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LITERATURE REVIEW
HEALTH BENEFITS
APPLE CIDER VINEGAR
ACIDIC FERMENTED APPLE PEEL & GRAPE EXTRACTS

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APPLE CIDER VINEGAR & FERMENTED ACIDIC GRAPE & APPLE EXTRACTS

HEALTH BENEFITS LITERATURE REVIEW

Botanical Innovations has developed a range of Naturally Fermented Vinegars and Extracts which combine great flavor with a range of health benefits.

Dating back 5,000 BC vinegar has been a staple part of the human diets for millennium. The first recorded use was by the Babylonians who used vinegar as a condiment and preservative. The Ancient Romans consumed vinegar as a beverage and the Ancient Greeks used vinegar to pickle meat and vegetables. The healing properties of vinegar have also been referenced in the bible and the work of Hippocrates. By 2,000BC vinegar production became commercialized and was used to treat disease and wounds.

Today vinegar is used as in foods and beverages and as a health supplement.

The potential benefits of Botanical Innovations

Today vinegar is used taken orally and topically as a health supplement, in foods and beverages and as an ingredients in skin and hair care products.

This literature review summerizes recently published literature about the potential health benefits of Apple Cider Vinegar, Fermented Vinegars and Extracts. The literature identifes the following potential health benefits:

- Asthma symptom alleviation
- Diabetes prevention and treatment
- Antioxidant
- Lowers glucose intake
- Prevention of Cardiovascular disease
- Lowers cholesterol
- Contains anti glycemic properties
- Weight loss
- Lowers blood pressure

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Recent Published Scientific Studies about the health benefits of Vinegar

Published Research Abstracts

Examination of the antiglycemic properties of vinegar in healthy adults.

Publication: Annals of Nutrition and Metabolism 2010: 56 (1) pp74-9

Authors: Johnston CS, Steplewska I, Long CA, Harris LN, Ryals RH

Background

Vinegar reduces postprandial glycemia (PPG) in healthy adults. This study investigated the vinegar dosage (10 vs. 20 g), timing (during mealtime vs. 5 h before meal) and application (acetic acid as vinegar vs. neutralized salt) for reducing PPG.

Methods

Four randomized crossover trials were conducted in adults (n = 9-10/trial) with type 2 diabetes (1 trial) or without diabetes (3 trials). All trials followed the same protocol: a standardized meal the evening prior to testing, an overnight fast (1 10 h) and 2-hour glucose testing following consumption of a bagel and juice test meal (3 trials) or dextrose solution (1 trial). For each trial, PPG was compared between treatments using area-under-the-curve calculations 120 min after the meal.

Results

Two teaspoons of vinegar (10 g) effectively reduced PPG, and this effect was most pronounced when vinegar was ingested during mealtime as compared to 5 h before the meal. Vinegar did not alter PPG when ingested with monosaccharides, suggesting that the antiglycemic action of vinegar is related to the digestion of carbohydrates. Finally, sodium acetate did not alter PPG, indicating that acetate salts lack antiglycemic properties.

Conclusions

The antiglycemic properties of vinegar are evident when small amounts of vinegar are ingested with meals composed of complex carbohydrates. In these situations, vinegar attenuated PPG by 20% compared to placebo.

Vinegar supplementation lowers glucose and insulin responses and increases satiety after a bread meal in healthy subjects.

Publication: European Journal of Clinical Nutrition 2005 Sept: 59 (9) pp 983-8

Authors: Ostman E1, Granfeldt Y, Persson L, Björck I.

Objective

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 glycaemia, insulinaemia and satiety.

Subjects and Setting

In all, 12 healthy volunteers participated and the tests were performed at Applied Nutrition and Food Chemistry, Lund University, Sweden.

Intervention

Three levels of vinegar (18, 23 and 28 mmol acetic acid) were served with a portion of white wheat bread containing 50 g available carbohydrates as breakfast in randomized order after an overnight fast. Bread served without vinegar was used as a reference meal. Blood samples were taken during 120 min for analysis of glucose and insulin. Satiety was measured with a subjective rating scale.

Results

A significant dose-response relation was seen at 30 min for blood glucose and serum insulin responses; the higher the acetic acid level, the lower the metabolic responses. Furthermore, the rating of satiety was directly related to the acetic acid level. Compared with the reference meal, the highest level of vinegar significantly lowered the blood glucose response at 30 and 45 min, the insulin response at 15 and 30 min as well as increased the satiety score at 30, 90 and 120 min postprandially. The low and intermediate levels of vinegar also lowered the 30 min glucose and the 15 min insulin responses significantly compared with the reference meal. When GI and II (insulinaemic indices) were calculated using the 90 min incremental area, a significant lowering was found for the highest amount of acetic acid, although the corresponding values calculated at 120 min did not differ from the reference meal.

Conclusion

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.

Anti-obesogenic effect of apple cider vinegar in rats subjected to a high fat diet

Publication: Pubplication: Ann Cardiol Angeiol (Paris). 2016 Jun;65(3):208-13.

Authors: Bouderbala H, Kaddouri H, Kheroua O2, Saidi D

Aim of the Study

The search of new anti-obesogenic treatments based on medicinal plants without or with minimal side effects is a challenge. In this context, the present study was conducted to evaluate the anti-obesogenic effect of apple cider vinegar (ACV) in Wistar rats subjected to a high fat diet.

Materials and Methods

Eighteen male Wistar rats (140±5g) were divided into 3 three equal groups. A witness group submitted to standard laboratory diet and two groups subjected to a high fat diet (cafeteria diet); one receives a daily gavage of apple cider vinegar (7mL/kg/d) for 30 days. Throughout the experiment monitoring the nutritional assessment, anthropometric and biochemical parameters is achieved.

Results

In the RCV vs RC group, we observed a highly significant decrease ($P<0.001$) in body weight and food intake. On the other hand, the VCP decreases very significantly different anthropometric parameters: BMI ($P<0.01$), chest circumference and abdominal circumference ($P<0.001$), decreases serum glucose levels (26.83%) and improves the serum lipid profile by reducing plasma levels of total cholesterol (34.29%), TG (51.06%), LDL-c (59.15%), VLDL (50%) and the total lipid (45.15%), and increasing HDL-c (39.39%), thus offering protection against oatherogenic risk (61.62%).

Conclusion

This preliminary study indicates that the metabolic disorders caused by high fat diet (cafeteria) are thwarted by taking apple cider vinegar which proves to have a satiating effect, antihyperlipidemic and hypoglycemic effects, and seems prevent the atherogenic risk.

Apple cider vinegar modulates serum lipid profile, erythrocyte, kidney, and liver membrane oxidative stress in ovariectomized mice fed high cholesterol.

Publication: Membrane Biology Journal 2014 Aug;247(8):667-73

Authors: Nazıroğlu M1, Güler M, Özgül C, Saydam G, Küçükayaz M, Sözbir E.

Abstract

The purpose of this study was to investigate the potentially beneficial effects of apple cider vinegar (ACV) supplementation on serum triglycerides, total cholesterol, liver and kidney membrane lipid peroxidation, and antioxidant levels in ovariectomized (OVX) mice fed high cholesterol.

Four groups of ten female mice were treated as follows: Group I received no treatment and was used as control. Group II was OVX mice. Group III received ACV intragastrically (0.6% of feed), and group IV was OVX and was treated with ACV as described for group III. The treatment was continued for 28 days, during which the mice were fed a high-cholesterol diet.

The lipid peroxidation levels in erythrocyte, liver and kidney, triglycerides, total, and VLDL cholesterol levels in serum were higher in the OVX group than in groups III and IV. The levels of vitamin E in liver, the kidney and erythrocyte glutathione peroxidase (GSH-Px), and erythrocyte-reduced glutathione (GSH) were decreased in group II. The GSH-Px, vitamin C, E, and β-carotene, and the erythrocyte GSH and GSH-Px values were higher in kidney of groups III and IV, but in liver the vitamin E and β-carotene concentrations were decreased.

In conclusion, ACV induced a protective effect against erythrocyte, kidney, and liver oxidative injury, and lowered the serum lipid levels in mice fed high cholesterol, suggesting that it possesses oxidative stress scavenging effects, inhibits lipid peroxidation, and increases the levels of antioxidant enzymes and vitamin.

Effects of apple cider vinegars produced with different techniques on blood lipids in high-cholesterol-fed rats.

Publication: Journal of Agricultural Food Chemistry 2011 Jun 22;59(12):6638-44.

Authors: Budak NH, Kumbul Doguc D, Savas CM, Seydim AC, Kok Tas T, Ciris MI, Guzel-Seydim ZB.

Abstract

Red delicious apples were used to produce natural apple cider with and without inclusion of maceration. Traditional surface and industrial submersion methods were then applied to make vinegar from apple ciders.

Apple cider vinegar samples produced with inclusion of maceration in the surface method had the highest total phenolic content, chlorogenic acid, ORAC, and TEAC levels.

Cholesterol and apple vinegar samples were administered using oral gavage to all groups of rats except the control group.

Apple cider vinegars, regardless of the production method, decreased triglyceride and VLDL levels in all groups when compared to animals on high-cholesterol diets without vinegar supplementation.

Apple cider vinegars increased total cholesterol and HDL and LDL cholesterol levels and decreased liver function tests when compared to animals on a high-cholesterol diet without vinegar supplementation. A high-cholesterol diet resulted in hepatic steatosis. VSBM and VSB groups significantly decreased steatosis.

Vinegar Published Research Papers

Functional Properties of Vinegar

Article attached
Publication: Journal of Food Science May 2014
Authors: Budak N, Akin Z, Seydum A, Greene A, Guzel-Seydum B

Vinegar: Medicinal Uses and Antiglycemic Effect

Article attached
Publication: MedGenMed 2006: 8(2) 61
Authors: Johnston C, Gaas C

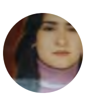
Appendix

Catalyst Video Transcript Vinegar Medicinal Benefits

Functional Properties of Vinegar

Article *in* Journal of Food Science · May 2014

DOI: 10.1111/1750-3841.12434



Nilgün Budak
T.C. Süleyman Demirel Üniversitesi

Elif Aykın
Akdeniz University

Functional Properties of Vinegar

Nilgün H. Budak, Elif Aykin, Atif C. Seydim, Annel K. Greene, and Zeynep B. Guzel-Seydim

Abstract: A variety of natural vinegar products are found in civilizations around the world. A review of research on these fermented products indicates numerous reports of health benefits derived by consumption of vinegar components. Therapeutic effects of vinegar arising from consuming the inherent bioactive components including acetic acid, gallic acid, catechin, ephicatechin, chlorogenic acid, caffeic acid, p-coumaric acid, and ferulic acid cause antioxidative, antidiabetic, antimicrobial, antitumor, antiobesity, antihypertensive, and cholesterol-lowering responses. The aims of this article are to discuss vinegar history, production, varieties, acetic acid bacteria, and functional properties of vinegars.

Keywords: acetic acid bacteria, bioactive compounds, therapeutic effects, vinegar

Introduction

The earliest known use of vinegar dates to more than 10000 y ago (Tan 2005; Johnston and Gaas 2006). Flavored vinegar has been produced and sold as a commercial product for approximately 5000 y. The Babylonians produced and sold vinegars flavored with fruit, honey, and malt until the 6th century. References in the Old Testament and from Hippocrates indicate vinegar was used medicinally to manage wounds. Sung Tse, who is credited with developing the field of forensic medicine in the 10th century in China, used sulfur and vinegar as hand washing agents to prevent infection (Chan and others 1993; Tan 2005). Early U.S. medical practitioners used vinegar to treat many ailments including poison ivy, croup, stomachache, high fever, and edema or "dropsy" as it was known in the 18th century (Tan 2005).

In 1778, Durande concentrated vinegar to create glacial acetic acid and in 1814, Berzelios conducted the analysis of acetic acid. By 1823, Schutzenbach had developed a method for manufacture of vinegar known as the generator process which allowed vinegar to be made within 3 to 7 d. In 1955, Hromatka developed a method of making vinegar called submerged acetification which used improved aeration and stirring to produce vinegar quickly (Tan 2005).

Traditional vinegar is produced from raw materials containing sugar or starch in a 2-stage fermentation to initially produce ethanol and subsequently produce acetic acid. Traditional vinegar typically results from a long fermentation (up to a month) and uses natural vinegar as the starter culture. Industrial vinegar typically can be manufactured in approximately 1 d. Traditional vinegar is produced from fruit juices such as grape, apple, plum, coconut and tomato, rice, and potato. Acetic acid bacteria (AAB) are present everywhere in the environment. They may propagate in food materials which contain sugar or in the fermented products which contain alcohol. Different species of AAB have been isolated from various kinds of vinegars including white wine, red wine, spirit, cider, traditional balsamic, rice, and industrial vinegars, which produced by submerged culture with aeration.

MS 20130797 Submitted 6/13/2013, Accepted 2/19/2014. *Author Budak is with Dept. of Food Technology, Egirdir Vocational School, Süleyman Demirel Univ., Isparta, Turkey. Author Aykin is with Dept. of Food Engineering, Engineering Faculty, Akdeniz Univ., Antalya, Turkey. Authors Seydim and Guzel-Seydim are with Dept. of Food Engineering, Engineering Faculty, Süleyman Demirel Univ., Isparta, Turkey. Author Greene is with Dept. of Animal and Veterinary Science, Clemson Univ., Clemson, SC, U.S.A. Direct inquiries to author Budak (E-mail: nilgunbudak@sdu.edu.tr).*

Vinegars are commonly used for pickling of fruits and vegetables and in the preparation of mayonnaise, salad dressings, mustard, and other food condiments. Although useful as a food ingredient for flavor and functional properties, the potential health benefits of vinegar varieties are leading researchers to further consider this long used food product (Türker 1963; Tan 2005). Regular consumption of bioactive substances is promoted by many nutritional researchers and the functional food properties of vinegar have been reported in a variety of scientific and lay publications. With documentation of the health benefits of vinegar, a concurrent increase in demand for fruit vinegar production has occurred (Mazza and Murooka 2009; Ou and Chang 2009).

Functional therapeutic properties of vinegar described include antibacterial activity, blood pressure reduction, antioxidant activity, reduction in the effects of diabetes, prevention of cardiovascular disease, and increased vigor after exercise (Nishidai and others 2000; Ogawa and others 2000a; Kondo and others 2001a; Shimoji and others 2002; Sugiyama and others 2003a).

Production of Vinegar

Production methods and varieties of vinegars

Vinegar is produced from raw materials containing starch or sugar via sequential ethanol and acetic acid fermentations (FAO/WHO 1982) and is used in a variety of food applications (Türker 1963; Tan 2005). Grape, apple, and other fruit juices are the primary starting materials used for vinegar production (Adams 1985) although rice vinegar, malt vinegar, and beer vinegar are also produced in some countries. 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 AAB during the last fermentation (Gullo and Giudici 2008). Several methods of vinegar production exist but primarily 2 methods are used commercially. The first is a traditional method classified as a "surface method" in which the culture of AAB grows on the surface of wood shavings and provides oxygen at the surface. The second method, classified as a "submerged culture" is a method in which oxygen is supplied in fermentation to accelerate industrial production (Garcia-Parilla and others 1997). The general production method for vinegar is shown in Figure 1.

A wide variety of different vinegars are produced around the world. Some of the vinegar varieties are listed in Table 1 and classified according to origin of production. One of the most famous vinegar varieties is the traditional balsamic vinegar produced from cooked and concentrated musts of white or red grapes (Masino

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and others 2008). The resultant vinegar product is aged in a successive set of progressively smaller barrels ranging in volume from 75 to 10 L (Giudici and others 2009).

Sherry vinegar is made from Sherry wines following traditional methods of acetification in the Jerez–Xérès–Sherry, Manzanilla de Sanlúcar and Vinagre de Jerez Denomination of Origin regions of southwest Spain (Mejias and others 2002). The unique aroma and flavor of Sherry vinegar is due to the traditional method of production followed in this region known as the "soleras y criaderas" system. This system involves a slow acetification during aging in American oak casks stacked in rows and levels. The final product is blended from the stacked casks across a mixture of vinegars of differing ages (Parrilla and others 1999; Alonso and others 2004).

Other vinegars produced around the world include the Japanese vinegar Kurosu and the Chinese vinegar Zhenjiang which are produced from rice (Nishidai and others 2000; Xu and others 2007). Production of rice vinegar begins with immersion of rice in water, heating, cooling, and inoculation with yeast to produce ethanol. Subsequently, an acetic acid fermentation is conducted and the product is matured (Chen and Chen 2009). Cane vinegar is made from fermented sugarcane juice, has a mild flavor and is used extensively in food preparation in the Philippines (Tan 2005). Persimmons are considered a medicinal fruit in traditional Chinese medicine and persimmon vinegar is produced in China (Ubeda and others 2011). In China, the plant known as *Radix Ophiopogon japonicus* (mondo grass, dwarf lily turf, liriope) is used as a traditional medicinal herb; ophiopogon vinegar produced from *Radix*

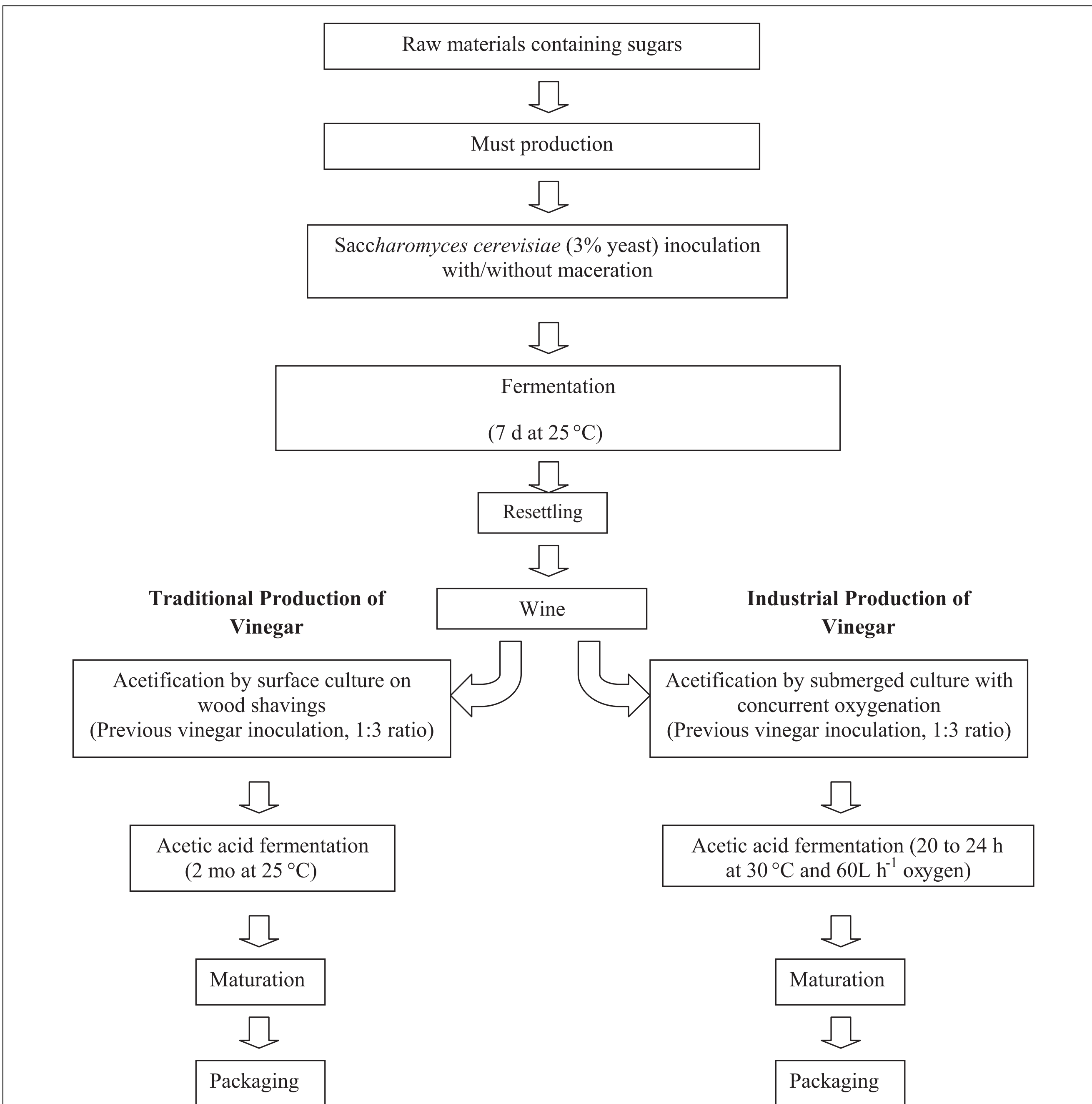

Figure 1–General production methods for vinegar.

Table 1–Vinegar varieties produced in different countries.

Vinegar varieties	Major production countries
Apple cider vinegar	World wide
Balsamic vinegar	Italy
Beer vinegar	Germany
Cane vinegar	Philippines
Champagne vinegar	France, United States
Coconut vinegar	Southeast Asian
Distilled vinegar	United States
Fruit vinegar	Austria
Kombucha vinegar	Japan
Malt vinegar	England
Potato vinegar	Japan
Red wine vinegar	World wide
Rice vinegar	United States, Taiwan
Sherry vinegar	Spain
Spirit vinegar	Germany
Tarragon vinegar	United States
White wine vinegar	Turkey, Italy

O. japonicus is a popular functional food in China (Lin and others 2011). Malt vinegar has a hearty flavor and is produced from fermented barley and grain mash in England (Horiuchi and others 1999). Yacon (*Smallanthus sonchifolius*) is a South American tuberous plant that is an abundant source of prebiotic fructooligosaccharides which are fermented into vinegar (Ojansivua and others 2011).

Fermentation with AAB

AAB are a group of bacteria in the family *Acetobacteriaceae.* AAB are obligate aerobes which stain as Gram negative or Gram variable, are catalase positive and oxidase negative. The nonsporeforming cells are rod to ellipsoidal-shaped (Sengun and Karabiyikli 2011). AAB have an optimum growth temperature range of 25 °C to 30 °C. Although the optimum pH growth range is 5.0 to 6.5, AAB are reported as resistant to acidic environments under pH 5.0 (Holt and others 1994; Trcek and others 2000; Gullo and Giudici 2008). *Acetobacter* and *Gluconobacter* are the 2 main AAB genera and choice of culture dictates vinegar production methods. The genus *Acetobacter* oxidizes alcohol preferentially over glucose whereas the genus *Gluconobacter* preferentially oxidizes glucose more readily than ethanol (Swings 1992; Yamada 2000; Gullo and Giudici 2008). Species of AAB isolated from different kinds of vinegars are presented in Table 2.

In production of vinegar, AAB require access to oxygen. In the slower surface method of vinegar fermentation used more frequently for traditional vinegars, AAB grow at the interface between air and liquid. In the faster submerged method used more commonly for commercial vinegars, AAB are supplied with oxygen through continual air sparging in the acetifying liquid (Fernández-Pérez and others 2010).

AAB may produce various organic acids including acetic, tartaric, lactic, malic, and citric acids as the result of the oxidation of sugars and alcohols; however, acetic acid is predominant among these acids (Sengun and Karabiyikli 2011). Organic acids isolated from different types of vinegars are presented in Table 3.

Table 2–Species of acetic acid bacteria isolated from different kind of vinegars.

Species	Type of vinegar	References
Acetobacter aceti	Cider	Trcek 2005
Acetobacter intermedius	Cider	Trcek and others 2000
Acetobacter pasteurianus	Cider, red wine, traditional Balsamic and rice	Haruta and others 2006; Bartowsky and Henschke 2008; Gullo and others 2009
Acetobacter pomorum	Industrial	Sokollek and others 1998
Acetobacter obiediens	Industrial	Sokollek and others 1998
Gluconacetobacter entanii	Industrial	Schüller and others 2000
Gluconacetobacter europaeus	White wine, red wine, spirit and cider	Sievers and Swings 2005; Callejón and others 2008 ; Vegas and others 2010
Gluconacetobacter hansenii	Cider and traditional Balsamic	Gullo and Giudici 2008; Fernández-Pérez and others 2010
Gluconobacter oxydans	Wine	González and others 2005; Vegas and others 2010
Gluconacetobacter xylinus	Cider, white wine, and traditional Balsamic	Gullo and others 2006; Vegas and others 2010; Fernández-Pérez and others 2010

Table 3–Organic acids in different type of vinegars.

Vinegars	Organic acids	References
Alcohol vinegar	Acetic acid	Sáiz-Abajo and others 2005
Cider vinegar	Acetic, citric, formic, lactic, malic, succinic acids	Caligiani and others 2007 Budak 2010
Malt vinegar	Acetic, citric, lactic, and succinic acids	Sáiz-Abajo and others 2005
Plum vinegar	Acetic, tartaric, and lactic acids	Liu and He 2009
Sherry vinegar	Acetic, tartaric, lactic, malic, and citric acids	Morales and others 1998
Tomato vinegar	Acetic, citric, formic, lactic, malic, and succinic acids	Caligiani and others 2007
Traditional Balsamic vinegar	Malic, tartaric, citric, and succinic acids	Cocchi and others 2006
Wine vinegar	Acetic, citric, formic, lactic, malic, succinic, and tartaric acids	Caligiani and others 2007; Budak 2010

Health and Therapeutic Effects of Vinegar

Antimicrobial effect

Vinegar has antimicrobial properties which makes it useful for a number of applications. Vinegar has been used for cleaning and treating nail fungus, head lice, warts, and ear infections (Rutala and others 2000; Dohar 2003). Consumers typically prefer natural preservative methods for inhibiting the growth of foodborne pathogenic microorganisms in food (Rauha and others 2000). The organic acids in vinegar and mainly acetic acid pass into cell membranes of microorganisms leading to bacterial cell death (Booth and Kroll 1989; Brul and Coote 1999; Blackburn and McClure 2002; Bjornsdottir and others 2006; Chang and Fang 2007). The bacterial strains, temperature, pH, acid concentration, and ionic strength influence the antimicrobial activity of organic acids (Buchanan and Edelson 1996; Entani and others 1998; Cheng and others 2003). Many organic acids are naturally found in a variety of fruits and fermented foods, including: acetic, lactic, ascorbic, citric, malic, propionic, succinic, and tartaric acids and in nonexcessive levels, none of these acids are dangerous to human health (Escudero and others 1999; Brennan and others 2000; Fang and Hsueh 2000;

Table 4–Phenolic compounds in various vinegar types.

Vinegar types	Phenolic compounds	Total polyphenolic ındex (mg/L GAE)	References
Apple cider vinegar	Gallic acid, catechin, epicatechin, chlorogenic acid, caffeic acid, and *p*-coumaric acid	400 to 1000	Budak and others 2011
Grape vinegar	Gallic acid, catechin, epicatechin, chlorogenic acid, caffeic acid, syringic acid, and ferulic acid	2000 to 3000	Budak and Guzel-Seydim 2010
Sherry vinegar	Gallic acid, protocatechuic acid, protocatechualdehyde, tyrosol, p-OH-benzoic acid, catechin, p-OH-benzaldehyde, siringic acid, vanillin, caftaric acid,cis-p-coutaric acid, trans-p-coutaric acid, fertaric acid, caffeic acid, cis-p-coumaric acid, trans-p-coumaric acid, i-ferulic acid, ferulic acid.	200 to 1000	Alonso and others 2004
Traditional Balsamic vinegar	Furan-2-carboxylic acid, 5- hydroxyfuran-2-carboxylic acid, 4-hydroxybenzoic acid, vanillic acid, protocatechuic acid, syringic acid, isoferulic acid, *p*-coumaric acid, gallic acid, ferulic acid, and caffeic acid		Plessi and others 2006

Sengun and Karapinar 2004). When the effects of organic acids on killing of foodborne pathogenic bacteria were compared, it was reported that acetic acid was the most lethal acid to *Escherichia coli* O157:H7, followed by lactic, citric, and malic acids (Entani and others 1998; Ryu and others 1999).

Different studies have reported that vinegar could be used to inhibit pathogenic bacteria on fresh fruits and vegetables (Wu and others 2000; Rhee and others 2003; Sengun and Karapinar 2004; Chang and Fang 2007). Sengun and Karapinar (2004) reported the effects of vinegar containing 4.03% acetic acid, lemon juice and a 1:1 (v/v) mixture of lemon juice and vinegar on *Salmonella typhimurium* when applied to carrots for different exposure times (0, 15, 30, and 60 min). While both vinegar and lemon juice demonstrated an antimicrobial effect on *S. typhimurium* at all times, the maximum reduction in *S. typhimurium* populations occurred at 60 min of treatment. Chang and Fang (2007) evaluated the antimicrobial effect of rice vinegar on lettuce inoculated with *E. coli* O157:H7 and noted a 3 log reduction was caused by treating with commercial vinegar containing 5% acetic acid for 5 min at 25 °C. However, less than 1 log reduction was noted using 0.5% acetic acid treatment for 5 min.

Antioxidant Effect

Reactive oxygen species such as superoxide, hydrogen peroxide, and hydroxyl radical have been reported to affect lipids, proteins and DNA resulting in accelerated aging, cancer, and brain degenerative disorders (Buonocore and others 2010; Maes and others 2011). Recent studies have suggested that bioactive compounds in foods may reduce incidences of these degenerative illnesses by providing an antioxidant effect (Iriti and Faoro 2010; Fernández-Mar and others 2012; Ramadan and Al-Ghamdi 2012). Bioactive substances such as polyphenols and vitamins in different types of vinegar defend against oxidative stress due to their significant antioxidant activity (Davalos and others 2005; Nishino and others 2005). Phenolic content for various vinegar types including grape vinegar (Garcia-Parrilla and others 1997; Budak and Guzel-Seydim 2010), Sherry vinegar (Alonso and others 2004), traditional balsamic vinegar (Plessi and others 2006; Verzelloni and others 2007), and apple cider vinegar (Budak and others 2011) are shown in Table 4.

Budak and Guzel-Seydim (2010) reported that traditional grape wine vinegar had higher content of chlorogenic and syringic acids than industrial grape wine vinegar. However, the amount of catechin in industrial vinegar was higher than in traditional vinegar. Oxygen Radical Absorbance Capacity (ORAC) and Trolox Equivalent Antioxidant Capacity (TEAC) values were 10.50 μmol/mL TE (trolox equivalents) and 13.50 mmol/L, respectively, for traditional vinegar and 8.84 μmol/mL TE and 10.37 mmol/L, respectively, for industrial vinegar (Budak and Guzel-Seydim 2010). ORAC and TEAC values of traditional vinegar were higher than industrial vinegar. ORAC and TEAC values of apple cider vinegar samples were 2 to 6 μmol/mL TE and 4 to 14 mmol/L, respectively (Budak and others 2011). ORAC and TEAC values of wine vinegar were higher than apple cider vinegar.

The Japanese rice vinegar Kurosu had a high composition of phenolic compounds indicating it was a potent source of antioxidant activity (Nishidai and others 2000). The antioxidant activity value of persimmon vinegar was higher than white and red wine vinegars; this higher antioxidant activity was attributed to the wild yeast strain used in persimmon vinegar production (Ubeda and others 2011).

Japanese plum vinegar is used for the production of a salted cherry blossom tea known as Sakura-cha often served at celebrations. In the preparation of Sakura-cha, cherry blossoms are immersed in Japanese plum vinegar resulting in an extract. This plum vinegar extract of cherry blossom was reported to have significant superoxide anion scavenging activity. Analysis of the extract indicated presence of cyanidin-3-glucoside, cyanidin-3-rutinoside, and caffeic acid as the most potent antioxidant components (Matsuura and others 2008).

Analysis of traditional balsamic vinegars indicated antioxidant activity was mainly due to melanoidins. Further investigation indicated traditional balsamic vinegar melanoidins prevented the absorption and the prooxidant and cytotoxic effects of heme during simulated gastric digestion of meat (Xu and others 2004, 2005; Verzelloni and others 2010).

Antidiabetic Effect

Diabetes is described as high blood glucose levels in both the state of hunger and after consumption of a meal. In type 1 diabetes, there is not enough insulin due to destruction of pancreatic cells resulting in hyperglycemia. In type 2 diabetes, insulin is present, but tissues are resistant to the insulin and therefore, blood glucose concentrations increase (WHO 2014). Insulin sensitivity has been improved through vinegar treatment in 19% of individuals with type 2 diabetes and 34% of individuals with prediabetes (Johnston and others 2004). Recent studies in both animals and humans have shown that vinegar may be used for diabetic treatment (Salbe and others 2009). In rats, the effect of vinegar on blood sugar has been investigated and it has been reported that blood glucose decreased when compared with normal diet after ingestion of a starch load coadministered with a 2% acetic acid solution (Ebihara and Nakajima 1988). In humans, the area under the insulin response curve decreased 20% after consumption of sucrose coadministered with vinegar (Brighenti and others 1995). Many placebo-controlled experiments have confirmed the blood glucose reducing or "antiglycemic" effect of vinegar (Johnston and others 2004; Leeman and others 2005). Several systems have been studied to explain the effect of vinegar on blood glucose concentrations. Acetic acid in vinegar may prevent the complete digestion of complex carbohydrates (Ogawa and others 2000b) by either accelerating gastric emptying (Liljeberg and Fjorck 1998) or by increasing the uptake of glucose by tissues resulting in reduced blood glucose levels (Fushimi and others 2002; Fushimi and Sato 2005).

Antitumor Effect

Kurosu is a traditional Japanese rice vinegar which is reported to be 1 of the most important sources of phenolic compounds for reducing cancer risk (Shimoji and others 2004). Antioxidant activity of an ethyl acetate extract of Kurosu vinegar was greater than the antioxidant activities of wine and apple vinegars (Nishidai and others 2000; Nishino and others 2005). The effect of Kurosu vinegar on the proliferation of a variety of human cancer cell lines has been studied. Cancer cell lines included colon adenocarcinoma, lung carcinoma, breast adenocarcinoma, bladder carcinoma, and prostate carcinoma cells. It was reported that Kurosu inhibited the proliferation of all tested cell lines in a dose-dependent manner (Nanda and others 2004).

Kibizu is sugar cane vinegar produced in Japan. Kibizu inhibited the growth of typical human leukemia cells with its potent radical scavenging activity (Mimura and others 2004). Vinegar ingestion indicated a protective effect with a decreased risk for esophageal cancer (Xibib and others 2003). Products of alcohol and acetic acid fermentations that were formed during the production of apple vinegar were investigated with regard to the neutral medium-sized alpha-glycan content, which acts against experimental mouse tumors. It was observed that neutral medium-sized alpha-glycan was formed mainly during acetic acid fermentation, but not during alcohol fermentation (Abe and others 2007).

Antiobesity Effect

Vinegar ingestion may decrease the glycemic effect of a meal through satiety thus reducing the total amount of food consumed (Mermel 2004). Lim and others (2009) used an obese insulin-resistant rat model to evaluate the antihyperglycemic and antiobesity effects of ginsam which is a vinegar extract from Panax ginseng. Ginseng is 1 of the most popular herbal medicines in particularly Asian populations. Panax ginseng is known that has several pharmacologic and physiologic effects. The rats fed ginsam had lower body weight and fasting, postprandial glucose and plasma insulin concentrations than the controls.

In a study reported by Johnston (2006a, b), human subjects consuming 2 tablespoons of red raspberry vinegar daily with freely access to food and water for 4 wk lost weight whereas the control group consuming a similar amount of cranberry juice daily for 4 wk had a slight weight gain. In another study, healthy volunteers consumed 3 levels of vinegar (18, 23, and 28 mmol acetic acid) with a portion of white wheat bread; bread consumption (no vinegar) was used as a control meal. When the hunger and satiety feelings of volunteers were evaluated it was noted that satiety increased with rising acetic acid level (Ostman and others 2005). Johnson and Buller (2005) studied 3 treatment conditions (control, consumption of vinegar containing 1 g acetic acid, or consumption of approximately 1 oz of peanuts for satiety). In the study, participants ingesting vinegar or peanuts had lower subsequent food consumption accounting for approximately 200 to 275 calories per day. After consumption of the bagel meal, energy consumption for the remainder of the day was weakly affected by vinegar and peanut treatments (a reduction of approximately 200 to 275 kcal, $P = 0.111$). This daily calorie reduction would result in a monthly weight loss of 1 to 1½ pounds (Johnston and Buller 2005). Budak and others (2011) identified a significant steatosis in rats fed the high-cholesterol diet when compared to the control group. Apple cider vinegars produced using the submersion method (with or without maceration) showed significantly decreased steatosis in groups fed these products when compared to the high-cholesterol diet group.

Prevention of Cardiovascular Diseases

Cholesterol-lowering effect

Cardiovascular disease is the leading cause of mortality accounting for more than half of the total mortalities (Lee and others 2007; Lloyd-Jones and others 2010). Cholesterol, elevated blood pressure, smoking, and physical inactivity are among the major risk factors for cardiovascular disease (Beaglehole 2001; Ebrahim and Davey-Smith 2001; Critchley and Capewell 2003). Many epidemiological studies show that polyphenol-rich foods provide protective effect and reduce mortality from cardiovascular diseases (Keys 1995; Giugliano 2000). Atherosclerosis induces chronic diseases (Fki and others 2007). Atherosclerosis is a chronic inflammatory disease initiated by the subendothelial retention of low-density lipoprotein (LDL) particles (Ross 1999). The initiation and progression of atherosclerosis are mainly dependent upon oxidative stress and the formation of oxidized LDLs (Berliner and Heinecke 1996; Lee and others 2007). Consumption of natural antioxidants like polyphenols may decrease the formation of oxidized LDLs in the bloodstream (Sugiyama and others 2003b).

Polyphenols such as chlorogenic acid which is present in high levels in apple cider vinegar could inhibit oxidation of LDLs and improve health by preventing cardiovascular diseases (Laranjinha and others 1994). The lipid profile of blood depends on genetic factors and dietary habits such as the consumption of food containing high levels of saturated fat (Krieger 1988; Fukushima and others 1999). Fushimi and others (2006) reported that 0.3% dietary acetic acid reduced serum cholesterol and triglycerides (TG) in rats fed a cholesterol-rich diet. *In vivo*, acetic acid enhanced lipid homeostasis and the cholesterol-lowering effect of acetic acid was described in detail by Yamashita and others (2007). Budak and others (2011) determined the cholesterol-lowering effect of apple vinegars in rats fed high-cholesterol diets and identified the serum levels of TG, total cholesterol (TC), high-density lipoprotein (HDL), LDL, and very low density lipoprotein (VLDL) of each of the groups. Serum levels of TG, TC, HDL, LDL, and VLDL significantly increased in rats fed the high-cholesterol diet when compared to the control. The increase of HDL level was significant only in rats fed apple cider vinegar produced by the surface method with maceration. The increase in LDL level was significant in the groups fed apple cider vinegars produced by the surface method, and by the submersion method with or without maceration. It was also noted that LDL level did not increase in the groups fed apple cider vinegars produced by the surface method with maceration.

The effect of dietary acetic acid, the main component of vinegar, was examined on serum lipid values in rats fed a diet containing 1% cholesterol and dietary acetic acid. The dietary acetic acid treated rats had lower values of serum TC and triacylglycerols, liver ATP citrate lyase (ATP-CL) activity, and liver 3-hydroxy-3-methylglutaryl-CoA content. In addition, liver mRNA levels of fatty acid synthase, ATP-CL, and sterol regulatory element binding protein-1 were lower and the rats had higher fecal bile acid content.

In rats cofed cholesterol, dietary acetic acid reduced triacylglycerol and serum TC levels by inhibiting lipogenesis and by promoting fecal bile acid excretion (Yamashita and others 2007). Hu and others (1999) reported a linear relationship between the consumption of oil and vinegar in salad and the reduction in risk of fatal ischemic heart disease (IHD) (Hu and others 1999).

Antihypertensive effect

Studies have investigated the effect of vinegar on lowering blood pressure. These studies have examined oral administration of vinegar on the renin-angiotensin system *in vitro* and *in vivo* using spontaneously hypertensive rats-stroke prone (Ohnami and others 1985; Tsuzuki and others 1992; Matui and others 1998). Ohnami and others (1985) observed that an ethanol extracted fraction of rice vinegar residues prevents angiotensin-converting enzyme (ACE) activity in spontaneously hypertensive rats. Nishikawa and others (2001) reported rice vinegar residues prevent ACE activity in the blood pressure regulatory system. Melanoidins, which are synthesized in the final stage of the Maillard reaction during traditional balsamic vinegar production, exhibit potential health benefits including antihypertensive activity (Rufián-Henares and Morales 2007). Although studies have shown that minor components of vinegar are responsible for the observed antihypertensive effects, the acetic acid content of vinegar is reported to also cause an antihypertensive effect (Ito 1978; Kondo and others 2001b). Vinegar (containing 0.57 mmol acetic acid) and acetic acid ingestion reduced plasma renin activity and plasma aldosterone which are factors associated with blood vessel constriction in rats (Honsho and others 2005).

Therapeutic Effect of Vinegar for Injuries

Mother of vinegar has been demonstrated to have a therapeutic effect on burns due to antibacterial properties (Krystynowicz and others 2000). In addition, it was reported that the extracellular structure synthesized by *Acetobacter xylinum* assisted tissue repair in rats (Bielecki and others 2000). Sugiyama and others (2009) suggested that oral intake of AAB was useful in attenuating muscle damage by inflammation after moderate-intensity exercise.

Impact of Vinegar on Brain

Sphingolipids are important building blocks for brain tissues. Studies have indicated that AAB produce precursors of sphingolipids known as the alkali-stable lipids (ASL). Dihydroceramide is 1 of the ASL generated by AAB. Fukami and others (2010) studied the effect of ASL on dementia model rats and determined that after treatment for 10 d, significant improvements in cognitive ability occurred. Further investigation indicated that ASL caused increased neurite growth in pheochromocytoma (PC12) cells and dihydroceramide had the most potent effect. Fukami and others (2009, 2010) hypothesized that vinegar consumption might improve cognitive function in humans. Other studies found that gangliosides which were composed of sialic acid and oligosaccharides conjugated to ceramide were effective in improving Alzheimer patients' symptoms (Svennerholm 1994).

Conclusion

Vinegar is manufactured worldwide from a wide variety of starting materials using different production methodologies. Acetic acid is the dominant flavor compound in vinegar and has a long history as an important direct food additive to acidulate food for preservation. Although vinegar traditionally has been used as a food flavoring and preservative, recent investigations demonstrate the potent bioactive effects of vinegars which may benefit human health. Functional therapeutic properties of vinegar described include antibacterial activity, blood pressure reduction, antioxidant activity, reduction in the effects of diabetes, and prevention of cardiovascular disease. Other positive health effects of daily consuming vinegar reported include improving blood glucose response which would be of benefit to diabetic patients.

Phenolic acids in vinegar can scavenge superoxide anion and free radicals *in vivo* resulting in a potent antioxidant activity. Depending on variety of vinegar and inherent acetic acid and total phenolic content, daily intake of vinegar may affect human health and metabolism. Further studies related to health effects of vinegar consumption by humans are necessary.

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Vinegar: Medicinal Uses and Antiglycemic Effect

Carol S. Johnston, PhD, RD and Cindy A. Gaas, BS

Carol S. Johnston, Department of Nutrition, Arizona State University, Mesa, Arizona;
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Disclosure: Cindy A. Gaas, BS, has disclosed no relevant financial relationships.

Abstract

Vinegar folklore is as colorful as it is practical. Legend states that a courtier in Babylonia (c. 5000 BC) “discovered” wine, formed from unattended grape juice, leading to the eventual discovery of vinegar and its use as a food preservative. Hippocrates (c. 420 BC) used vinegar medicinally to manage wounds. Hannibal of Carthage (c. 200 BC), the great military leader and strategist, used vinegar to dissolve boulders that blocked his army's path. Cleopatra (c. 50 BC) dissolved precious pearls in vinegar and offered her love potion to Anthony. Sung Tse, the 10th century creator of forensic medicine, advocated hand washing with sulfur and vinegar to avoid infection during autopsies. Based on the writings of US medical practitioners dating to the late 18th century, many ailments, from dropsy to poison ivy, croup, and stomachache, were treated with vinegar,[1] and, before the production and marketing of hypoglycemic agents, vinegar “teas” were commonly consumed by diabetics to help manage their chronic aliment. This review examines the scientific evidence for medicinal uses of vinegar, focusing particularly on the recent investigations supporting vinegar's role as an antiglycemic agent. Epidemiologic studies and clinical trials were identified by a MEDLINE title/abstract search with the following search terms: vinegar, glucose; vinegar, cancer; or vinegar, infection. All relevant randomized or case-control trials were included in this review.

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Vinegar Production

Vinegar, from the French *vin aigre*, meaning “sour wine,” can be made from almost any fermentable carbohydrate source, including wine, molasses, dates, sorghum, apples, pears, grapes, berries, melons, coconut, honey, beer, maple syrup, potatoes, beets, malt, grains, and whey. Initially, yeasts ferment the natural food sugars to alcohol. Next, acetic acid bacteria (*Acetobacter*) convert the alcohol to acetic acid. Commercial vinegar is produced by either fast or slow fermentation processes. For the quick methods, the liquid is oxygenated by agitation and the bacteria culture is submerged permitting rapid fermentation. The slow methods are generally used for the production of the traditional wine vinegars, and the culture of acetic acid bacteria grows on the surface of the liquid and fermentation proceeds slowly over the course of weeks or months. The longer fermentation period allows for the accumulation of a nontoxic slime composed of yeast and acetic acid bacteria, known as the *mother* of vinegar. Vinegar eels (nematoda*Turbatrix aceti*) feed on these organisms and occur in naturally fermenting vinegar.[2] Most manufacturers filter and pasteurize their product before bottling to prevent these organisms from forming. After opening, *mother* may develop in stored vinegar; it is considered harmless and can be removed by filtering. Many people advocate retaining the *mother* for numerous, but unsubstantiated, health effects.

The chemical and organoleptic properties of vinegars are a function of the starting material and the fermentation method. Acetic acid, the volatile organic acid that identifies the product as vinegar, is responsible for the tart flavor and pungent, biting odor of vinegars. However, acetic acid should not be considered synonymous with vinegar. The US Food and Drug Administration (FDA) states that diluted acetic acid is not vinegar and should not be added to food products customarily expected to contain vinegar.[3] Other constituents of vinegar include vitamins, mineral salts, amino acids, polyphenolic compounds (eg, galic acid, catechin, caffeic acid, ferulic acid), and nonvolatile organic acids (eg, tartaric, citric, malic, lactic).[4,5]

In the United States, vinegar products must contain a minimum of 4% acidity.[6] European countries have regional standards for vinegar produced or sold in the area. White distilled vinegars are generally 4% to 7% acetic acid whereas cider and wine vinegars are 5% to 6% acetic acid. Specialty vinegars are grouped as herbal or fruit vinegars. Herbal vinegars consist of wine vinegars or white distilled vinegars, which may be seasoned with garlic, basil, tarragon, cinnamon, clove, or nutmeg. Fruit vinegars are wine and white vinegars sweetened with fruit or fruit juice to produce a characteristic sweet-sour taste. Traditional vinegars are produced from regional foods according to well-established customs. The balsamic vinegar of Modena, Italy, is made from the local white Trebbiano grapes, which are harvested as late as possible, fermented slowly, and concentrated by aging in casks of various woods. Traditional rice wine vinegars are produced in Asia, coconut and cane vinegars are common in India and the Philippines, and date vinegars are popular in the Middle East.

Medicinal Uses of Vinegar

Anti-infective Properties

The use of vinegar to fight infections and other acute conditions dates back to Hippocrates (460-377 BC; the father of modern medicine), who recommended a vinegar preparation for cleaning ulcerations and for the treatment of sores. Oxymel, a popular ancient medicine composed of honey and vinegar, was prescribed for persistent coughs by Hippocrates and his contemporaries, and by physicians up to modern day.[7] The formulation of oxymel was detailed in the *British Pharmacopoeia* (1898) and the *German Pharmacopoeia* (1872), and, according to the *French Codex* (1898), the medicine was prepared by mixing virgin honey, 4 parts, with white wine vinegar, 1 part, concentrating and clarifying with paper pulp.[8]

Recent scientific investigations clearly demonstrate the antimicrobial properties of vinegar, but mainly in the context of food preparation.[9–12] Experts advise against using vinegar preparations for treating wounds.[13] At concentrations nontoxic to fibroblasts and keratinocytes (≤ 0.0025%), acetic acid solutions were ineffective at inhibiting the growth of *Escherichia coli*, group D *Enterococcus*, or *Bacteroides fragilis* bacteria, and only slightly effective at inhibiting the growth of *Staphylococcus aureus* and *Pseudomonas aeruginosa* bacteria.[13] Similarly, experts caution against using vinegar as a household disinfectant against human pathogens because chemical disinfectants are more effective.[14,15] However, undiluted vinegar may be used effectively for cleaning dentures, and, unlike bleach solutions, vinegar residues left on dentures were not associated with mucosal damage.[16]

Although investigations have demonstrated the effectiveness of diluted vinegar (2% acetic acid solution at pH 2) for the treatment of ear infections (otitis externa, otitis media, and granular myringitis),[17,18] the low pH of these solutions may irritate inflamed skin and damage cochlear outer hair cells.[19] Immediate vinegar application at the site of jellyfish stings is practiced at various coastal locations around the world[20,21] because vinegar deactivates the nematocysts. However, hot-water immersion is considered the most efficacious initial treatment for jellyfish envenomation because the venom is deactivated by heat.[22,23]

In the popular media, vinegar is commonly recommended for treating nail fungus, head lice, and warts, yet scientific support for these treatment strategies is lacking. Takano-Lee and colleagues[24] demonstrated that, of 7 home remedies tested, vinegar was the least effective for eliminating lice or inhibiting the hatching of eggs. Scattered reports suggest that the successive topical application of highly concentrated acetic acid solutions (up to 99%) alleviated warts,[25,26] presumably due to the mechanical destruction of wart tissue. One treatment protocol, however, required local anesthesia, excision, and rapid neutralization at the site of application, thus limiting its use by the lay public.

Although not a treatment modality, vinegar washes are used by midwives in remote, poorly resourced locations (eg, Zimbabwe and the Amazon jungle) to screen women for the human papilloma virus infection.[27,28] Contact with acetic acid causes visual alterations of the viral lesions permitting rapid detection of infection with 77% sensitivity[29] and the option of immediate treatment with cryotherapy.

Cardiovascular Effects

Kondo and colleagues[30] reported a significant reduction in systolic blood pressure (approximately 20 mm Hg) in spontaneously hypertensive (SHR) rats fed a standard laboratory diet mixed with either vinegar or an acetic acid solution (approximately 0.86 mmol acetic acid/day for 6 weeks) as compared with SHR rats fed the same diet mixed with deionized water. These observed reductions in systolic blood pressure were associated with reductions in both plasma renin activity and plasma aldosterone concentrations (35% to 40% and 15% to 25% reductions in renin activity and aldosterone concentrations, respectively, in the experimental vs control SHR rats). Others have reported that vinegar administration (approximately 0.57 mmol acetic acid, orally) inhibited the renin-angiotensin system in nonhypertensive Sprague-Dawley rats.[31]

Trials investigating the effects of vinegar ingestion on the renin-angiotensin system have not been conducted in humans, and there is no scientific evidence that vinegar ingestion alters blood pressure in humans. In their report, Kondo and colleagues[30] speculated that dietary acetic acid promoted calcium absorption and thereby downregulated the renin-angiotensin system.[32] In the rat model, acetic acid administration enhanced calcium absorption and retention[33]; moreover, in humans, calcium absorption in the distal colon was enhanced by acetate.[34] Clearly, much work is needed to establish whether vinegar ingestion alters calcium absorption and/or blood pressure regulation in humans.

Whether chronic vinegar ingestion affects other risk factors for cardiovascular disease in humans is not known. Hu and colleagues[35] reported a significantly lower risk for fatal ischemic heart disease among participants in the Nurses' Health Study who consumed oil-and-vinegar salad dressings frequently (5-6 times or more per week) compared with those who rarely consumed them (multivariate RR: 0.46; CI: 0.27-0.76, *P* for trend = .001). Frequent consumption of mayonnaise or other creamy salad dressings was not significantly associated with risk for ischemic heart disease in this population (multivariate RR: 0.84; CI: 0.50-1.44, *P* for trend = .44). The study authors contend that because oil and vinegar dressings are a major dietary source of dietary alpha-linolenic acid, an antiarrhythmic agent, alpha-linolenic acid may potentially be the beneficial ingredient of this food.[35] Yet, creamy, mayonnaise-based salad dressings are also rich in alpha-linolenic acid and did not show the same risk benefit as the oil and vinegar dressings.

Antitumor Activity

In vitro, sugar cane vinegar (Kibizu) induced apoptosis in human leukemia cells,[36] and a traditional Japanese rice vinegar (Kurosu) inhibited the proliferation of human cancer cells in a dose-dependent manner.[37] An ethyl acetate extract of Kurosu added to drinking water (0.05% to 0.1% w/v) significantly inhibited the incidence (−60%) and multiplicity (−50%) of azoxymethane-induced colon carcinogenesis in male F344 rats when compared with the same markers in control animals.[38] In a separate trial, mice fed a rice-shochu vinegar-fortified feed (0.3% to 1.5% w/w) or control diet were inoculated with sarcoma 180 (group 1) or colon 38 (group 2) tumor cells (2×10^6 cells subcutaneously).[39] At 40 days post-inoculation, vinegar-fed mice in both experimental groups had significantly smaller tumor volumes when compared with their control counterparts. A prolonged life span due to tumor regression was also noted in the mice ingesting rice-shochu vinegar as compared with controls, and in vitro, the rice-shochu vinegar stimulated natural killer cell cytotoxic activity.[39]

The antitumor factors in vinegar have not been identified. In the human colonic adenocarcinoma cell line Caco-2, acetate treatment, as well as treatment with the other short-chain fatty acids (SCFA) n-butyrate and propionate, significantly prolonged cell doubling time, promoted cell differentiation, and inhibited cell motility.[40] Because bacterial fermentation of dietary fiber in the colon yields the SCFA, the investigators concluded that the antineoplastic effects of dietary fiber may relate in part to the formation of SCFA. Others have also documented the antineoplastic effects of the SCFA in the colon, particularly n-butyrate.[41] Thus, because acetic acid in vinegar deprotonates in the stomach to form acetate ions, it may possess antitumor effects.

Vinegars are also a dietary source of polyphenols,[6] compounds synthesized by plants to defend against oxidative stress. Ingestion of polyphenols in humans enhances in vivo antioxidant protection and reduces cancer risk.[42] Kurosu vinegar is particularly rich in phenolic compounds, and the in-vitro antioxidant activity of an ethyl acetate extract of Kurosu vinegar was similar to the antioxidant activity of alpha-tocopherol (vitamin E) and significantly greater than the antioxidant activities of other vinegar extracts, including wine and apple vinegars.[43] Kurosu vinegar extracts also suppressed lipid peroxidation in mice treated topically with H_2O_2-generating chemicals.[43] Currently, much interest surrounds the role of dietary polyphenols, particularly from fruits, vegetables, wine, coffee, and chocolate, in the prevention of cancers as well as other conditions including cardiovascular disease[44]; perhaps vinegar can be added to this list of foods and its consumption evaluated for disease risk.

Epidemiologic data, however, is scarce and unequivocal. A case-control study conducted in Linzhou, China, demonstrated that vinegar ingestion was associated with a decreased risk for esophageal cancer (OR: 0.37).[45] However, vinegar ingestion was associated with a 4.4-fold greater risk for bladder cancer in a case-control investigation in Serbia.[46]

Blood Glucose Control

The antiglycemic effect of vinegar was first reported by Ebihara and Nakajima[47] in 1988. In rats, the blood glucose response to a 10% corn starch load was significantly reduced when coadministered with a 2% acetic acid solution.[45] In healthy human subjects, although the glucose response curve was not significantly altered, the area under the insulin response curve following the ingestion of 50 g sucrose was reduced 20% when coadministered with 60 mL strawberry vinegar.[47] Several years later, Brighenti and colleagues[48] demonstrated in normoglycemic subjects that 20 mL white vinegar (5% acetic acid) as a salad dressing ingredient reduced the glycemic response to a mixed meal (lettuce salad and white bread containing 50 g carbohydrate) by over 30% ($P < .05$). Salad dressings made from neutralized vinegar, formulated by adding 1.5 g sodium bicarbonate to 20 mL white vinegar, or a salt solution (1.5 g sodium chloride in 20 mL water) did not significantly affect the glycemic response to the mixed meal.[48] Separate placebo-controlled trials have corroborated the meal-time, antiglycemic effects of 20 g vinegar in healthy adults.[49–51]

While compiling a glycemic index (GI) table for 32 common Japanese foods, Sugiyama and colleagues[52] documented that the addition of vinegar or pickled foods to rice (eg, sushi) decreased the GI of rice by 20% to 35%. In these trials, healthy fasted subjects ingested the reference and test foods, each containing 50 g carbohydrate, on random days, and the food GI was calculated using the areas under the 2-hour blood glucose response curves. In the vinegar-containing foods, the amount of acetic acid was estimated to be 0.3-2.3 g, an amount similar to that found in 20 g vinegar (approximately 1 g). Ostman and colleagues[53] reported that substitution of a pickled cucumber (1.6 g acetic acid) for a fresh cucumber (0 g acetic acid) in a test meal (bread, butter, and yogurt) reduced meal GI by over 30%[53] in healthy subjects.

Recently, the antiglycemic property of vinegar was demonstrated to extend to individuals with marked insulin resistance or type 2 diabetes.[54] In this crossover trial, individuals with insulin resistance (n = 11, fasting insulin concentrations greater than 20 mU/mL) or with diagnosed type 2 diabetes (n = 10) consumed a vinegar test drink (20 g vinegar, 40 g water, 1 tsp saccharine) or placebo immediately before the consumption of a mixed meal (87 g total carbohydrate). In the insulin-resistant subjects, vinegar ingestion reduced postprandial glycemia 64% as compared with placebo values ($P = .014$) and improved postprandial insulin sensitivity by 34% ($P = .01$). In individuals with type 2 diabetes, vinegar ingestion was less effective at reducing mealtime glycemia (−17%, $P = .149$); however, vinegar ingestion was associated with a slight improvement in postprandial insulin sensitivity in these subjects (+19%, $P = .07$).[54] The lack of a significant effect of vinegar on mealtime glycemia in the type 2 diabetics may be related to the use of venous blood sampling in this trial. Greater within-subject variation in glucose concentrations are noted for venous blood as compared with capillary blood; moreover, the concentration of glucose in venous blood is lower than that in capillary blood. Thus, capillary blood sampling is preferred for determining the glycemic response to food.[55]

The marked antiglycemic effect of vinegar in insulin-resistant subjects is noteworthy and may have important implications. Multicenter trials have demonstrated that treatment with antiglycemic pharmaceuticals (metformin or acarbose) slowed the progression to diabetes in high-risk individuals[56,57]; moreover, because these drugs improved insulin sensitivity, the probability that individuals with impaired glucose tolerance would revert to a normal, glucose-tolerant state over time was increased.[57]

In healthy subjects, Ostman and colleagues[58] demonstrated that acetic acid had a dose-response effect on postprandial glycemia and insulinemia. Subjects consumed white bread (50 g carbohydrate) alone or with 3 portions of vinegar containing 1.1, 1.4, or 1.7 g acetic acid. At 30 minutes post-meal, blood glucose concentrations were significantly reduced by all concentrations of acetic acid as compared with the control value, and a negative linear relationship was calculated between blood glucose concentrations and the acetic acid content of the meal ($r = -0.47$, $P = .001$). Subjects were also asked to rate feelings of hunger/satiety on a scale ranging from extreme hunger (−10) to extreme satiety (+10) before meal consumption and at 15-minute intervals after the meal. Bread consumption alone scored the lowest rating of satiety (calculated as area under the curve from time 0-120 minutes). Feelings of satiety increased when vinegar was ingested with the bread, and a linear relationship was observed between satiety and the acetic acid content of the test meals ($r = 0.41$, $P = .004$).[58]

In a separate trial, healthy adult women consumed fewer total calories on days that vinegar was ingested at the morning meal.[50] In this trial, which used a blinded, randomized, placebo-controlled, crossover design, fasting participants consumed a test drink (placebo or vinegar) followed by the test meal composed of a buttered bagel and orange juice (87 g carbohydrate). Blood samples were collected for 1 hour after the meal. At the end of testing, participants were allowed to follow their normal activities and eating patterns the remainder of the day, but they were instructed to record food and beverage consumption until bedtime. Vinegar ingestion, as compared with placebo, reduced the 60-minute glucose response to the test meal (−54%, $P < .05$) and weakly affected later energy consumption (−200 kilocalories, $P = .111$). Regression analyses indicated that 60-minute glucose responses to test meals explained 11% to 16% of the variance in later energy consumption ($P < .05$).[50] Thus, vinegar may affect satiety by reducing the meal-time glycemic load. Of 20 studies published between 1977 and 1999, 16 demonstrated that low-glycemic index foods promoted postmeal satiety and/or reduced subsequent hunger.[59]

It is not known how vinegar alters meal-induced glycemia, but several mechanisms have been proposed. Ogawa and colleagues examined the effects of acetic acid and other organic acids on disaccharidase activity in Caco-2 cells.[60] Acetic acid (5 mmol/L) suppressed sucrase, lactase, and maltase activities in concentration- and time-dependent manners as compared with control values, but the other organic acids (eg, citric, succinic, L-maric, and L-lactic acids) did not suppress enzyme activities. Because acetic acid treatment did not affect the de-novo synthesis of the sucrase-isomaltase complex at either the transcriptional or translational levels, the investigators concluded that the suppressive effect of acetic acid likely occurs during the posttranslational processing of the enzyme complex.[60] Of note, the lay literature has long proclaimed that vinegar interferes with starch digestion and should be avoided at meal times.[61]

Several investigations examined whether delayed gastric emptying contributed to the antiglycemic effect of vinegar. Using noninvasive ultrasonography, Brighenti and colleagues[50] did not observe a difference in gastric emptying rates in healthy subjects consuming bread (50 g carbohydrate) in association with acetic acid (ie, vinegar) vs sodium acetate (ie, vinegar neutralized by the addition of sodium bicarbonate); however, a significant difference in post-meal glycemia was noted between treatments with the acetic acid treatment lowering glycemia by 31.4%. In a later study, Liljeberg and Bjorck[62] added paracetamol to the bread test meal to permit indirect measurement of the gastric emptying rate. Compared with reference values, postmeal serum glucose and paracetamol concentrations were reduced significantly when the test meal was consumed with vinegar. The results of this study should be carefully considered, however, because paracetamol levels in blood may be affected by food factors and other gastrointestinal events. In rats fed experimental diets containing the indigestible marker polyethylenglycol and varying concentrations of acetic acid (0, 4, 8, 16 g acetic acid/100 g diet), dietary acetic acid did not alter gastric emptying, the rate of food intake, or glucose absorption.[63]

Safety of Vinegar

Vinegar's use as a condiment and food ingredient spans thousands of years, and perhaps its use can be labeled safe by default. Yet there are rare reports in the literature regarding adverse reactions to vinegar ingestion. Inflammation of the oropharynx and second-degree caustic injury of the esophagus and cardia were observed in a 39-year-old woman who drank 1 tablespoon of rice vinegar in the belief it would dislodge a piece of crab shell from her throat.[64] (The use of vinegar in these situations is a popular Chinese folk remedy.) Her symptoms resolved spontaneously after several days. Esophageal injury by vinegar is likely very rare but deserves notice. Chronic inflammation of the esophagus is a cancer risk; but, as reported previously,[45] vinegar use was inversely related to risk for cancer of the esophagus.

The unintentional aspiration of vinegar has been associated with laryngospasm and subsequent vasovagal syncope that resolved spontaneously.[65] Hypokalemia was observed in a 28-year-old woman who had reportedly consumed approximately 250 mL apple cider vinegar daily for 6 years.[66] Although speculative, the hypokalemia was attributed to elevated potassium excretion related to the bicarbonate load from acetate metabolism.

These complications attributed to vinegar ingestion are isolated occurrences, but with the increased interest in vinegar as adjunct therapy in diabetes, carefully controlled trials to examine potential adverse effects of regular vinegar ingestion are warranted.

Summary

For more than 2000 years, vinegar has been used to flavor and preserve foods, heal wounds, fight infections, clean surfaces, and manage diabetes. Although vinegar is highly valued as a culinary agent, some varieties costing $100 per bottle, much scrutiny surrounds its medicinal use. Scientific investigations do not support the use of vinegar as an anti-infective agent, either topically or orally. Evidence linking vinegar use to reduced risk for hypertension and cancer is equivocal. However, many recent scientific investigations have documented that vinegar ingestion reduces the glucose response to a carbohydrate load in healthy adults and in individuals with diabetes. There is also some evidence that vinegar ingestion increases short-term satiety. Future investigations are needed to delineate the mechanism by which vinegar alters postprandial glycemia and to determine whether regular vinegar ingestion favorably influences glycemic control as indicated by reductions in hemoglobin A1c. Vinegar is widely available; it is affordable; and, as a remedy, it is appealing. But whether vinegar is a useful adjunct therapy for individuals with diabetes or prediabetes has yet to be determined.

Contributor Information

Carol S. Johnston, Department of Nutrition, Arizona State University, Mesa, Arizona.

Cindy A. Gaas, Department of Nutrition, Arizona State University, Mesa, Arizona.

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Appendix

Catalyst Video Transcript New Research about the interplay between food and bacteria deep with out guts.

Catalyst Video Transcript
Australian Broadcasting Corporation
Gut Reaction Part 2
Broadcast 2nd August 2016

Could our food be making us sick – very sick? In the second episode of this two-part special, Dr Graham Phillips reveals new research about the interplay between food and the bacteria deep within our guts. This program was originally broadcast in 2014 but is back by popular demand.

Narration Reporter: Dr Graham Phillips
Producer: Geraldine McKenna, Co-Producer: Roslyn Lawrence
Researcher: Roslyn Lawrence

Prof Matt Cooper
Institute for Molecular Bioscience
University of Queensland

Transcript

NARRATION
New discoveries about food are rocking the foundations of medicine and nutrition.

Professor Charles Mackay
I think this is one of the biggest developments in medical research. I really think we're encountering a revolution that maybe we can prevent diseases by simply changing our diet.

NARRATION
Last time on Catalyst, we learned about this paradigm-changing new research.

Dr Graham Phillips
The bottom line is the modern Western diet could be making us very sick, contributing to heart disease, diabetes, asthma, emphysema, multiple sclerosis, even autism, and the list goes on.

NARRATION
The reason for the revelation that a good diet is even more important than we thought is the discovery of the many trillions of new contributors to our health - the tiny good bacteria living in our guts ………………………………………

NARRATION
Now, eating more fibre will improve your health. But there are other things you might be able to do, as well.

Dr Graham Phillips
Cheers.

Professor Matt Cooper
Cheers. That's quite sweet.

Dr Graham Phillips
Yeah. That's not bad.

Professor Matt Cooper
Shall we do shots?

Dr Graham Phillips
Shots sound perfect.

Professor Matt Cooper
Shots it is.

Dr Graham Phillips
Cheers.

Professor Matt Cooper
Down the hatch.

Dr Graham Phillips
Hoo!

Professor Matt Cooper
Ahh!

Dr Graham Phillips
Not as sweet. Ah!

NARRATION
This is no social drink. **Professor Matt Cooper** and I may be medicating ourselves. But they won't be adding these tipples to the wine list anytime soon. We're downing different kinds of vinegar because it could turn out to be a medicine.

Professor Matt Cooper
So the most important thing is to have a balanced diet and lots of high fibre. But we've also shown that with a lot of the studies we're doing in animals now that supplementing the diet by giving vinegar can actually stop things like asthma.

NARRATION
Treating asthma with vinegar? It seems remarkable. Unless of course you're into alternative health.

Dr Graham Phillips
The idea of using vinegar medicinally has been around for centuries.

Professor Matt Cooper
Oh, thousands of years, back to the Egyptian times, the Greek times. The beneficial effects of vinegars in society have been known for a long time. Even Italians - a lot of vinegar on salads, a lot of vinaigrette - they have very, very low incidences of

inflammatory disease.

NARRATION
In fact, even the research on eating a good diet has an air of ancient wisdom about it.

Professor Charles Mackay
Hippocrates said 'Let thy food be thy medicine and thy medicine be thy food.' And we agree with that entirely.

NARRATION
The reason vinegar could be a medicine is because it contains acetate - that molecule we met in the first episode, the very one our good bacteria make.

Professor Matt Cooper
So we now know that acetate, which is very small and can get all around the body, can stop the immune system from overreacting.

NARRATION
By calming the immune system, it promotes good health. Matt Cooper developed asthma at about 18.

Professor Matt Cooper
I ended up taking a puffer twice a day and I was taking steroids two or three times a day. I had several incidents where I was really worried, I was almost gonna go to hospital, it was that bad. I was taking puff after puff, I could barely breathe.

Alessio
It hurts your chest a lot when you cough.

NARRATION
But now he's started eating more fibre and using liberal quantities of vinegar.

Professor Matt Cooper
I radically changed my diet. I dropped certain processed foods, I made sure it was brown rice, brown pasta, brown bread, bran in the morning and lots of fresh fruit and vegetables. And now I probably have one puff a year, if that.

Dr Graham Phillips
Really?

Professor Matt Cooper
Yeah.

Gideon Cordover
It's kind of going OK. I miss fast food. I really miss it.

NARRATION
Now, there are no proper clinical trials yet proving that vinegar can treat asthma in people, but there are results for mice. After showing she could reduce asthma in these animals by simply feeding them high-fibre food, Alison tried something else - she fed them acetate instead.

Dr Alison Thorburn
In fact, when we give acetate directly in the drinking water to the mice, that also

suppressed their asthma.

NARRATION
So it seems incredible that simple stuff we splash on a salad may help treat a disease that plagues the Western world.

PURE NATURE

Botanical Innovations

AUSTRALIAN FUNCTIONAL NUTRACEUTICAL FLAVOURS, FRAGRANCES & INGREDIENTS

Plant Extracts-Naturally Fermented Fruits and Vinegars
Cold Pressed Oils-Essential Oils-Phenolic Rich Powders

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NEW LIGHTLY ACIDIC FUNCTIONAL INGREDIENTS WITH CONCENTRATED PHENOLS FOR ADDED HEALTH & WELLNESS BENEFITS

NEW CLASS OF WATER SOLUBLE EXTRACTS WITH AN ACIDIC BASE TO INCREASE SHELF LIFE AND FUNCTIONALITY

FERMENTED RED GRAPE SEED EXTRACT

Shelf stable preservative free slighlty acidic red grape seed extract with concentrated Phenolics, Antioxidants. & Anthocyanins. Total Phenolic content 10,000-50,000mg/L

FERMENTED WHITE GRAPE SEED EXTRACT

Shelf stable preservative free slighlty acidic white grape seed extract with concentrated Phenolics, Antioxidants.. Total Phenolic content 10,000-50,000mg/L

FERMENTED RED GRAPE SKIN EXTRACT

Shelf stable preservative free slighlty acidic red grape skin extract with concentrated Phenolics, Antioxidants.. Anthocyanins & Resveratrol.Total Phenolic content 10,000-50,000mg/L

FERMENTED WHITE GRAPE SKIN EXTRACT

Shelf stable preservative free slighlty acidic white grape skin extract with concentrated Phenolics, Antioxidants.. Anthocyanins & Resveratrol.Total Phenolic content 10,000-50,000mg/L

FERMENTED APPLE PEEL EXTRACT

Shelf stable preservative free slightly acidic apple peel extract with Quercetin, Phenols and Antioxidants. Phenolic content 10,000-50,000mg/L.

Botanical Innovations slow fermentation process ensures its Apple Cider Vinegar is true to nature concentrating all the health and healing propderties, phenolics and prebiotic phytonutrients that have ensured vinegar has survived through the centuries.

APPLE CIDER VINEGAR RAW

Tradionally fermented apple cider viengar with 'Mother'
Unfiltered & Unpasteurised

APPLE CIDER VINEGAR OAK AGED RAW

Traditionally fermented apple cider vinegar aged with oak with 'Mother'.
Unfiltered & Unpasteurised

APPLE CIDER VINEGAR

Traditionally fermented apple cider vinegar.
Filtered & Pasteurised

Made in Australia with 100% Australian Ingredients

Botanical Innovations
ABN 84 151 629 702
Unit 2, 390 Clergate Road
Orange NSW 2800 Australia
Telephone: +61 488196527
General.Industry@bigpond.com
BotanicalInnovations.com.au

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CONTACT US

Botanical Innovations
ABN 84 151 629 702
Unit 2, 390 Clergate Road
Orange NSW 2800 Australia
Telephone: +61 488196527
General.Industry@bigpond.com
BotanicalInnovations.com.au