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Review Article

A Review of the Therapeutic Applications of Vinegar

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Abstract: Vinegar may be defined as a condiment made from various sugary and starchy materials by alcoholic and subsequent acetic fermentation. Vinegar has been produced and sold for thousands of years, dating back to before the 6th century. Vinegars flavoured with fruit and honey was popular among the Babylonians. Hippocrates used vinegar as an antiseptic to treat wounds. This review will examine the therapeutic effects of vinegar including the antibacterial properties, anti-tumor effects, anti-diabetic effects, antioxidant activity and prevention of cardiovascular disease.
Keywords: Vinegar, acetic acid, antibacterial, anti-diabetic, anti-tumour, cardiovascular, antioxidant

INTRODUCTION

Vinegar was first made from wine, as its name indicates. It has been produced and sold for thousands of years, dating back to before the 6th century [1]. Vinegars flavoured with fruit, honey and malt were popular among the Babylonians. Hippocrates used it as a medicine in the wound healing process.

Vinegar produced from grapes was being used in France in the 16th century for household purposes. In England vinegar was first made from malt liquors, a method of disposing of ale and beer which had soured. For this reason it was known as alegar. Although this name has long since become obsolete, malt vinegar is still the standard in the British Isles. In the United States of America, apple juice is largely used to produce vinegar. Vinegar, now manufactured in large quantities throughout the globe, is extensively used for flavouring, preserving and pickling purposes. Some of the common vinegars include malt, wine, sherry, rice, fruit, apple cider, balsamic, white distilled, palm, coconut, sugar cane, date, raisin, beer and honey [2].

Sung Tse, who is considered a pioneer in the field of forensic medicine in the 10th century in China [3], used a solution containing sulphur and vinegar as hand washing agent to prevent infection. In the early days of USA, vinegar was used in the treatment of fever, poison ivy, croup, oedema, etc. [4].

Vinegar may be defined as a condiment made from various sugary and starchy materials by alcoholic and subsequent acetic fermentation [5]. The concentration of acetic acid ranges from 4% to 8% by volume for table vinegar and could be as high as 18% for pickling [6].

Natural vinegars also contain smaller amounts of vitamins, mineral salts, amino acids, polyphenolic compounds (eg, galic acid, catechin, caffeic acid, ferulic acid) and organic acids like tartaric, citric, malic and lactic. After oral administration, acetic acid is readily absorbed, uptake then occurs in liver and peripheral tissues [7]. It is metabolized via acetyl-CoA in the tricarboxylic acid cycle in liver and skeletal muscle [8].

Most of the diseases are preventable and treatable with appropriate use of drugs. Because of the duration of the therapy and side effects due to chemical drugs in the treatment of various diseases; substances found in natural environment may sometimes become suitable and act as substitutes for these drugs or at least can serve as adjunctive therapy to compliment the primary treatment strategy. Studies should be carried out in order to establish naturally occurring, low-cost and effective herbal remedies as prophylactic and/or complimentary measures in preventing metabolic disorders in both developing and under-developed countries.

The following review will focus on the importance of the therapeutic effects of vinegar including the antitumor effects, antibacterial properties, blood pressure reduction, antioxidant activity, in controlling hyperglycemia and in the prevention of cardiovascular disease.

Production of vinegar

Vinegar is produced from raw materials containing starch or sugar via sequential ethanol and acetic acid fermentations [9]. The production of vinegar typically involves a first fermentation where simple sugars in raw material are converted to alcohol by yeasts. The resultant alcohol is further oxidized to acetic acid by Acetic Acid Bacteria (genus: Acetobacter) during the last fermentation [10].

Slow methods are generally used in the manufacture of traditional vinegars and the process of fermentation proceeds slowly which takes a few months [11]. Longer fermentation periods lead to the accumulation of a nontoxic slime containing acetic acid bacteria and soluble cellulose, referred as the mother of vinegar. This process is slow because only the surface of the alcoholic liquid is exposed to the air.

In commercial methods, mother of vinegar is added to the source liquid and then air is added to promote oxygenation to give the fastest fermentation [12]. In such fast production processes, vinegar is produced in the course of a few days.

Antibacterial effects of vinegar

Hippocrates, (Greek physician in the 3rd and 4th centuries BC) used vinegar as antiseptic to promote wound healing. Wound healing is a complex, multifaceted process which is influenced by both intrinsic and extrinsic factors. The pH of the wound can affect many factors including oxygen release, angiogenesis, protease activity and bacterial toxicity. Chronic non-healing wounds have an elevated alkaline environment. Healing occurs more readily in an acid environment. As a 0.25% to 0.5% solution [13], white distilled vinegar has bactericidal action against many Gram-positive and Gram-negative organisms, and is effective in reducing bacterial burden [14, 15, 16]. Vinegar has been used as an adjunctive short-term treatment for superficial wound infections.

Avicenna, the Persian physician, elaborated a series of applications of vinegar in the treatment and clinical management of injuries caused by dog bites, ulcers, scabies, impetigo, skin infections, etc. in his famous reference book, The Canon of Medicine which has been used by the medical schools in medieval Europe through the 18th century [17].

The genus *Pseudomonas*, of the *Pseudomonadaceae* family, are motile gram-negative aerobic bacteria, 2 – 4 μm long plump-shaped rods, with polar flagella which have an important role in pathogenicity [18].The overall incidence in 2012 for *Pseudomonas* spp. bacteraemias was 6.4 cases/100,000 population in England, Wales and Northern Ireland. *Pseudomonas aeruginosa* is the most common cause of pseudomonal infection [19].

Since Pseudomonas spp. typically develop quick resistance to many topical and systemic agents, this simple approach, which reduces local pH, can reduce the bacterial burden of this microorganism in the wound. Diluted vinegar soaks for 15 minutes per day are effective and reduce problems of local wound odour if a mixed aerobic-anaerobic flora is present. This approach is effective for critically colonized wounds in the superficial compartment.

In a study with patients with venous leg ulcers [20], gauze dressings wetted with acetic acid were shown to effectively decrease the number of *Staphylococcus aureus* and Gram-negative rods.

Jung H.H. and colleagues has demonstrated the therapeutic effectiveness of pH therapy in the management of granular myringitis [21]. Among the study group of 30 patients, 15 of them were treated with antibiotic ear drops and the remaining 15 were treated with daily irrigation of the external canal with dilute vinegar solution. Statistical evaluation of therapeutic efficacy revealed that a dry ear was attained in the dilute vinegar-treated group at 6 weeks compared to 6 months in the antibiotic ear drop treated group ($p<0.01$).

In another study, 96 patients suffering from chronic suppurative otitis media were exposed to ear irrigation with 2% acetic acid solution at least 3 times / week for the maximum of 3 weeks [22]. No antibiotic therapy was given to the patients during the study period. 88 patients recovered whereas 8 of them showed no response to the treatment. Bacteria thrive in a narrow pH range of 6.5 to 7.5 and a fairly constant balance of pH must be maintained for its survival.

Antitumour effects of vinegar

Vinegar derived from natural sources are rich sources of phenolic compounds and function as antioxidants which accounts for its protective effects against cancer [23, 24]. Naturally fermented vinegar such as Kibizu [25] (sugar cane vinegar in Amami Ohshima, Japan), Kurozu (black rice vinegar in Kagoshima, Japan), Kouzu (black rice vinegar in China) and red wine vinegar in Italy had potent radical-scavenging activity. Mimura A, et. al. showed that apoptosis was induced in the leukemia cells by the fraction of sugar cane vinegar (Kibizu) and resulted in

the repression of growth of the human leukemia cells [25].

In another study, the protective effects of the Japanese traditional vinegar from unpolished rice (Kurosu), were investigated. Various cancer cell lines included in the study were colon adenocarcinoma (Caco-2), lung carcinoma (A549), breast adenocarcinoma (MCF-7), bladder carcinoma (5637), and prostate carcinoma (LNCaP) cells. Kurosu inhibited the proliferation of all tested cell lines in a dose-dependent manner. Analysis revealed p21 mRNA expression was induced in Kurosu -treated Caco-2 cells. Moreover, PARP cleavage was promoted in Kurosu - treated Caco-2 cells. These results suggest that Kurosu causes G0/G1 arrest through p21 induction and, thus, is a potential apoptosis inducer in Caco-2 cells [26].

The modifying effects of administering an ethyl acetate extract of Kurosu (EK), a vinegar made from unpolished rice, in drinking water on the development of azoxymethane (AOM)-induced colon carcinogenesis were investigated in male F344 rats. Animals were given 2 weekly subcutaneous injections of AOM (20 mg/kg body weight). They also received drinking water containing 0%, 0.05% and 0.1% EK for 35 weeks, starting 1 week after the last dosing of AOM. EK administration significantly inhibited the incidence and multiplicity of colon adenocarcinoma ($P < 0.05$), compared with those in the AOM alone group. These findings suggest that EK may be effective for inhibiting colon carcinogenesis [27].

In a case-control study conducted in the Linzhou City of China (which recorded highest incidences of oesophageal cancer in the world) the consumption of vinegar showed a protective effect with a decreased risk of oesophageal cancer (odds ratios of 0.37) [28].

Antidiabetic effects of vinegar

Meal time glycemic load is associated with risk for chronic disease. Numerous animal as well as human studies have shown the antiglycemic effects of vinegar. Application of vinegar to the diet not only controls the postprandial blood glucose and insulin profiles but also improves the satiety value of diet [29]. In order to investigate the potential of acetic acid supplementation as a means of lowering the glycaemic index (GI) of a bread meal and to evaluate the possible dose–response effect on postprandial glycemia, insulinemia and satiety, a study was conducted in Sweden by E. Ostman and colleagues [30]. Their study showed that supplementation of a meal based on white wheat bread with vinegar reduced postprandial responses of blood glucose and insulin, and increased the subjective rating of satiety. There was an inverse dose–response relation between the level of acetic acid and glucose and insulin responses and a linear dose–response relation between acetic acid and satiety rating. The results indicate an interesting potential of fermented and pickled products containing acetic acid.It was proposed that this effect was the result of delayed gastric emptying [31, 32].

Vinegar dressings are common used as a seasoning agent for salads, in sauces, in stews, in marinades, etc. Ingestion of vinegar in appropriate proportions to a glycemic-load meal reduces postprandial glycemia [33,34,35]. Another study published in 2007 has demonstrated that vinegar ingestion at bedtime may favourably impact morning fasting blood glucose concentrations in Type-II Diabetes Mellitus [36].

How acetic acid present in vinegar affects glucose metabolism has been studied by various researchers. Ogawa et al demonstrated that acetic acid suppresses disaccharidase activity in Caco-2 cells (human colonic carcinoma cells) [37]. Acetic acid was found to significantly suppress sucrase, maltase, trehalase and lactase. in a time and concentration dependent manner. However acetic acid did not have any effect on the transcription and translation of sucrase but rather it affects its enzymatic activity, indicating a post-translational mechanism of action. In another study conducted by Fushimi et al, acetic acid has been shown to activate gluconeogenesis and induce glycogenesis in the rat liver after a fasting state [38].

Vinegar is readily available, affordable and widely used as a seasoning agent in a variety of cuisines. Therefore, is acetic acid by may present a viable tool to assist individuals attempting to achieve their glycemic targets. Besides having a rich supply of acetic acid, vinegar also contains anthocyanin (e.g. cyanidin-3- glucoside) flavonols (e.g. quercetin, kaempferol), flavanols (catechin, epicatechin) [39], vitamins, mineral salts, amino acids and nonvolatile organic acids (eg. tartaric, citric, malic, lactic) [40].

Vinegar exerts various metabolic effects such as glycogen repletion [41], hypotensive action thereby decreasing the risk of hypertension [42], stimulation of Ca^{+2} absorption [43], reduction in serum total cholesterol and triglycerides in animal studies [44].

Hypertension is considered a major risk factor for the progression of cardiovascular disorders [45]. A positive association between consumption of a drink containing vinegar (at a concentration of 15 g /100 ml) and Blood Pressure has been demonstrated in a study conducted by Kajimoto et al [46]. Another group reported the hypotensive effect of vinegar at a concentration of 2.07 g/90 ml [47].

Postprandial hypertriglyceridemia is an established risk factor for cardiovascular disease. Obesity and/or insulin resistance results in an overproduction and/or decreased catabolism of lipoproteins with high content of triacylglycerols). Concomitant consumption of cholesterol enriched diet with high doses of vinegar modifies the atherogenic effects of cholesterol and significantly prevents the increase of oxidized-LDL, LDL-C, ApoB100, Total Cholesterol, Malondialdehyde, glucose and fibrinogen [48].

In 2006, Fushimi T. conducted a study on rats and showed that vinegar consumption with diet containing 1% cholesterol for 2-3 weeks significantly reduced TG and total cholesterol [49].

More studies are required to explore the advantages and disadvantages of vinegar therapy as a tool for controlling metabolic disorders like hyperlipidemia.

Antioxidant effects of vinegar

Free radicals and other reactive oxygen species (ROS) are constantly formed in the human body. Free-radical mechanisms have been implicated in the pathology of several human diseases, including cancer, atherosclerosis, malaria, and rheumatoid arthritis and neurodegenerative diseases [50].

Rice shochu distilled residue (RSDR) is a byproduct of rice shochu production. RSDR was converted into vinegar by acetate fermentation. In our present study, two major antioxidant compounds, tyrosol and ferulic acid, were identified from the RSDR-derived vinegar [51].

Total polyphenol and flavonoid contents in bokbunja vinegar were 38.0 mg/g and 17.8 mg/g, respectively. The ellagic acid and gallic acid contents in bokbunja vinegar were 1,127.43 μg/g and 962.44 μg/g, respectively. At concentration of 500 μg/mL bokbunja vinegar, the DPPH radical scavenging activity and reducing power were 60.3% and 0.50, respectively [52].

In one study, vinegar was produced from barley, sweet potato and rice-shochu post-distillation slurry using jar fermentor within 19 hours. All the vinegars showed radical-scavenging activity. The radical scavenging activity of the vinegar produced from sweet potato-shocchu post distillation slurry was higher than that of other two kinds of vinegar on the organic matter basis [53].

CONCLUSION

Since biblical times, vinegar has been used as a food preservative and has medicinal properties as shown above. Contained with the power of antimicrobial properties, antioxidant action along with cardio-protective effects, anti-hyperglycemic effects, etc. in appropriate proportions, vinegar can be utilized as an adjunctive therapy along with the primary treatment. Since vinegar is widely available and affordable, clinical trials must be started with various concentrations and dilutions of vinegar and /or acetic acid in order to validate its numerous medicinal uses.

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