Zheng, Y., Xia, M.-L., Wu, Y.-N., Liu, X.-J., Xie, S.-K., Wu, Y.-F., Wang, M. (2020): Knowledge domain and emerging trends in vinegar research: A bibliometric review of the literature from WoSCC. *Foods,* 9(2), 166. https://doi.org/10.3390/foods9020166

Zubaidah, E., Rukmi Putri, W. D., Puspitasari, T., Kalsum, U., Dianawati, D. (2017): The effectiveness of various salacca vinegars as therapeutic agent for management of hyperglycemia and dyslipidemia on diabetic rats. *International Journal of Food Science, 2017,* 8742514. https://doi.org/10.1155/2017/8742514