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Therapeutic effects of vinegar: a review

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Vinegar is a natural product derived from a process of fermentation. Carbohydrates-rich foods are excellent sources of substrate to produce vinegar. Vinegar is mainly used as an ingredient in food preparation due to its taste and aroma. It is one of the most famous folk medicines used to fight infections. Several studies have showed vinegar has a potential to ameliorate obesity, diabetes, cardiovascular disorders, cancer and microbial infections. Daily intake of a drink containing 15 mL vinegar (750 mg of acetic acid) was reported to improve lifestyle-related diseases, such as hypertension, hyperlipidemia, and obesity. The presence of acetic acid and other components in vinegar could be responsible for its therapeutic effect. This paper reviews recent studies on therapeutic values of vinegar derived from different food sources. Possible mechanisms of therapeutic action of vinegar are also discussed.

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Introduction

Vinegar is a natural food product derived from fermentation processes (alcoholic and subsequently acetous fermentation) that involve fermentable glucose in apple, dates, grape, fig, and many other carbohydrate-rich food products [1]. Historically, the production of vinegar is for medicinal purposes due to its therapeutic values. Health-promoting properties of vinegar have been traditionally known to include as an antimicrobial agent and in preventing negative health outcomes [2].

Vinegar has been used as a therapeutic agent to attenuate obesity since late 18th century. Post World War 1, anti-obesity drugs such as dinitrophenol, amphetamine, and fenfluramine started to be used but caused many health complications and side effects [3]. Thus, scientists have investigated the effectiveness of vinegar as an alternative medicine for obesity. Several studies have reported acetic acid is a bioactive compound present in vinegar that exhibits various therapeutic values. Furthermore, Cho *et al.* [4] reported that phenolic compounds (chlorogenic acid, gallic acid and caffeic acid) in vinegar could improve lipid metabolism and have antiobesity effect in obese rats. Up to date, vinegar has been reported not only for attenuating obesity [5], but also shown to exhibit therapeutic effects on diabetes [2,6], cardiovascular disorders [7] and cancer [8,9] as shown in Table 1.

One of the main ingredients in the Mediterranean diet is vinegar, and vinegar was believed to play crucial role in impeding cardiovascular disease as vinegar ingestion may diminish blood pressure [10–13]. In exerting its hypotensive action, taking vinegar may prevent the bradyarrhythmia effect, a slow heart rate symptom that can lead to fatigue, weakness, dizziness, and loss of consciousness [14]. Vinegar also possesses antioxidant capacity that may be a reliable health-promoting activity [15]. Moreover, it has been recommended that daily vinegar supplements could increase HDL-cholesterol and diminish LDL-cholesterol levels [16].

In the other case, vinegar (5%, v/v) or acetic acid (0.3%, w/v) were used in treating ulcerative colitis (UC) due to its ability in hindering inflammation through suppressing T helper 17 (Th17) and mitogen-activated protein kinase (MAPK), the pivotal signaling in pathway of UC. Supplementation of vinegar and acetic acid to dextran sulfate sodium (DSS)-induced mice reported effectively ameliorate body weight loss, shorten the colon length in a murine experimental colitis, reduce disease activity index (DAI), and histopathological scores [17].

Vinegar improves lipid profiles and suppresses fat accumulation

High dietary cholesterol will induce significant increases in liver cholesterol and triacylglyceride concentrations [18] which can lead to health complication such as atherosclerosis and hypertension. Intriguingly, vinegar supplementation is one of effective and low cost medications suggested to reduce the formation of triacylglycerides in the liver [19] by elevating hepatic glutathione (GSH) and trolox equivalent antioxidant capacity (TEAC) levels, as well as catalase (CAT) and glutathione peroxidase (GPx) activities [20].

The presence of acetic acid in vinegar will stifle sterol regulatory element-binding protein (SREBP) gene

Table 1

Health benefits of different vinegar types.

Type of vinegar	Effects	References
Persimmon vinegar	- reduce hepatic triglyceride (TG) and total cholesterol (TC) concentration - lower the acetyl-CoA carboxylase (ACC) mRNA level • Effective in reducing obesity	Moon *et al.* [21•]
Tomato vinegar	- reduced the body and visceral fat weight - lower plasma free fatty acid, triglyceride and hepatic triglyceride levels - enhance fatty acid beta-oxidation carnitine palmitoyltransferase activities - increase glucokinase activity and decreased glucose-6-phosphatase activity - lower plasma LDL-cholesterol level and elevate HDL-cholesterol • Can be used as an antiobesity and antidiabetic agent	Seo *et al.* [5] Lee *et al.* [16]
Pomegranate vinegar	- increase phosphorylation of AMP-activated protein kinase (AMPK) - decrease sterol regulatory element binding protein-1c (SREBP-1c) and peroxisome proliferator-activated receptor (PPARγ) • Attenuate adiposity through AMPK regulation	Ok *et al.* [27] Park *et al.* [28•]
Ginseng radix vinegar	- decrease insulin resistance up to 90% - inhibit weight gain - lower fasting and postprandial glucose concentrations • Ameliorate obesity and diabetes through improved lipid and glucose metabolism	Yun *et al.* [15] Lim *et al.* [30]
Nypa palm vinegar	- Its aqueous extract showed significant blood glucose lowering effect - significant improvement in serum insulin levels up to 80% • Should be taken by type 2 diabetes patient because its antihyperglycaemic effect comparable to metformin	Yusoff *et al.* [6]
Kurosu vinegar	- inhibit the proliferation of cancer cells - enhance programmed necrosis (necroptosis) in cancer cells • Possess anticancer effects against almost human cancer cells	Baba *et al.* [8] Nanda *et al.* [43]

expression in mRNA level and also reduce activity of ATP citrate lyase (ATP-CL). This process may reduce the level of pivotal substrates (acetyl-CoA and HMG-CoA) required for cholesterol and fatty acid synthesis [21••]. Acetic acid increases alternative oxidase (AOX) gene expression, thus resulting in boosting fatty acid oxidation. The study showed acetic acid not only inhibits cholesterol and fatty acid formation in liver, but also enhances lipolysis [22]. Ingestion of vinegar produced from persimmon will ameliorate blood lipid profiles through elevating body carnitine level and may promote lipid oxidation [22]. Both human and animal studies showed that the supplementation of acetic acid reduced the level of serum triacylglyerides [14,23].

As shown in Table 1, it has been demonstrated that tomato vinegar beverage (TVB) supplementation significantly reduced triglyceride and cholesterol levels in liver and also lessen plasma free fatty acid concentration [16,24••]. In addition, TVB lowered plasma LDL-cholesterol level [25], reduced the development of fatty plaques in the arteries, and increased ratio of HDL-cholesterol to total cholesterol [16,26,27]. Fecal triglyceride excretion also increased due to vinegar supplementation, indicating it helps in cholesterol flush out from the body [16,20].

Ok *et al.* [28•] have reported that supplementation of acetic acid and pomegranate vinegar (PV) contributed to lowering both plasma and hepatic triglyceride levels. Interestingly, in their study the effectiveness of PV in reducing plasma triglyceride was favored more at a low dose when compared to a high dose. This could be due to various properties of diverse chemical compounds present in PV.

Vinegar derived from pomegranate seems to be popular for obesity treatment because it has been reported to inhibit lipogenesis and enhance fatty acid beta-oxidation [28•,29]. Moreover, ingestion of PV may induce upregulation of peroxisome proliferator-activated receptor alpha (PPARα) [21••] and carnitine palmitoyltransferase 1 alpha (CPT-1a) mRNA expressions including phosphorylation of adenosine monophosphate-activated protein kinase (AMPK) better than acetic acid [28•], indicating that PV is more potent than acetic acid in attenuating obesity.

Yamashita [30] investigated possible mechanisms of vinegar in obesity attenuation. AMPK, a kinase enzyme which acts as a key metabolic master switch, and plays a pivotal role in lipid homeostasis will increase as AMP/ATP ratio increases due to vinegar supplementation. Phosphorylation of AMPK will induce PPAR-alpha gene expression [14] that regulates mRNA expression of fatty acid oxidation enzymes, such as acetyl-CoA (ACCA) oxidase and CPT-1a, which may enhance fatty acid β-oxidation. Activation of AMPK as well as down-regulation of SREBP-1c [29] and carbohydrate-responsive element-binding protein (ChREBP) expression will inhibit lipid