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* **Corresponding author**.
deevenajemima@gmail.com

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A Short Review on Pineapple (*Ananas comosus*) Vinegar: A Functional Therapeutic and Natural Preservative

Deevena Jemima[1]*, Sheila John[1], Sarah Jane Monica[2]

1 Department of Home Science, Women's Christian College (Autonomous), Chennai, Tamil Nadu, India
2 Department of Food Science, M.O.P. Vaishnav College for Women (Autonomous), Chennai, Tamil Nadu, India

Abstract

Background: Pineapple vinegar that is often prepared from the by-products of fruit processing, shows promising health and preservative benefits in many areas. **Objectives:** This review focuses on compiling and analyzing the production and standardization methods of pineapple vinegar. It seeks to assess its therapeutic value including, induction of apoptosis in cancer cell lines, inhibiting metastasis, restoring liver antioxidants, and modifying the gut microbiome. **Methods:** This study covers a literature review across scientific databases for *in-vitro* and *in-vivo* studies that were conducted on Pineapple vinegar's beneficial properties using PRISMA guidelines. **Findings:** Fermentation time, differences in the microorganisms used for fermentation, combination of ingredients used as a substrate, variability in bioactive compounds and volatile profiles affect the final vinegar. The most common starter used was *Acetobacter sp*. Nutrient analysis showed the presence of essential amino acids, B vitamins, Vitamin C, and antioxidants. DPPH, FRAP, SOD, TEAC and NO assays showed increased percentage of antioxidant activity. Pineapple vinegar reduced liver injury and lipid peroxidation while restoring antioxidant defenses (glutathione and superoxide dismutase). It suppressed inflammatory mediators (iNOS, NF-κB) and brought down cytochrome P450 2E1 protein expression. Reduction in blood glucose and improvement in gonadosomatic index was found. Antimicrobial activity was observed against *Escherichia coli, Staphylococcus aureus, Bacillus sp, Candida sp, Salmonella typhi,* and *Klebsiella sp*. Usage of pineapple vinegar in food kept vegetable pickles fresh, prevented spoilage in fish, and improved the tenderness of meat. **Novelty:** This review comprehensively extracts evidence on the therapeutic properties of pineapple vinegar from recent peer-reviewed studies, addressing a gap in the literature. Its novelty is in the rigorous critical appraisal of the study quality along with a comparative analysis of various fermentation methods. By focusing on these gaps, this work provides a clearer direction for further research to unlock the therapeutic potential of pineapple vinegar.

Keywords: Pineapple vinegar; fermentation; bioactive compounds; therapeutic benefits; functional food

1 Introduction

Vinegar is an important ingredient that has been traditionally used as a condiment, preservative, and a medical remedy. Ancient texts such as those found in Unani, speak of the diffusible, resolvent and astringent properties of vinegar *(sirka)*[1]. Other studies show the usage of infused vinegar in Babylon, application in wound care and disinfection in China, and as a remedy for dropsy, croup and fevers in early America[2]. Although vinegar has taken many forms across various cultures and time-periods, its basic nature remains the same, that is, it is a water-based solution of acetic acid that is formed when ethanol undergoes oxidation during fermentation, rather than being produced through direct chemical synthesis. Vinegar has been produced from a variety of ingredients such as cereals, vegetables, fruits, honey, and whey. In recent years, in contrast to cereal vinegars or synthetic vinegars, fruit vinegars have gained attention as healthy beverages due to the presence of multiple bioactive compounds. These include gallic acid, chlorogenic acid, vanillic acid, caffeic acid, rutin, quercetin, ferulic acid, quinic acid, apigenin, Kaempferol, benzoic acid, narirutin and naringin. The presence of these bioactive substances, as evidenced by recent literature, are the reason for several benefits including antimicrobial, antioxidant, anti-inflammatory, and metabolic regulatory effects. This also supports the fact that while modern drug research emphasizes isolating a single compound in the production of medicine, there is growing evidence that the combined action of multiple compounds working together shows better results[3].

Vinegar also features prominently in the historical texts of many countries, spanning ancient to medieval times, for medicinal uses such as wound cleaning, cough relief, digestive issues, detoxification, and prevention of infection. Vinegar has also been found to be paired with honey to form a substance called *oxymel* that was used to create ointments, plasters, disinfecting solution and bandages. The vinegars were mostly derived from fermented grapes and other fruits such as figs and dates, that were commonly available during those times[4]. In comparison, the most used vinegars today seem to be apple cider vinegar, followed by balsamic vinegar. There are a few evidence-based examples of the effect of fruit vinegar on health, published from 2019. Orange vinegar was found to suppress RAGE and NADPH activity, while reducing the inflammatory markers in Caco 2 cells[5]. Date fruit vinegar showed good antioxidant and anti-hypertensive properties[6], while wolfberry vinegar treatment demonstrated protective effect on the liver[7].

As vinegar is expected to be a low-cost commodity, it is made using inexpensive raw ingredients. This brings the focus on the usage of fruit peels for vinegar production. Fruit and vegetable byproducts are usually discarded as waste; therefore, valorising peels offers a cost-effective strategy to reduce nutritional losses and address sustainability goals. One of the fruits that produces a large number of byproducts after processing is pineapple. The peels, core, crown, and pomace of pineapple, constituting nearly 60% of the whole fruit, are typically discarded. These by-products are being extensively studied for their potential applications in various added processes to minimize wastage, for their use as growth media for probiotic bacteria[8], pectin recovery[9], enzyme extraction, and production of biofuels[10]. However, the studies undertaken to analyse pineapple vinegar are few. A title search of "pineapple vinegar" produced only 42 results in Google scholar compared to "apple vinegar" that gave 467 results. Despite a growing interest in natural and fruit-based vinegars, the therapeutic benefits of pineapple vinegar remain largely unexplored. No comprehensive reviews exist specifically for pineapple vinegar. The existing literature consists of primary research articles, broader pineapple waste reviews, and some mentions of pineapple vinegar in general vinegar reviews. Some articles published before 2019, provide some baseline data on the phenolic content but no systematic review. These studies have focused more on waste valorization and production quality as compared to health outcomes. We therefore wished to conduct this review to bring together the documented therapeutic benefits of pineapple vinegar and test the hypothesis that, pineapple vinegar exhibits medicinal potential by regulating metabolic stress pathways and supporting its use as a functional ingredient and a natural remedy. This review also integrates the medicinal and preservative functions of pineapple vinegar with recent advances in fermentation monitoring and optimization of substrates. This provides a comprehensive understanding beyond previous studies.

2 Review Methodology

The search for articles assessing the therapeutic and preservative nature of pineapple vinegar was conducted between 10-15 November using Google Scholar, Web of Science, EBSCOhost, and PubMed databases. Search terms such as ("Pineapple Vinegar" AND "Antioxidant "OR "Anticancer" OR "Antimicrobial" OR "Antiobesity" OR "Anti-inflammatory" OR "Preservation" were used to search for relevant documents. The studies were searched for and analysed using PRISMA guidelines (Figure 1). The inclusion criteria were studies that focused on pineapple vinegar and their therapeutic characteristics, studies that used pineapple vinegar as a preservative and articles that analysed the production and fermentation conditions of pineapple vinegar. The exclusion criteria included articles that did not give clear results, articles published before 2019 and articles published in other languages that did not have an English translation.

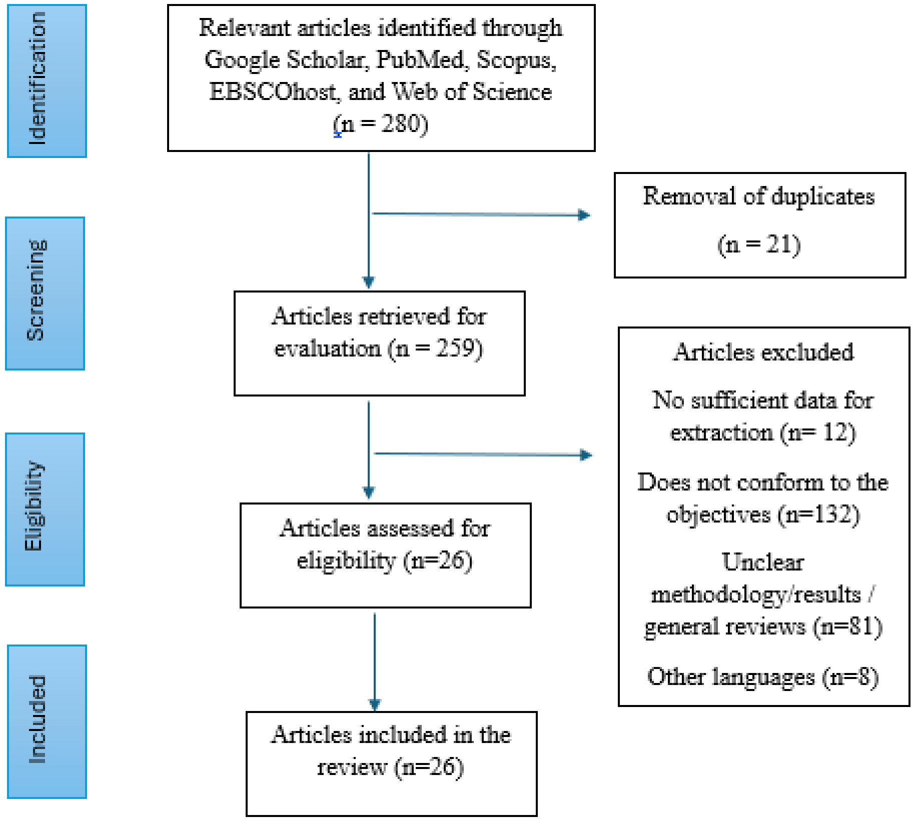

Fig 1. PRISMA flowchart of search strategy

3 Overview

We conducted a systematic review in November 2025 to search for papers that included the production methods and optimization methods of pineapple vinegar, including the ones where sensory analysis was conducted, *in*-vitro and *in*-vivo studies where pineapple vinegar was used to assess its efficacy for antioxidant activity and against disease conditions. We also searched for papers including its microbial flora, its action against pathogens and its preservative quality. As of this date, there are no available reviews compiling the quantitative evidence of pineapple vinegar. Full text articles were identified using the flowchart given as shown in Figure 1. Pineapple vinegar has been observed to be produced using the whole fruit or with only the peels and pomace of the fruit. Though wild fermentation of the fruit can be used to produce vinegar, literature shows that the usage of optimized microbial strains can produce far more desirable products. The commonly used organisms for this purpose are *Acetobacter sp.*

3.1 Production and Optimization

Fermentation time, differences in the strains used for fermentation, variety of fruit used as a substrate, variability in bioactive compounds and volatile profiles affect the final vinegar (Table 1). Pineapple vinegar that was produced in a self-priming fermenter to examine how flavour relates to metabolic changes during industrial processing, showed that the most notable changes occurred in the first 4 days, when ethanol-derived floral notes declined and were replaced by fruity aromas from acetic acid and ethyl-2-methylbutanoate. Bitterness decreased, while acidity and astringency increased due to shifts in amino and organic acids. The vinegar's scent is shaped by the presence of higher alcohols, aldehydes, and ketones, which are typical fermentation by-products that add fruity, floral, or sharp notes. Pineapple waste that was fermented into wine and then

Table 1. Production details of Pineapple Vinegar from existing literature

Reference	Substrate used	Starter organisms	Time of fermentation	Acetic acid %
(11)	Pineapple peel	*Acetobacter pasteurianus* FPB2-3	16 days	7.2%
(12)	Pineapple Peel	*Propionic bacterium acidipropionici, Panteo agglomerans, Pantea dispersa*	21 days	6.15%
(13)	Pineapple fruitlets	*Saccharomyces cerevisiae* TISTR 5019 *Acetobacter pasteurianus* TISTR 102	48 days	7.84%
(14)	Pineapple pulp and peel, Red Jambo leaf extract	*Saccharomyces cerevisiae f. r. bayanus,* Wild culture of acetic acid bacteria	144 hours	7.06%

continued to produce vinegar by inoculating with *Acetobacter aceti* showed that vinegar contained higher amounts of L-lysine (amino acid), mullein (microbial metabolite) and gallic acid (Phenolic antioxidant). Similarly, another study using *Saccharomyces cerevisiae* and *A. pasteurianus* to produce pineapple vinegar, also identified amino acids and organic acids as the primary non-volatile compounds [15]. Acetic acid is the primary acid in vinegar. Pineapple vinegar that was produced after 20 days of fermentation showed an acidity of 7.35%, while fermentation with *Propionibacterium acidipropionici* strain, produced 6.15 g/L after 72 hours of fermentation. Thermotolerant *A. pasteurianus* FPB2-3 also allowed for an efficient vinegar production from pineapple waste, yielding high acetic acid, improved antioxidant activity, and distinctive volatile profiles. Other organisms of similar characteristics can also be used to produce pineapple vinegar to see the best yielding strain.

While microbial strains and fermentation methods enable scalable production of pineapple vinegar, their impact on final nutrient profiles such as phenolics, flavonoids and organic acid remain underexplored. Variability in optimization parameters such as the type of substrate (pulp or peel) and aeration directly influence these nutrients and therefore may change the therapeutic properties evaluated next.

3.2 Nutrient Analysis

Nutrient analysis, as shown in Table 2, indicates the presence of vitamin B_1, folate, vitamin C, essential amino acids, dietary fiber, sodium, with higher calorie and sodium content than standard vinegar. Fermentation with *Acetobacter aceti* produced pineapple vinegar was found to be rich in acetic acid and diverse amino acids. The predominance of sweet and umami amino acids, alongside dynamic polyphenol changes, highlights its nutritional and functional potential. The phenolic content of the phulae pineapple vinegar was found to be 30.20 mg (gallic acid equivalents) GAE/100mL, whereas the phenolic content of a pineapple vinegar combined with agave was found to be between 359-417 mg GAE/L, showing a difference between plain and combined vinegars. Fermented pineapple juice also supported strong probiotic growth, maintained stability during storage, and showed promise as a functional probiotic drink [16]. Vinegar made from pineapple showed the highest phenolic acid content and strongest antioxidant activity compared to coconut and nipah vinegars. These strengthen the fact that fermentation preserves bioactive components despite some losses.

3.3 Antioxidant, anti-inflammatory and hepatoprotective activity

The nutrient composition of pineapple vinegar, provides the foundation for its potent antioxidant capacity. We found that pineapple vinegar exhibits a strong antioxidant activity due to the variety and amount of phenolics such as catechin, epicatechin, caffeic, p-coumaric, ferulic, and gallic acids. Antioxidant assays such as DPPH (2,2-diphenyl-1-picrylhydrazyl), FRAP (Ferric reducing antioxidant power), SOD (Superoxide dismutase), TEAC (Trolox equivalent antioxidant capacity), NO (Nitric oxide) and MDA (Malondialdehyde) have been used in these studies to analyse the antioxidant capacity of pineapple vinegar. DPPH assay of pineapple vinegar showed an increase in antioxidant activity from 143.79 ± 0.43 μg TE/g at the first day to 189.52 ± 1.53 μg TE/g at the 20^{th} day. Compared to commercially available pineapple vinegar, fermented pineapple vinegar had better antioxidant activity [18]. Other fruit vinegars such as blackened pear vinegar also showed a continual increase in total phenolic content and total flavonoid content during fermentation [19].

Some studies showed that the antioxidant content improved when pineapple vinegar was produced in combination with other ingredients. The peel vinegars enriched with *Syzygium malaccense* (red-jambo) leaf extract, enhanced their phenolic content and antioxidant activity, contained notable compounds such as catechin, epicatechin, caffeic, p-coumaric, ferulic, and gallic acids, with enrichment raising polyphenol levels to 337.3–443.6 mg GAE/L. A blended vinegar of Agave sap with pineapple juice yielded a high acetic acid (5.50 ± 0.09%), phenolic content (359.12 ± 6.31 mg GAE/L), and antioxidant activity

Table 2. Nutritional composition of Pineapple vinegar [17]

Nutrient	Quantity per 100mL
Total carbohydrates	3.51g
Protein	Trace amounts
Fat	Trace amounts
Acetic acid	4-6.5%
Phenolic compounds	Significant levels (vary by time of fermentation)
Flavonoids	Significant levels
Vitamin C	4.2 mg
Thiamine	0.0098 mg
Folic acid	1.1 mcg
Sodium	25.5 mg (higher compared to commercial vinegar)
Potassium	5.6 mg
Magnesium	Trace amounts
Copper	Trace amounts
Selenium	Trace Amounts
Dietary fiber	0.98g (Peel residue)
Bromelain (Proteolytic enzyme)	1.9 mg

(176.21 ± 1.19 μg TE/g). Supplementation of sugar to pineapple waste vinegar also affected the acetic acid production and antioxidant activity. A 2% sugar addition was very efficient and provided a strong antioxidant potential with 51.46% free radical inhibition [20]. This antioxidant potential is due to the presence of phenolic compounds (169.67 ± 0.05 μg GAE/mL), with gallic acid as the dominant phenolic compound.

Beyond direct radical scavenging, several fruit vinegars such as pomegranate, *Hovenia dulcis* and apple vinegars have shown hepatoprotective activity. While pomegranate vinegar has very good effect in regulating lipid metabolism, pineapple vinegar was found to reduce necrosis and reduce inflammation. This highlights how fermentation derived metabolites protect against chronic inflammation and liver damage. In mice that were treated with paracetamol, pineapple vinegar at 2 mL/kg body weight significantly lessened liver injury biomarkers after seven days. Also, antioxidant defenses such as glutathione, superoxide dismutase, and ferric-reducing ability were restored, while lipid peroxidation and nitric oxide levels declined. The treatment also suppressed inflammatory mediators (iNOS, NF-κB) and reduced cytochrome P450 2E1 protein expression, demonstrating strong hepatoprotective and anti-inflammatory effects [21]. Toxicity tests reported no harmful effects or mortality, with biochemical profiles were similar to controls. In sub-chronic studies, antioxidant levels in the liver were improved most by pineapple vinegar, while coconut vinegar promoted stronger immune responses by increasing CD4+ and CD8+ T-lymphocytes along with higher IL-2 and IFN-γ cytokines [22]. Pineapple vinegar displayed bioactivities comparable to apple cider vinegar and stronger than pineapple juice, particularly in inhibiting metabolic enzymes linked to diabetes and cholesterol. Though observational data on vinegar exists for metabolic syndrome, effect of pineapple vinegar on liver specific conditions remain untested. Till date, only certain vinegars such as wolfberry vinegar, pomegranate, prickly pear, apple, mulberry, Shanxi, and *Rosa roxburghii* have been tested on animal models and have been found to have a positive result.

3.4 Antimicrobial activity

The same polyphenolic and acidic profile of pineapple vinegar also has been observed to have a broad-spectrum antimicrobial efficacy against known pathogens. We found studies showing the effect of both water based and methanol-based extracts of pineapple vinegar on pathogens. However, these were a combination of pineapple peel/pineapple juice. The water-based extract of pineapple peel vinegar inhibited the growth of *Escherichia coli, Staphylococcus aureus, Bacillus* species, and *Candida* species. However, the methanolic extract of pineapple juice vinegar was active against *Staphylococcus aureus, Bacillus* species, and *Candida* species, but it did not suppress *E. coli* [23]. Biovinegar produced from pineapple peels, sugar, and the starter culture *Acetobacter xylinum*, showed stronger inhibition against *Enterobacter* and comparable activity to vinegar against *E. coli, Staphylococcus aureus, Salmonella typhi*, and *Klebsiella.* In contrast, mice treated with pineapple vinegar showed increased amounts of *Akkermansia muciniphila*, a beneficial gut bacterium [24]. Another study tested the antifungal action of pineapple vinegar against *Malassezia furfur* (a pathogenic yeast) in the concentration of 4000g/mL. While the given concentration did not inhibit the organism's growth, a linear regression test showed a relationship between the two, implying that an increased concentration may inhibit the growth of the fungus [25]. These studies support existing literature that acetic acid inhibits the growth of pathogens by damaging bacterial cell membranes, disrupting homeostasis and metabolic processes of pathogenic organisms.

3.5 Antidiabetic activity

Very few fruit vinegars have been tested for their antidiabetic potential. Surprisingly, one of the fruits is dates, which is often known for its sugar content. Date vinegar showed excellent results by decreasing the HbA1c from 6.85 to 6.08% and fasting glucose levels from 168.4 to 147.6 mg/dL. In comparison, pineapple peel vinegar demonstrated promise as a sustainable, waste-derived product with therapeutic potential for β-cell regeneration and glycemic control in diabetes, as seen in the study where twenty-four rats were divided into control, negative, positive, and three treatment groups receiving varying doses of pineapple peel vinegar. After 21 days, the 0.4 mL dose produced notable improvements in islet morphology and reduced blood glucose by 41.63% [26]. Diabetes is known to cause organ damage leading to inflammation and other complications. Pineapple peel vinegar demonstrated a strong capacity to improve the gonadosomatic index in diabetic rats, with higher doses showing the most pronounced effect. These findings suggest its potential as a natural therapeutic agent for mitigating diabetes-related reproductive impairments [27].

3.6 Anticancer activity

We found promising evidence of anticancer activity by pineapple vinegar in the literature search. This is usually in the form of apoptosis induction, inhibition of metastasis and downregulation of inflammation pathways in cancer models (Figure 2). The primary phenolic compounds linked to the anticancer effects seem to be gallic acid and caffeic acid. Pineapple vinegar demonstrated apoptosis induction in 4T1 breast cancer cells (IC_{50} = 0.25 mg/mL) and reduced cell migration. In mice, a dose of 2 mL/kg lowered tumour size by 45%, enhanced T cell and NK cell activity, and increased IL-2 and IFN-γ expression. Metastasis was suppressed through downregulation of inflammatory (iNOS, NF-κB, COX-2), metastasis (ICAM, VEGF, MMP9), and angiogenesis-related genes (CD26, TIMP1, HGF, MMP3, IGFBP-1, IGFBP-2) [28]. Another study tested both methanolic extracts of fermented pineapple waste that contained slightly higher phenolic content (120 mg gallic acid/100 g) and unfermented samples (112 mg/100 g). Both showed strong antioxidant activity and demonstrated anticancer effects against MCF-7, A549, and HCT116 cell lines, comparable to doxorubicin, while showing no activity against HepG2, HL-60, or normal HFB4 cells. GC/MS analysis picked up various compounds linked to these bioactivities. Pineapple vinegar produced using a central composite design showed an IC_{50} value of 3.4% v/v against colorectal adenocarcinoma cells [29]. Bromelain and other phenolic compounds may also work synergistically to produce this anticancer effect.

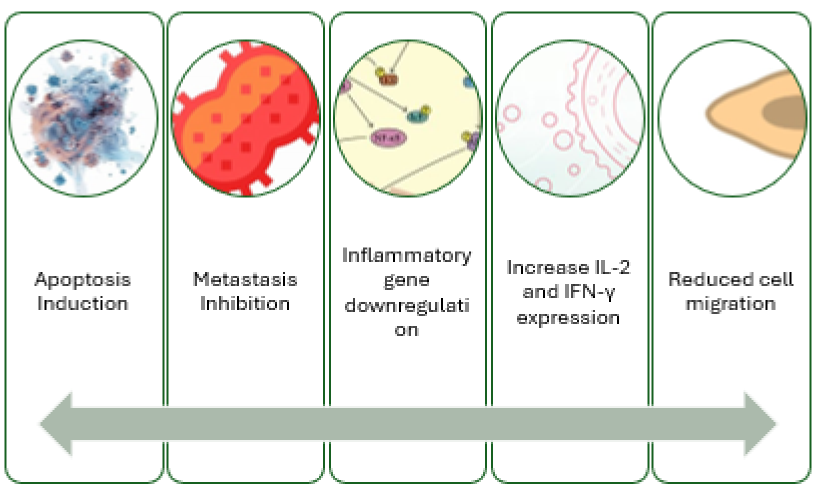

Fig 2. Anticancer activity of Pineapple Vinegar

3.7 Antiobesity Activity

Obesity, largely driven by high-fat diets, is a growing global health issue. Pineapple vinegar was tested as a functional food in obese C57BL/6 mice, and after 12 weeks of treatment, the higher dose (1 mL/kg) reduced body weight by about 20%, improved lipid profiles, boosted antioxidant activity, and lowered oxidative stress. It also regulated adipokines and inflammatory genes, while increasing beneficial gut bacteria such as *Akkermansia muciniphila*[30].

The various therapeutic activities of pineapple vinegar, as demonstrated in scientific studies, are shown in Figure 3. However, evidence supporting other claims, such as its effects on fatigue recovery and digestive disorders, remains scarce. Current limitations include the absence of standardized protocols, unclear mechanisms of action, lack of clinical trials and insufficient dose optimization.

Fig 3. Major bioactive compounds and their therapeutic properties in Pineapple vinegar

Translating the bioactivities of pineapple vinegar (Table 3) to more practical uses, the vinegar's antimicrobial and antioxidant properties enhance food preservation by extending shelf life and improving attributes such as colour stability.

3.8 Food quality and preservation

Food spoilage is a global challenge and problem caused due to the action of microbes, enzymes, and some chemicals. Due to the increasing demands for longer shelf life and safe food, preservation methods that address both quality and safety are required. These methods should also oversee aspects such as transport and storage. Although synthetic preservatives like sulphites and benzoates are widely used, they may sometimes be a cause for health risks, whereas natural methods such as drying,

Table 3. Pharmacological details of Pineapple Vinegar from existing literature

Pharmacological property	Bioactive compounds mentioned	Mechanisms/pathways	Main findings	References
Antioxidant	Flavonoids hydroxycinnamate, ascorbic acid	Not mentioned specifically	Pineapple peel Biovinegar showed good radical scavenging activity Mixed fruit vinegar of pineapple and dragon fruit juice with peel showed high antioxidant activity.	(17), (18)
Anti-inflammatory and Hepatoprotective	Phenolic acids, flavonoids	Downregulation of NF-$_K\beta$ and pro-inflammatory cytokines	Pineapple vinegar reduced tumor inflammation and regulated inflammation causing genes.	(21), (22)
Antimicrobial	Saponins, tannins	Disruption of cell membranes, inhibition of enzymes	Pineapple Biovinegar showed antimicrobial activity against *Staphylococcus aureus, Bacillus* species, and *Candida* species An increased relationship was observed between pineapple vinegar and a pathogenic yeast.	(24), (25)
Antidiabetic	Not mentioned specifically	Not mentioned specifically	Pineapple peel vinegar has high potency in restoring the gonadosomatic index (GSI) in diabetic rats.	(27)
Anti-cancer	Catechins, epicatechins, bromelain, saponins, tannins, alkaloids, gallic acid, caffeic acid, terpenoids	p53 induction, upregulation of Bax, downregulation of Bcl-2, regulation of MAPK and Akt/PKB, decreased expression of COX2, inhibition of G2/M phase cycle, inhibition of c-myc, ICAM-1, VEGF and MMP9 genes	Pineapple vinegar causes the induction of apoptosis, inhibiting metastasis and activates immune response in cancer cells.	(28), (29)
Anti-obesity	Not mentioned specifically	Regulation of adipokines and inflammation related genes	Pineapple vinegar reduced body weight, restored lipid profiles and increased beneficial gut bacteria	(30)

fermentation, pickling, smoking, and dehydration offer such safer alternatives. Acetic acid that is present in vinegar inhibits the growth of pathogens. Natural antimicrobial preservatives are considered to be safe as they are able to reduce microbial resistance and at the same time, meet the demand of consumers for healthier foods[31].

Vinegar is usually used for pickling various ingredients for better storage. Fermentation of pineapple juice with added sugar and mixed cultures yielded vinegar containing up to 5.8% acetic acid. When this vinegar was used in carrot pickle and mango chutney, the products maintained safe acid levels ($pH < 4$) and were shelf stable for three months at room temperature. Although vitamin C losses were high, consumer testing showed no decline in acceptability. Fish preserved with pineapple peel vinegar and NaCl also retained 90% freshness, with 10% moderately fresh and no spoilage[32]. Pineapple vinegar not only kept the meat safe, it also improved the yield and tenderness of spent hen meat, but concentrations above 30% negatively affected sensory quality, suggesting lower levels or combinations with other ingredients are preferable[33]. Overall, pineapple vinegar provides a practical, affordable way to make food last longer and cut down on waste.

4 Conclusion

Pineapple vinegar is not just a good way to use up leftover bit and pieces of the fruit. Instead, it is a clever and sustainable option that changes agricultural waste into valuable products. This systematic review shows the preclinical evidence of pineapple vinegar's potential in areas such as its antioxidant capacity in reducing liver injury and damage, reduce the risk of obesity by improving the gut microbiome, induce apoptosis in breast cell lines and demonstrate better enzyme inhibition compared to synthetically available vinegars. These therapeutic properties may be due to their elevated phenolics and organic acids that enable free radical scavenging and oxidative stress mitigation.

Even though good phenolic content (169.67μg GAE/mL) and dose dependent decline of certain inflammatory markers was observed, there was a great diversity in the fermentation and study methods used. This made it difficult to generalize the findings. Furthermore, it has been observed to exhibit antimicrobial action against foodborne pathogens and antidiabetic potential through lipid and glucose regulation as seen in rat models.

This study fills a gap in between primary studies without any previous reviews on pineapple vinegar. It also highlights its benefit over synthetic and other fruit vinegar such as coconut vinegar for usage in food processing. For future research RCTs in humans are needed to validate the preclinical results on lipid profiles, obesity, diabetes, cancer and inflammation starting with small doses. Pineapple vinegar can be used in comparison with apple cider vinegar or balsamic vinegar to study endpoints such as enzyme modulation and immune responses. or Fermentation methods need to be standardized to make sure that the bioactive yield is consistent. More strains can be tried to check which ones give better results. Overall, pineapple vinegar is an interesting ingredient that can provide health benefits, preserve and improve food quality while also being sustainable. Thus, subsequent research can take pineapple vinegar from the experimental level to a more validated ingredient used for better nutrition.

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