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An Overview on Types, Production and Therapeutic Potential of Vinegar

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ABSTRACT

A well-known natural food item, vinegar is produced by fermenting meals high in carbohydrates with alcohol first, then with acetic acid. It consists of about 5-20 % of acetic acid, prepared by fermentation of alcohol with the help of *Acetobacter* species. Acetic acid (CH_3COOH) is present in water in a concentration of close to 5 % in vinegar. It is thought to be an excellent source of several bioactive substances, including as tryptophol, ligustrazine, organic acids, melanoidins and polyphenols. The array of mechanisations used in the manufacturing of vinegar includes the use of wooden carks, the traditional Orlean process, and the generator technique for submerged fermentation. These bioactive compounds in vinegar are thought to be the cause of its pharmacological and metabolic advantages. The primary ingredient in vinegar is acetic acid, which has a strong, sour flavour and aroma and is somewhat volatile. There are numerous varieties of vinegar available worldwide. There are several varieties of vinegar available around the world, including black, rice, grain, balsamic and fruit vinegar. Vinegar has traditionally been used in applications for food preservation. Furthermore, it is extensively utilised in the food sector as a spice and food preservative, as well as in the United States for pickling fruits and vegetables and as a component of condiments like mayonnaise and salad dressings. In the past, people have used vinegar as a medicine to treat oedema disorders, burns, wounds, and stomach aches. It is among the most well-known traditional remedies for treating infections. According to a number of studies, vinegar may help treat microbiological infections, cancer, diabetes, heart disease, and obesity.

Also, it is used to treat injuries and acts as an antioxidant as well. This review aims to highlight the health advantages of vinegar consumption for a person's physiological well-being.

Keywords: Preservative; Pharmacological; Antioxidant; Traditional

1. INTRODUCTION

A condiment known as vinegar is created when fruits such as grapes, apples, berries, pears, molasses, honey, and many other foods high in carbs undergo alcoholic fermentation followed by the acetification of glucose [1]. This is a two-stage bioprocess in which the yeast converts sugar to ethanol in the first phase, and then, under aerobic conditions, the ethanol is oxidised to produce acetic acid. In vinegar, sugar fermentation is initiated by yeast and later *acetobacter* converts alcohol into acetic acid. Vinegar has a long history of use as a treatment for ailments like fever, obesity, laryngitis, oedema and stomach aches [2]. In the food industry, vinegar is frequently used for pickling fruits and vegetables, in condiments like ketchup, mayonnaise and salad dressings, and has long been a staple seasoning and preservation component [3]. The Malaysian Food Act of 1983 states that vinegar cannot contain any mineral acids or acetic acid with a level lower than 4% (w/v). Additionally, just like in the Food Regulation of 1985, vinegar is permitted to contain permitted preservatives, with spices serving as the permitted flavouring and caramel serving as the permitted colouring. Different forms of vinegar are produced using various starting ingredients for the fermentation process; for example, rice vinegar is produced by acetous fermentation of sugars supplied from rice [4]. Fruit vinegar is made from fruits like grapes or apples, whereas grain vinegar is made from grains like wheat, sorghum or other types of grains. A variety of techniques and raw ingredients are used to make vinegar. Substrates include fruit musts, beer, barley, cider and wine (white, red, and fortified wine). Ancient methods of producing vinegar included surface culture and wood casks, as well as submerged fermentation in acetators. Whether used purposefully or produced naturally during fermentation, vinegar reduces microbial growth and enhances flavour in a range of dishes. Vinegar production has increased as a result of the vast variety of products that incorporate it (such as mayonnaise, sauces, ketchup etc.) and the current decline in wine consumption.

Early techniques for making vinegar included the Orleans process (also known as the slow process), the quick method (also known as the generator process), and the submerged culture process. Today's industrial manufacturing of vinegar uses the fast method and the submerged culture method[5]. In an incredibly lengthy four-step process, acetic acid is produced by turning starch into sugar using amylases, fermenting sugars into alcohol under anaerobic conditions using yeast, turning ethanol

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into hydrated ethanol, and dehydrating the ethanol to produce acetic acid using aldehyde dehydrogenase. The latter two stages were completed aerobically with the aid of microorganisms that generate acetic acid. From spoiled sugar, around 25% of the acetic acid is generated; the other sugar metabolites are either converted into other compounds or lost to volatilization. By aerating at high rates during continuous production, acid yield improvements can be made. When ethyl alcohol (C_2H_5OH) is oxidised, acetic acid (CH_3CO_2H) is produced. This ability sets apart members of the genus Acetobacter, sometimes referred to as vinegar bacteria or acetic acid bacteria; as shown below:

$$2C_2H_5OH \rightarrow 2CH_3CHO \rightarrow 2CH_3CO2H + 2H2O$$

2. BACKGROUND AND HISTORICAL ASPECTS OF VINEGAR

Vinegar is nearly 10,000 years old. Nevertheless, the use of flavoured vinegar was created, produced, and consumed more than 5,000 years ago. Vinegar is the oldest cooking ingredient in use today and also serves as a food preservation (class 1 preservative). There are different vinegar variations available today, but they are not brand-new. In the sixth and fifth centuries BC, the Babylonians produced vinegar with a variety of flavours (honey, rice, malt etc.). Colourless vinegar was declared to be a necessary component of distillation in 1100 by "Albucases." A scientist named "Basilius Venlentinus" claimed that a weak vinegar produces a powerful final quality in the fifteenth century. Gerber first proposed the hypothesis about how to increase wine vinegar productivity by using the distillation method between 1650 and 1700. The chemist named Stahl created the sour principle of vinegar made of acetic acid during the eighteenth century.

3. TYPES OF VINEGAR

Under the right conditions, vinegar can be produced from any aqueous media that has enough fermentable carbohydrates. The end product will be vinegar that satisfies the requirements for acetic acid content. As a result, various vegetables, fruits and animal products including whey and honey are employed as the primary raw materials in the creation of vinegar. There are various types of vinegar that can be made, depending on the basic ingredients utilised in the fermentation. Regional differences exist in the kind of materials used.

3.1 Apple Cider Vinegar

It is the most popular variety of vinegar consumed worldwide, not only in the United States. This vinegar, which has a small amount of tartaric acid and fruit flavour, is used in cooking[6]. It is frequently used to improve the flavour of real cooking ingredients like salad dressing, marinades, and sauces. *Acetobacter intermedius, Acetobacter aceti, Acetobacter pasteurianus, Gluconacetobacter Hansenii, Gluconacetobacter Europaeus, Gluconacetobacter xylinus* AAB bacterial species are used for production of apple cider vinegar.

3.2 Wine Vinegar

Germany first introduced wine vinegar, a type of vinegar. Most frequently, wine vinegar is used in Japan. White and red wine are combined to make it. Because it contains fresh berries, low-moisture herbs, and clean, raw hears, wine vinegar has more flavour than other types. Innovative chefs frequently add more flavour to wine vinegars by adding a few sprigs of fresh herbs, dried herbs, or fresh berries that have been thoroughly cleaned. With a subtle natural raspberry flavour, wine vinegar. The acetic acid bacteria (AAB) species *Acetobacter pasteurianus, Gluconacetobacter europaeus,* and *Gluconobacter oxydans* are employed in the manufacturing of vinegar [6].

3.3 Malt Vinegar

It is dark brown in colour and manufactured from malt. It is mostly made in England and has a deep-brown ale-like flavour. Malt vinegar manufacture typically begins with the germination of barley seeds, also known as sprouting. To activate enzymes that break down starch, a favourable environment is created during germination. *Acetobacter pomorum* is added during the production process as the sugar begins to degrade and eventually transform into brewing (product) with malt-occupied alcohol content[6].

3.4 Balsamic Vinegar

According to sensory characteristics, it has a dark look and smells salty and sweaty. White trebbiano grapes are used in the creation of balsamic vinegar, which is then aged in wooden barrels. Balsamic vinegar is the oldest type of vinegar and has been produced for close to a century. *Acetobacter intermedius, Gluconacetobacter xylinus* and *Gluconacetobacter hansenii* acetic acid bacteria (AAB) species are used in the manufacture [6].

3.5 Cane Vinegar

It also goes under the name "Kibizu." Fermented sugarcane is preferred for making cane vinegar because it has a mild, amusingly sweet flavour. The Philippines is most likely the region where this vinegar was used in cooking. *Gluconacetobacter entanii* AAB was employed in its manufacturing.

3.6 Coconut Vinegar

Since coconut is the primary ingredient, the acidity is minimal. It is renowned for its incredible aftertaste and has a musty flavour. Southern Asian nations are the world's top producers of coconut vinegar, which is used in the creation of "Thai cuis

3.7 Beer Vinegar

Beer is used as an alternative raw material to make vinegar. On a map of the world, the most productive countries are the United Kingdom, Austria, Germany and the Netherlands. The final sensory characteristics of vinegar are influenced by the quality of the beer and the raw material substitutes employed in the brewing process. Its flavour is malty. Similar types of fermentation processes are available for wine and beer vinegar to convert ethanol into acetic acid.

4. OVERVIEW OF VINEGAR PRODUCTION

Fruits such as apples, mangoes, plums, blackberries, and grapes can all be used to make vinegar. Apple vinegar is also known as cider. Mango vinegar is made by fermenting mango juice. Plum vinegar is made by fermenting palm juice. Blackberry vinegar is made by fermenting blackberry juice. Grape vinegar is made by fermenting red or white wine.

4.1 Microbes for Vinegar Production

Acetification and alcohol fermentation, which occur after the preparation of the feed stocks, are crucial steps in the manufacturing of vinegar[8]. Microorganisms used in the production of vinegar are discussed below:

4.1.1 Yeasts

Because of their effect on the rate of fermentation, wine flavour, and other aspects of wine, yeasts are beneficial microorganisms throughout the alcoholic fermentation process. In 2009, Raineri and Zambonelli published research on substrate sugar utilising yeast from the class *Saccharomycetes* that improved the fermentation of alcohol, turning sugar into ethanol. Monosaccharides including glucose, fructose, and mannose were the primary feed stocks used by yeast for metabolism through the Embden-Meyerhof-Parnas pathway, which converts pyruvate into glycolysis. The *Sacchromyces* genus is mostly used in the beverage industry because of its high capacity for fermenting sugar[9]. *Sacchromyces* have been shown in studies to be capable of converting sugarcane juice into ethanol while producing vinegar utilising wood shavings, bagasse, and corn cobs[10].

4.1.2 Acetic Acid Bacteria (AAB)

Acetic acid bacteria are gram-negative, ellipsoidal or cylindrical bacteria that can be seen under a microscope alone, in pairs, or in chains. They are the primary ingredient in the formation of vinegar. The bacteria are aerobic, and oxygen serves as their final electron acceptor. They can be found on substrates like fruit juice, urine, cider, beer, and vinegar. The acetic acid bacteria are present in the environment but are unable to grow because of anaerobic circumstances during the fermentation of alcohol. However, when the acetic acid bacteria come into contact with oxygen, they proliferate on surfaces, also investigated how acetic acid bacteria convert ethanol into acetic acid by acetous fermentation[11].

4.2 Conversion Process of Vinegar Production

The process of making vinegar involves oxidising alcohol in a sugar solution that also contains fruit juice, molasses, vegetables, and cereals. The two-stage process of fermentation consists of acetous and alcoholic fermentation. In three weeks, alcoholic fermentation quickly depletes the majority of the sugar. Yeasts turn fermentable carbohydrates into ethanol through the process of fermentation. In acetous fermentation, bacteria from the species *Acetobacter* oxidise ethanol to produce acetic acid. Alcoholic fermentation needs anaerobic circumstances, while acetous fermentation needs aerobic settings.

4.3 Techniques of Vinegar Production

Traditional methods such as the slow process used in oak barrels (Orleans process), the generator process, and submerged fermentation with immobilised cells are all used in the manufacturing of vinegar. Many technological tools are used in the industrial manufacture of vinegar to accelerate the conversion of ethanol to acetic acid when *acetobacter* acetic acid bacteria are present[12].

4.3.1 Orleans Method

The Orleans technique, the oldest and most widely used method for producing vinegar, was developed in France in 1670. It is a gradual process where the starter culture is high-grade vinegar, and wine is added to this weekly. Large oak barrels with a capacity of 200 litres and holes above a few inches at the end of the barrels are used to ferment the vinegar. Fresh vinegar added to barrels at a typical rate of 20 to 25 % promoted the best bacterial growth and this promote the bacteria to settle in the liquid and produced a gelatinous slime layer[13]. The delayed vinegar production procedure (Orleans method) resulted in the development of flavour and smell. It was discovered that this processing procedure makes vinegar persistently available[14]. The Orleans approach relies on acetobacter contained in the raw material and uses seed culture from a previous production batch.

4.3.2 Generator Technique

The Generator processes, sometimes known as “trickling” or “German” processes, were first used in Germany in 1832 by German chemist Schutzenbach. They have a nearly 200-year history. It is also referred to as a quick procedure since it speeds up the acetification surface during the quick process of making vinegar using wood shavings. This method makes use of a generator, a cylindrical tank filled with wood shavings, charcoal, or coke, as well as equipment that increases airflow from the bottom to the top and allows alcohol to trickle down. Microbes are immobilised on the wood shavings during this surface-level process. By conducting the procedure at 27–30^0 Celsius, overheating can be avoided.

4.3.3 Submerged Fermentation Technique

This method, which was first used to produce vinegar in 1952, is the most widely used production method in which there is an improvement of fermentation parameters like aeration, stirring, heating etc, used on an industrial scale. The fermenter is equipped with a heat exchanger in this approach, and the mash is regularly aerated and stirred to keep the fermentation process at its ideal temperature. The Frings acetator, which was invented at the beginning of 1950, was the first submerged type bioreactor. It was later superseded by other patented techniques such as cavitation and bubble column fermenters. The main components of this method are a fermentation tank made of stainless steel, a cooling system, a foam controller, loading and unloading valves, and an air supply system. It includes batch, semi-continuous, and continuous methods. The batch technique is a three-step process that involves loading raw materials, inoculating the fermentation medium, and finally discharging the medium. Semicontinous follows, which is identical to batch but where the final product is unloaded, and the leftovers are left in the vessel to be used for inoculation in the subsequent cycle. The continuous technique keeps the volume of the fermenting medium in the bioreactor constant by continuously adding substrate and continuously unloading a tiny aliquot of the biotransformed product over time. The period of exponential growth is the most crucial for maintaining bacterial cultures because it is at this stage that nutrients and oxygen are supplied to ensure the survival of the bacteria. An effective and quick aeration method is provided by submerged fermentation. Aeration systems can easily deliver oxygen from the medium to bacteria and can easily break up air bubbles, hence they are a crucial step in preventing *Acetobacter* cell death.

5. BENEFITS OF VINEGAR

5.1 Vinegar and Injuries

Damage or physical loss to the body brought on by an assault or accident are considered injuries. According to Hippocrates, vinegar was once used to cure wounds. Due to its anti-bacterial qualities, the mother of vinegar has been investigated for its ability to cure burns [15]. According to one study, 3.75 % of apple cider vinegar reduced bacteria load as effectively as cefotaxime (an antibiotic). However, compared to taking them separately, combining a combination of equal parts cefotaxime and apple cider vinegar led to better and faster recovery. According to a different study, acetic acid solutions nontoxic to keratinocytes and fibroblasts at concentrations of 0.0025 % did not inhibit the growth of group D *Enterococcus, Escherichia coli*, or *Bacteroides fragilis* bacteria, but they did inhibit the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus***.** Since the time of Ancient Greece, vinegar has been widely employed as an antifungal and antibacterial agent due to its extraordinarily low pH, which is brought on by the presence of acetic acid as a primary component. Reduced muscular injury caused by inflammation during intentional activity was achieved by taking acetic acid bacteria orally.

5.2 Antimicrobial Activity

Because more bacteria are displaying antibiotic resistance, this is the reason it is considered as an issue on a global scale. Sepsis is caused by several microbial infections and causes organ failure and systemic inflammation. Apple cider vinegar is marketed as a supplement for promoting weight reduction, providing nutritional support, and decreasing blood pressure. It is made via acetous bioconversion and has a low acidic content that contains polyphenols, vitamins, flavonoids, and minerals. According to Yagnik, apple cider vinegar has antibacterial properties that are effective against *E. coli, S. aureus,* and *C. albicans*.

5.3 Antioxidant

Bioactive substances alter physiological or cellular processes, enhancing health. Bioactive substances foster more positive health effects as compared to minerals and nutritional supplements. According to certain theories, bioactive substances can reduce the likelihood of developing an illness rather than treat it. Additionally, polyphenolic chemicals are highly sought-after as quality indicators since, in addition to their antioxidant activity, they also determine the colour and astringency of vinegar. The modification of proteins, lipids, and DNA by various reactive oxidants, including hydrogen peroxide, superoxide, and the hydroxyl radical, has been linked to effects on cancer, ageing, and brain-related disorders. According to recent studies, bioactive food ingredients may reduce the risk of several degenerative diseases through their antioxidant effects. Having a high content of phenolic compounds "Kurosu", a Japanese rice vinegar, indicates that it is a potent source of antioxidant activity. It was discovered that the amount of phenolic and total anti-oxidant activity in apple cider vinegar created using the surface approach was higher, whereas the amount of phenolic and total anti-oxidant activity in vinegar made using the submersion method was lower[16]. The specific type of yeast strain utilised to make persimmon vinegar accounts for its increased antioxidant activity compared to the red and white wine vinegar. Persimmon vinegar has a higher antioxidant effect than either of the wine vinegar[17].

5.4 Antitumor Activity

Traditional Japanese rice vinegar known as "kurosu" is thought to be one of the most significant sources of phenolic chemicals for lowering the risk of cancer. It has been investigated how "Kurosu" vinegar affects the growth of various human neoplastic cell lines. Lung carcinoma, breast adenocarcinoma, bladder carcinoma, colon adenocarcinoma and prostate carcinoma cells were among the cancer cell lines. "Kurosu" was found to suppress all evaluated cell lines' proliferative processes in a dose-dependent way. "Kibizu" is a Japanese product made from sugarcane vinegar. "Kibizu's" powerful radical scavenging activity prevented the growth of cells that typically cause malignant neoplastic diseases in humans. Consuming vinegar had a preventive effect and reduced the incidence of oesophageal cancer.

5.5 Antibacterial and Anti-Infection

Before Pasteur and Koch's research on bacteria in the nineteenth century, vinegar was frequently used in antibacterial and anti-infection applications. Hippocrates, a physician in ancient Greece, employed fruit vinegar to treat illnesses, coughs, and inflammations around 400 BC[17]. The Ming dynasty (16th century)-written Chinese medical text "Compendium of Materia Medica" contains documentation on the usage of grain vinegar for a variety of purposes, including the treatment of Ascaris infections, sterilisation of labour rooms, and the preservation of meat. According to current scientific studies, fruit vinegar with 0.1% acetic acid effectively prevent the growth of food-borne pathogens in vitro, including those caused by *Salmonella enteritidis, Escherichia coli O157:H7, Staphylococcus aureus, S. typhimurium, Aeromonas hydrophila, Vibrio parahaemolyticus and Bacillus cereus*. In addition, harmful bacteria were efficiently eliminated from vegetables by soaking them in either fruit or grain vinegar for a brief period time. While apple vinegar significantly reduces the growth of harmful bacteria like *Proteus mirabilis, Staphylococcus epidermidis, Pseudomonas aeruginosa and Klebsiella pneumonia* whereas grain vinegar are more effective at eliminating respiratory pathogens like *Micrococcus catarrhalis, Staphylococcus albus, Diplococcus pneumonia, and Alpha streptococcus*[18].

6. THERAPEUTIC PROPERTIES OF VINEGAR

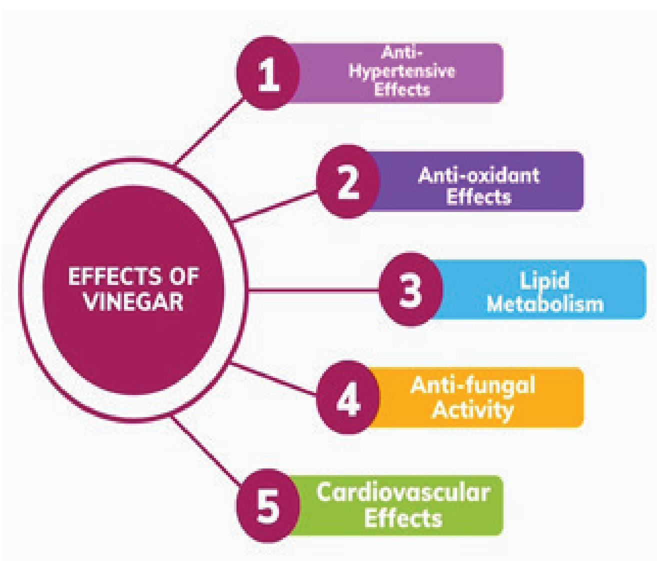

Figure 1. Effects of Vinegar

6.1 Vinegar and Cardiovascular Health

It is known that cardiovascular diseases (CVDs) are a key factor in population mortality. Significant CVD risk factors include smoking, high blood pressure, inactivity, and cholesterol[19]. Clinical evidence has been found in numerous earlier research demonstrating the ability of foods high in polyphenols, such as vinegar, to lower mortality and improve protection against CVDs. Low-density lipoproteins (LDL) that have undergone oxidation in the bloodstream have a strong correlation with coronary illnesses. Consuming natural antioxidants like polyphenols will lower blood levels of LDL cholesterol as demonstrated[20]; similarly, vinegar contains higher concentrations of polyphenols such as chlorogenic acid, which prevents the oxidation of LDL cholesterol and reduces the risk of CVDs. Foods containing acetic acid, such as vinegar, help to maintain not just the level of LDL cholesterol but also the levels of triglycerides (TG), total cholesterol (TC) and high-density lipoproteins (HDL). The long-term ingestion of acetic acid in food has been associated with a significant drop in TC, TG, and LDL cholesterol as well as an increase in HDL cholesterol.

6.2 Anticancer Effect of Vinegar

Vinegar's anticancer properties are linked to its polyphenol concentration, particularly with polyphenols like resveratrol [21]. According to the researchers, resveratrol is a dietary polyphenol that prevents cancer cells from proliferating and interferes with all three stages of carcinogenesis. Weak acids, like acetic acid, have been demonstrated to have an anticancer effect [22]. There are few epidemiological studies on the anticancer properties of vinegar. However, research is being done to determine its anticancer components. Colonic experiments on people, acetate treatments significantly reduced tumour development and metastasis[23]. Acetate and polyphenols, which are abundant in vinegar, strengthen antioxidant defence and reduce the risk of cancer.

Kandylis,[24] *et al.* investigated how grain vinegar affected oesophageal cancer, and they found a negative correlation between the outcomes. Cell-based studies also demonstrated that vinegar's acetate can stop colon cancer cells from proliferating. Additionally, consuming vinegar in your diet lowers the incidence of the risk of oesophageal cancer compared to eating pickled or salted veggies[25]. A blood malignancy called leukaemia causes the body's white blood cells to grow abnormally quickly. Studies have demonstrated that vinegar encourages the death of human leukaemia cells, which lowers the incidence of leukaemia[26]. According to claims made by the Vinegar Institute in 2005, inhibiting glycolysis starves cancer cells already present in the body, slows the growth of new cancer cells, and slows the course of cancer. The protection offered by the antioxidant properties of polyphenols and acetate's role in regulating cancer cell proliferation, and cancer cell death is recognised as the known factors influencing the anticancer effect of vinegar in humans.

6.3 Control of Blood Glucose Level

Consuming vinegar can affect the blood sugar level in the blood. Type 2 diabetes patients can significantly improve their glycemic control by consuming vinegar[27]. According to the American Diabetic Association in 2010, diabetes mellitus is a chronic metabolic illness brought on by the body's failure to manufacture insulin efficiently or the pancreas' inability to maintain an adequate level of insulin for metabolic activity. Diabetes is characterised by elevated level of blood glucose, also called blood sugar is too high, according to the World Health Organization. The most common sign of early-stage diabetes mellitus is postprandial hyperglycemia[28]. The acetate in the vinegar helps blood glucose be converted into glycogen, which lowers fasting blood glucose levels[29]. Furthermore, it has been demonstrated that consuming one tablespoon of vinegar at dinner, twice a day, can lower a person's fasting blood glucose level to a level comparable to that attained by frequent administration of diabetic medications. Ebihara and Nakajima (1988) found that pairing a starchy dinner with a 2% acetic acid dose significantly lowers postprandial blood glucose levels. Additionally, consuming vinegar improves type 2 diabetes patients' insulin sensitivity. Consuming vinegar after a high-glycemic meal has been shown to reduce postprandial glucose levels and insulin responses[30]. As part of the digestion of carbohydrates, disaccharide breakdown takes place in the small intestine. Acetic acid in vinegar, which is regulated by low blood glucose levels, inhibits this process[31]. Additionally, research on the hypoglycaemic effects of vinegar has revealed that its capacity to inhibit the digestive amylase, which is necessary for carbohydrate breakdown in the small intestine, is what causes the vinegar to lower blood glucose levels.

6.4 Control of Obesity

The incidence of obesity has rapidly increased globally over the past few years, and it is a risk factor for many lifestyle-related disorders. Obesity is created by a long-term imbalance in calorie intake[32]. Numerous studies have shown that vinegar can help people manage their weight and combat obesity. Taking vinegar orally for one to six months can lower type 2 diabetes which is associated with obesity[33]. A study on 155 obese Japanese patients indicated that vinegar drinking for 12 weeks had a favourable impact on body fat, waist circumference, weight and body mass index reduction (BMI) demonstrated by[34]. Additionally, they demonstrated that ongoing vinegar administration is essential for helping persons with disorders associated with obesity lose weight. Additionally, they stated that lipogenesis was a key factor in the basic process underlying vinegar's ability to reduce body weight. It is based on how vinegar inhibits the activation of many lipogenic genes, which are in charge of turning glucose into fatty acids in the liver. Additionally, consuming vinegar can lower the glycaemic index by enhancing satiety, which will result in less food and fewer calories being consumed[35].

6.5 Vinegar and Gut Health

Many digestive tract issues can be helped by vinegar, especially apple cider vinegar, which helps gut health. It is generally known that vinegar's acetic acid inhibits the growth of dangerous bacteria in the stomach while enhancing the number of helpful bacteria there. Additionally, it reduces inflammation by offering treatment for a variety of digestive issues. Vinegar helps with constipation-related issues. In the clinical investigation, vinegar is known to be a successful medication for easing constipation in fat people[36]. Additionally, white vinegar has been discovered to be a constipation remedy that may be taken orally. Black bean vinegar has been demonstrated to be an effective treatment for constipation in a related study as demonstrated by Perumpuli, *et al.*[37]. The illness known as "inflammatory bowel disease" (IBD) is brought on by intestinal inflammation. IBD patients experience chronic digestive tract lining inflammation that results in ulcers, aches, and diarrhoea. Vinegar is well known for preventing bodily inflammations[38]. Vinegar's acetic acid concentration is primarily responsible for its anti-inflammatory effects. Serum acetate levels increase above normal levels shortly after consuming vinegar because the body absorbs this acetate. The upper digestive tracts jejunum and stomach instantly absorb acetate, which is then immediately circulated throughout the body. Treatments with 5% (v/v) of vinegar or 0.3% (w/v) of acetic acid significantly reduce IBD episodes, and a related study recommends vinegar supplementation as a novel and effective dietary strategy for the management of IBD[39].

6.6 Vinegar and Renal Health

Renal issues have been treated with vinegar as a medicinal agent for centuries. One of the most typical conditions affecting the kidneys is nephrolithiasis, which is brought on by the deposit of calcium-based minerals in the kidneys. This disease condition is known to cause severe suffering in people of all ages throughout the world[40]. Various clinical studies have suggested treatments for renal issues. Numerous studies have shown that acetate-based therapies can significantly lower the prevalence of kidney disorders. According to a 2019 epidemiological study vinegar, which has acetate as its main bioactive ingredient, can prevent kidney stones from forming by encouraging the body to expel calcium from the urine and acids that cause kidney stones[41].

7. TOXICOLOGICAL STUDIES ON VINEGAR CONSUMPTION

Since vinegar is a well-known food item that is frequently used in cooking, it is automatically regarded as a product that is safe to consume by humans and has a low level of toxicity. Consuming too much vinegar, however, may have adverse effects on one's health, particularly on the enamel of the teeth and the gastrointestinal tract. Major effects of excessive vinegar consumption include tooth erosion[43]. The pH of vinegar is less than 3.0, making it an acidic condiment. Naturally, high-acidity chemicals can cause dental erosion or dissolution, resulting in the irreversible loss of tooth enamel and dentin. Many people use vinegar as a treatment to lower blood sugar after meals and to reduce visceral fat. However, the outcomes

Table 1. Health benefits of different vinegar types[42]

Types of vinegar	Effects
Persimmon vinegar	• Effective in reducing obesity • Decrease the mRNA level of acetyl-CoA carboxylase (ACC) • Decrease the levels of total cholesterol (TC) and hepatic triglycerides (TG)
Tomato vinegar	• Suitable for usage as an antidiabetic and anti-obesity medication • Decreased the weight of visceral and body fat • Lower plasma LDL-cholesterol level and elevate HDL-cholesterol • Reduced levels of triglycerides, hepatic triglycerides, and plasma free fatty acids • Boost carnitine palmitoyltransferase activity and fatty acid beta-oxidation • Decrease glucose-6-phosphatase activity and increase glucokinase activity
Pomegranate vinegar	• Attenuate adiposity through AMPK regulation • Reduce the levels of peroxisome proliferator-activated receptor (PPAR) and sterol regulatory element binding protein-1c (SREBP-1c) • Elevate AMP-activated protein kinase (AMPK) phosphorylation
Ginseng radix vinegar	• Improve lipid and glucose metabolism to reduce obesity and diabetes. • Inhibit weight gain • Reduce insulin resistance by 90% • Reduce levels of postprandial and fasting glucose
Kurosu vinegar	• Have the ability to combat nearly human cancer cells • Enhance programmed necrosis
Nypa palm vinegar	• As it has an antihyperglycemic action similar to metformin, it is recommended for patients with type 2 diabetes • Significant improvement of up to 80% in serum insulin levels • Its aqueous extract significantly reduced blood glucose levels

of a study carried out with a group of individuals taking vinegar as medicine regularly (3.6 g of acetic acid together with vinegar) revealed that the frequent intake of vinegar had a detrimental effect on oral health [44]. Contrarily, the study explained that using vinegar in its diluted form instead of its concentrated version for medical purposes might prevent tooth erosion. Additionally, research showed vinegar to be a significant risk factor for kids by encouraging tooth erosion. To prevent the harm that vinegar can do to oral health, it should only be consumed in moderation, whether as a beverage or in value-added items like fruit vinegar, salad dressings and pickles [45]. The digestive system may also be impacted by excessive vinegar use. The most frequent effects of consuming too much acetic acid in the digestive system are oesophageal injuries. Table vinegar typically contains 4 to 8% (w/v) acetate, but pickling vinegar can have up to 18% (w/v) acetate. Since it can seriously harm the oesophagus, acetic acid concentrations of more than 20% are regarded as harmful. Acetic acid has an immediately hazardous to life or health (IDLH) concentration of 50 ppm, based on acute inhalation toxicity, according to the Centre for Disease Control and Prevention (CDC)[46].

8. CONCLUSION

Vinegar is produced on a global scale using a variety of raw materials, bacterial species, and mechanised manufacturing methods. Acetic acid, a possible component of vinegar, has both food preservation and class-one preservative properties. Because of different useful parameters of vinegar, it has a long history. Consuming vinegar, which has several bioactive componentslike polyphenols and flavonoids, can improve one's health. It plays a crucial role in the food industry as a food preservative. It has therapeutic qualities as well as being used as a flavouring agent, pickling, and drink. Vinegar can be made using a variety of techniques, including the Orleans process, the generator method, and submerged fermentation. It has therapeutic and functional potential including anti-cancer, anti-glycemic, anti-cardiovascular, antioxidant, and antibacterial properties. Although vinegar is palatable and interesting as a healthy food, future research needs to more clearly define vinegar's significance for improving health. To use vinegar as a useful and secure ingredient in the food and health industries, further study on the health advantages of vinegar consumption must be done because there are numerous unidentified therapeutic and epidemiological impacts of vinegar on human health.

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