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The Effect of Various Vinegars on Infectious Diseases and Body Metabolism

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The Effect of Various Vinegars on Infectious Diseases and Body Metabolism

An Honors Program Thesis

By

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Important Terms and Abbreviations

- **Polyphenols:** Micronutrients with antioxidant activity that play an important role in preventing the progression of diabetes and other diseases.
- **Antimicrobials:** An agent that kills microorganisms or stops their growth.
- **Antimicrobial resistance:** When pathogens become resistant to the actions of antimicrobials due to overuse.
- **Microorganisms:** Small organisms, such as bacteria, viruses, fungi, or parasites that invade the tissues of an organism.
- **Pathogen:** Microorganism that causes disease.
- **Epidemics:** Widespread infectious outbreak of a disease during a specific time.
- **Virus:** The smallest agents of infectious diseases that are often round in shape and consist of a small piece of genetic material with a thin protein covering around it.
- **Bacteria:** Are about 10-100 times larger than viruses and often take on the shape of a sphere or a rod. They consist of a ring of DNA surrounded by a fatty membrane.
- **Parasites:** Organisms that live in or on another organism and take nutrients from that organism.
- **Fungi:** Organisms that live by decomposing and absorbing the organic material in which they live on.
- **Prophylactic therapy:** A type of therapy to prevents diseases from occurring.
- **Glycemic Index:** A scale that ranks foods in accordance to what causes the fastest rise in blood sugar.
- **Virulence:** Severity of a disease.
- **Epidemiology:** The study of disease conditions in human populations.

- **Phagocytosis:** Process by which phagocytic cells, such as neutrophils and macrophages, engulf and destroy microorganisms.

Acknowledgements

I would like to thank two professionals for the guidance through this thesis. First, thank you to Dr. Tejas Bouklas for being my advisor and directing me through the process of writing this thesis. Second, I would like to thank Dr. Marci Swede for being my reader and for the helpful advice she provided. The guidance from these two allowed me to complete my thesis to my best ability.

Abstract

Regular vinegar and apple cider vinegar have historically been used as home remedies to cure illness and diseases; however, not enough empirical research has been done to substantiate these assertions. This thesis will discuss the different ways that various vinegar forms affect one's body metabolism, and the effect that they have on infectious diseases. This is an important topic to examine because of the growing number of infectious diseases. Vinegar contains polyphenols, which display antioxidant qualities in the body. Polyphenols found in the acetic acid of vinegar also inhibit microbial growth. This microbial growth is usually controlled by antimicrobials; however these are losing their efficacy due to increasing microbial resistance. Antimicrobial resistance is when microorganisms develop a defense against something that used to be able to kill them in the past. It is also important to see the positive effect that vinegar has on one's body metabolism because of conditions, such as obesity and diabetes, which have also become more prevalent in the world today. Obesity is important to be controlled because it can increase one's susceptibility to other life threatening diseases. Vinegar has been found to lower low density lipoprotein levels, and increase high density lipoprotein levels, which helps deter weight gain. Vinegar has also been found to lower average blood glucose levels in diabetic subjects. Vinegar has also been found to have an anti-obesogenic effect on patients; a few studies documented weight loss in obese people. This thesis investigated the scope of these research studies and reviewed their validity to examine the effect of vinegar on the human body and several infectious diseases.

Introduction

I. Infectious diseases are on the rise

With the growing number of infections caused by microorganisms, such as *Candida albicans,* antimicrobials are increasingly prescribed. Infectious diseases are an issue because if they are not treated properly and efficiently, they can spread to become epidemics. Examples of such global infectious disease outbreaks, often include viruses, such as HIV/AIDS, severe acute respiratory syndrome (SARS), or Zika, but can also be a result of bacterial infections, such as tuberculosis, or fungal infections, such as *Candida auris* (Centers of Disease Control and Prevention).

Infectious diseases are caused by microorganisms, such as bacteria, viruses, fungi, or parasites that invade the tissues of an organism. These microorganisms can be passed through direct or indirect contact. Examples of direct contact where infectious diseases can be passed are contaminated food, water, fecal material, body fluids or animal products. Some diseases can be passed indirectly through the air. Infectious diseases that are passed indirectly are more of a threat to populations because they can be spread faster globally (Black, 2014. Microbiology: *Principles and Explorations*).

Infectious diseases are defined as disorders caused by viruses, bacteria, parasites (protozoans and metazoans), or fungi. A virus is defined as the smallest agents of infectious diseases. Viruses are mostly round in shape and consist of a tiny piece of genetic material with a thin protein covering around it. Viruses are different than the other three microorganisms because they cannot multiply outside of a host cell. They also do not ingest food compared to the more evolved microorganisms, such as protozoans. They get their energy from seizing materials and nutrients from the host cell that they invade. Bacteria are about 10-100 times larger than

viruses and often take on the shape of a sphere or a rod. They consist of a ring of DNA surrounded by a fatty membrane. Bacteria get their energy from the same sources as humans, which are sugars, fats, and proteins. Bacteria are dangerous because they are very adaptable to their environment. They are able to live outside in nature or they can live inside humans or their hosts. Some bacteria also double every 15 minutes, while some take months; however this is a very quick multiplication rate, meaning bacteria could spread quite quickly (Black, 2014. Microbiology: *Principles and Explorations*).

Parasites are very different than bacteria and viruses because parasites cells are very similar to human cells, including having a defined nucleus. Parasites can multiply in a host organism, but some can multiply freely in the environment outside the host cell as well. Waterborne parasites are the main cause of disease in the United States. Fungi are eukaryotes like parasites, meaning they contain a nucleus as well. Fungi are usually found in the forms of mold and spores in the environment. However, when they infect humans they do so in the form of yeasts. Fungal infections usually lead to skin infections and pneumonia. Fungal infections are especially dangerous to people with compromised immune systems (Black, 2014. Microbiology: *Principles and Explorations*).

An important factor to look at when discussing the transmission of infectious agents is the amount of time that an infectious agent can stay alive when passed from one host to another. If it can only stay alive for a few minutes, such as many parasites or fungi, then it has less of a chance to be able to infect another organism. If it can survive hours or days while in transmission from one host to another, such as many bacteria and most viruses, then it is more likely to find another host to infect. An example of a recent global pandemic that spread from indirect contact is the influenza pandemic, also known as the “swine” flu (Centers of Disease Control and

Prevention). This quickly spread globally from travelers around the globe. Fortunately, the scope of the disease was relatively mild in most people. However, this rapid spread of the disease showed us how fast diseases that are airborne can spread. With the ease which with people travel around the world, this increases the chances for infectious diseases to become epidemics.

Infectious diseases are a major cause of death, especially in developing countries. According to the World Health Organization, in 2016 there were three infectious diseases that accounted for the top ten causes of death worldwide. The three infectious diseases were lower respiratory diseases, diarrheal diseases, and tuberculosis. Lower respiratory diseases accounted for about 3 million deaths, diarrheal diseases accounted for 1.4 million deaths, and tuberculosis accounted for about 1.3 million deaths. HIV/AIDS was previously on the list, but the amount of deaths decreased to 0.5 million from 2010-2016. HIV/AIDS is still a major cause of death in developing countries. Malaria is the top cause of death in these countries. The majority of infectious diseases are caused by viruses or bacteria; however some diseases such as malaria are caused by protozoan (Centers of Disease Control and Prevention).

There are some critical challenges with the treatment of infectious diseases that complicate their effectiveness. Some of these challenges are that new infectious diseases continue to emerge, old infectious diseases that were previously cured are starting to re-emerge, there is a breakdown in public health systems, and there is increasing resistance of pathogens to antimicrobials. Another issue with the treatment of infectious diseases and their prevention is climate change. With the Earth getting warmer in places it never used to be, this allows infectious agents to live and spread to parts of the world where they were previously unable to live and thrive. For example, mosquitoes, which carry viruses and other microorganisms are now

inhabiting new environments and successfully spreading disease over a wider geographical region.

II. Apple cider vinegar as an antimicrobial treatment

With adequate treatment, potentially universal and fatal diseases can be treated. However, the problem with the frequent prescription of antimicrobials to address these infectious diseases is that antimicrobial resistance is on the rise (Darshna, et al. 2018). Antimicrobial resistance is when pathogens become resistant to the actions of antimicrobials due to overuse. Bacteria, viruses, and other microorganisms change and adapt over time, developing a resistance to the original antimicrobial, which causes them to be ineffective in combating the disease. According to the World Health Organization, infections due to antibiotic resistant pathogens will cause severe patient health issues in the future. This can lead to increased hospital stays and costs, which causes a problem for patients, healthcare professionals, and the economy. The search for alternative antimicrobials is important for the treatment of future infections due to these microorganisms. The use of apple cider vinegar (apple cider vinegar) as one of these alternative treatments has some potential in treating these infections. This may be a way to combine if not circumvent reliance on antimicrobials.

The antimicrobial qualities of apple cider vinegar are said to be due to the phenolic acid content. Phenolic acid is a polyphenol; polyphenols are found in grapes, berries, dark chocolate, coffee, tea, and plants. The polyphenols in plants are made in response to harsh outdoor conditions and help protect them from (Kowalczyk, 2015). Polyphenols display a large range of biological activities, including antimicrobial qualities, which have a positive effect on human health. Recent findings show that certain properties in polyphenols interact with

neurotransmitters in the brain. This interaction could suppress neuroinflammation and prevent toxic and degenerative effects (Almeida, 2016). Polyphenols, which consist of aromatic rings, are also capable of quenching free radicals, which makes them antioxidants. Free radicals harmfully alter lipids, proteins, and DNA and trigger a number of human diseases (Lobo, 2010).

A balance between free radicals and antioxidants is important for the proper physiological functioning of the human body. A number of studies have shown that dietary polyphenols exert a protective effect against hypertension, dyslipidemias, inflammation, endothelial function, and atherosclerosis. Hypertension is another term for high blood pressure, when the force of the blood against the artery walls is too high. Dyslipidemia is when lipids, which are composed of fatty acids such as triglycerides and cholesterol, are too high in the blood. Inflammation usually occurs as a defense mechanism in the body; however, it can lead to other diseases when it is chronic. The endothelium functions to control the passage of immune cells, such as white blood cells, in and out of the bloodstream. Atherosclerosis is the buildup of plaque inside of the artery walls. Plaque is composed of fats, cholesterol, and other substances. This buildup of plaque causes an obstruction of blood flow, which can lead to heart attacks and/or strokes. These are all conditions associated with an increased risk for cardiovascular disease (Murillo, 2017).

An important finding from the effects of vinegar is its positive effect on killing bacterial and fungal pathogens. According to a study done by Yagnik *et. al.*, the presence of apple cider vinegar prevents the fungal pathogen, *Candida albicans*, from spreading as they normally would (Figure 1). It exerted a similar influence as antimicrobials. This is significant because if apple cider vinegar could be used instead of antimicrobials to kill microorganisms, such as *C. albicans*,

then healthcare providers would not have to prescribe antimicrobials as often, or could combine antimicrobials with a prophylactic therapy that includes apple cider vinegar (Yagnik, 2018).

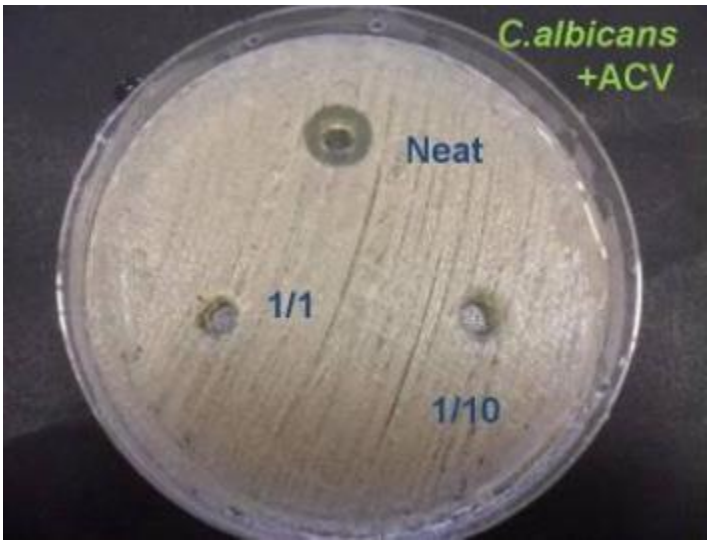

Figure 1. This picture (Yagnik, 2018) represents how a full dosage of apple cider vinegar is needed to kill a microorganism. 1/10 means 1 part apple cider vinegar and 9 parts water. 1/1 means 1 part apple cider vinegar and 1 part water. Neat means a full dosage of apple cider vinegar. One can see how around the "neat" dosage, there is the highest inhibition of microbial growth.

III. Additional benefits of apple cider vinegar

Studies have been done to show the effect apple cider vinegar on glucose and lipid levels in one's bloodstream. This is important to learn about because according to the National Institute of Diabetes and Digestive and Kidney Diseases, more than two out of three adults in America are considered to be overweight or obese. Obesity is an important issue as it can predispose one to diseases, such as type 2 diabetes, heart disease, gallbladder disease, stroke, hypertension, dyslipidemia, osteoarthritis, sleep apnea, coronary heart disease, and even certain types of cancer

that are some of the leading causes of preventable death. In order to determine if one is obese, healthcare providers measure a person's body mass index (BMI). BMI is a number that represents the body's mass compared to height. A healthy BMI ranges between 18.5 and 24.9, while 25-29.9 is considered overweight, and anything over 30 is considered obese. Based on these criteria, the majority of Americans are overweight or obese.

If apple cider vinegar could be conclusively proven to be a useful method for weight loss, this would benefit the aforementioned population. According to a study done by Shishehbor *et. al.* 2008, apple cider vinegar lowered the lipid profile of rats fed vinegar with low and high glycemic index diet. Glycemic index is a scale that ranks foods in accordance to what causes the quickest rise in blood sugar. It is beneficial to have a low glycemic index because then one metabolizes food much slower, which causes a steady rise in the glucose levels in blood. This leaves one feeling more energized without craving sugar. Interestingly, in the study, lower triglyceride and low density lipoprotein levels and increased high density lipoprotein levels, associated with a better lipid profile was seen in both normal and diabetic rats.

Thus, apple cider vinegar may have added benefits when discussing glycemic index. In addition, it serves as an antimicrobial treatment to improve the burden of infectious diseases and antimicrobial resistance. The number of studies done towards this work is very limiting, but presented here nonetheless. More research will need to be done to validate many of these findings.

Hypothesis

Apple cider vinegar and other polyphenol-containing vinegars can serve as an antimicrobial treatment to improve the burden of infectious diseases and antimicrobial resistance. These treatments can provide additional benefits to improve body metabolism.

Materials and Methods

This thesis is a result of analysis of multiple research studies regarding the effects of vinegars on body functions and infectious diseases. Primary and secondary research articles were found on a database maintained by the National Center for Biotechnology Information at the National Institute of Health (pubmed.gov). This is a well-established resource that contains research studies on life sciences and biomedical topics that are peer-reviewed.

To search the relevant primary articles and secondary articles (reviews), the following keywords were used in various combinations:

"apple cider vinegar"

"vinegar health"

"vinegar and weight loss"

"vinegar and glycemic index"

"vinegar and diabetes"

"infectious diseases"

"antimicrobial resistance".

Searching for "apple cider vinegar" yielded 70 results. With "vinegar weight loss", there were 229 results; however only a few of them were relevant to the hypothesis. For "vinegar and glycemic index," 15 results were found. "Vinegar and diabetes" yielded 417 results. Out of these 417 results, only eight were relevant to the hypothesis. As expected, keywords, such as "infectious diseases" and "antimicrobial resistance" yielded several results, 315,568 and 215,706 respectively. Of these 52,445 were reviews, and the most recent findings were used to narrow the number of articles.

For the most part, each study was organized in the same format. Each contained an abstract, an introduction, materials and methods, results, and a discussion. The abstract contained a general summary of the entire research study, and was used to first determine if the study was relevant to the hypothesis and should be included in this thesis. It explained important factors, such as how the experiment was run, how results were obtained, who the study was done on, when and where was it done, and more. It also briefly explained the results and a general statement of the importance of the experiment. The introduction of the research studies gave a background of why the study should be done, and how it would be useful and helpful. It also explained to what is tested and the relevant background. Next was the materials and methods section, which explained the procedure done in the study. This is where experimental/placebo groups, subjects/participants, and protocols were explained in detail. It also explained how results were going to obtained. The results section provided the data, and the outcomes of the experiment; usually comparing the placebo with the experimental groups. The discussion made conclusions about apple cider vinegar with regard to the results obtained in the experiment. The discussion is where the researchers explained the importance of their results to the field.

After analysis of article, brief summaries of each study were written and compiled into an annotated bibliography prior to writing the thesis. Several studies and a textbook (Nutrition: Concepts and Controversies), constituted the literature search to investigate the hypothesis presented here. The fact that the literature on apple cider vinegar is so limited highlights the fact that more research needs to be done to examine its effect on infectious diseases, and on the body's metabolism.

Results

I. The scope of infectious diseases

Microbial infections and diseases are common, widespread and on the rise. Antimicrobial agents used for the treatment of these infections often have undesirable side effects with expensive costs. Antimicrobial resistance is also an issue, where our bodies adapt to these antimicrobials, which causes issues treating people with these recurrent infectious diseases. This increaseing resistance of the microorganisms to the antimicrobial drugs causes us to look into alternative remedies, including ones not sourced from microorganisms as many antimicrobials currently are. The search for natural antimicrobial compounds continues to receive widespread attention (Lastauskienė, et. al. 2014).

Well known bacterial pathogens, such as *Staphylococcus aureus* and *Mycobacterium tuberculosis*, are an issue because they acquire new virulence due to antimicrobial resistance (Van der Meer et. al. 2013). According to Van der Meer, the emerging infections reflect the adaptable nature of the organisms within the microbial world. Due to the versatile nature of these microorganisms, major challenges will continue to rise for those involved in the research of infectious diseases. To use preventative treatments to stop these microorganisms from evolving could be more straightforward than previously thought, and things that we that are readily available could end up saving lives.

There are important challenges faced when it comes to dealing with the proper treatment of infectious diseases. The challenges that stand in the way when trying to address these diseases may be hard to overcome. One challenge includes climate change and the animals that come along with it. For example, the warmer weather due to climate change brings mosquitoes, which are vectors that carry several pathogens, to dwell and multiply in new places (Figure 3).

Mosquitoes can carry infectious diseases, such as Zika and Dengue, that can spread to healthy individuals, and for which we do not have conventional antimicrobial treatments. Another issue with addressing infectious diseases is the overuse of antimicrobials that leads to antimicrobial resistance. Invading parasites adapt to antimicrobials that are used and become immune to them. Also, when dealing with infectious diseases, there is too much conflicting data. This makes it hard to pinpoint the original issue and address it efficiently. High numbers of immunocompromised patients also make it difficult to address infectious diseases because there are so many pathogens out there, and testing does not include the less common ones. The last issue in dealing with the treatment of infectious diseases is that new pathogens are constantly emerging. Old pathogens are also re-emerging due to antimicrobial resistance, which makes it difficult to contain infectious diseases (Centers of Disease Control and Prevention).

Figure 2. Locations of emerging infectious diseases are located. The number on each country represents the number of people living with HIV/AIDS at the end of 2002. Some of these infectious diseases are re-emerging (Racaniello, 2004).

According to a report by Madeline Drexler called, "What You Need to Know about Infectious Disease," a lot of progress has been made on our part in curbing the spread of infectious diseases. This includes, but is not limited to keeping immunizations up to date, general hygiene, proper handling of food and water, and use of antibiotics only for bacterial infections, and completing the course of those antibiotics. Because many diseases can be spread from animals or insects to human, cleansing wounds or wearing repellents should also be practiced.

HIV/AIDS continues to pose a threat along with other sexually transmitted diseases, and therefore safe sex practices and avoiding risk of exposure to needles is important. Given that much of the world is close to us geographically, it is important to learn and take measures when traveling to moderate-to-high disease risk countries (Drexler, 2010). Despite these available recommendations and their practice, it is still possible to acquire infectious diseases.

Infectious diseases continue to be on the rise due to new infectious agents, as well as antimicrobial resistance. According to the Centers for Disease Control and Prevention, antimicrobial resistance. About one fourth of deaths worldwide were due to infectious organisms, many in children in the twentieth century. Infectious diseases were also the cause of most premature death and disabilities until the end of the twentieth century (Holmes, 2017). Infectious diseases, such as smallpox, cholera, and influenza have threatened entire populations in the past. This shows how dangerous infectious diseases could be and the importance of finding different methods when antimicrobials become ineffective. Although vaccines and antimicrobials are available for some of the major infectious diseases, many are underused because of cost and lack of access contributing to poorly functioning health care systems (Holmes, 2017). The development of new drugs to combat these infectious diseases is needed now more than ever.

An important factor that should be considered when discussing infectious diseases is climate change. Climate change is an extreme factor when dealing with infectious diseases because it causes their epidemiology to shift. Climate change refers to the long term change in weather conditions and the extreme weather conditions that are accompanied with it (Wu, 2016). The role of human activities has played a major role in climate change, and for the worse, for infectious disease spread. According to the European Environment Agency in 2008, the world's average surface temperature has increased by 0.74 °C in the 20th century, the global sea level has

been rising 1.8 mm per year since 1961, and the Arctic sea ice has been shrinking by 2.7% per decade. Also, mountain glaciers are contracting, ocean water is becoming more acidic, and extreme weather events are occurring more often.

According to the Intergovernmental Panel on Climate Change, a predicted average temperature rise of 1.5–5.8 °C is expected across the world during the 21st century. This temperature rise can lead to extreme weather events, including heat waves, floods, and droughts. In this review, the researchers suggested a sustainable development approach to counter the effect of climate change. Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Shah, 2008). With this climate change, it allows for new infectious diseases to develop, reproduce, distribute, and transmit to hosts. Different studies also found that the warming of climate leads to more spread of a select number of infectious diseases, and that extreme climate changes and weather outbreaks create opportunities for groups of disease outbreaks in unexpected areas (Shah, 2008). The infectious diseases that are most sensitive to climate change are the ones that are carried by vectors, such as insects. This is because climate change allows for insects to live in previously uninhabited areas, thus allowing for expansion and spread of the diseases they carry.

By observing the figure below (Figure 4), the authors showcase how climate change is interlinked to infectious diseases and impacts society. Climate change is described here by temperature, amount of precipitation and humidity, wind and dust, and other factors. Infectious diseases can be vector-borne (transmission from bite of infected arthropods), water-borne, food-borne, air-borne, and other ways.

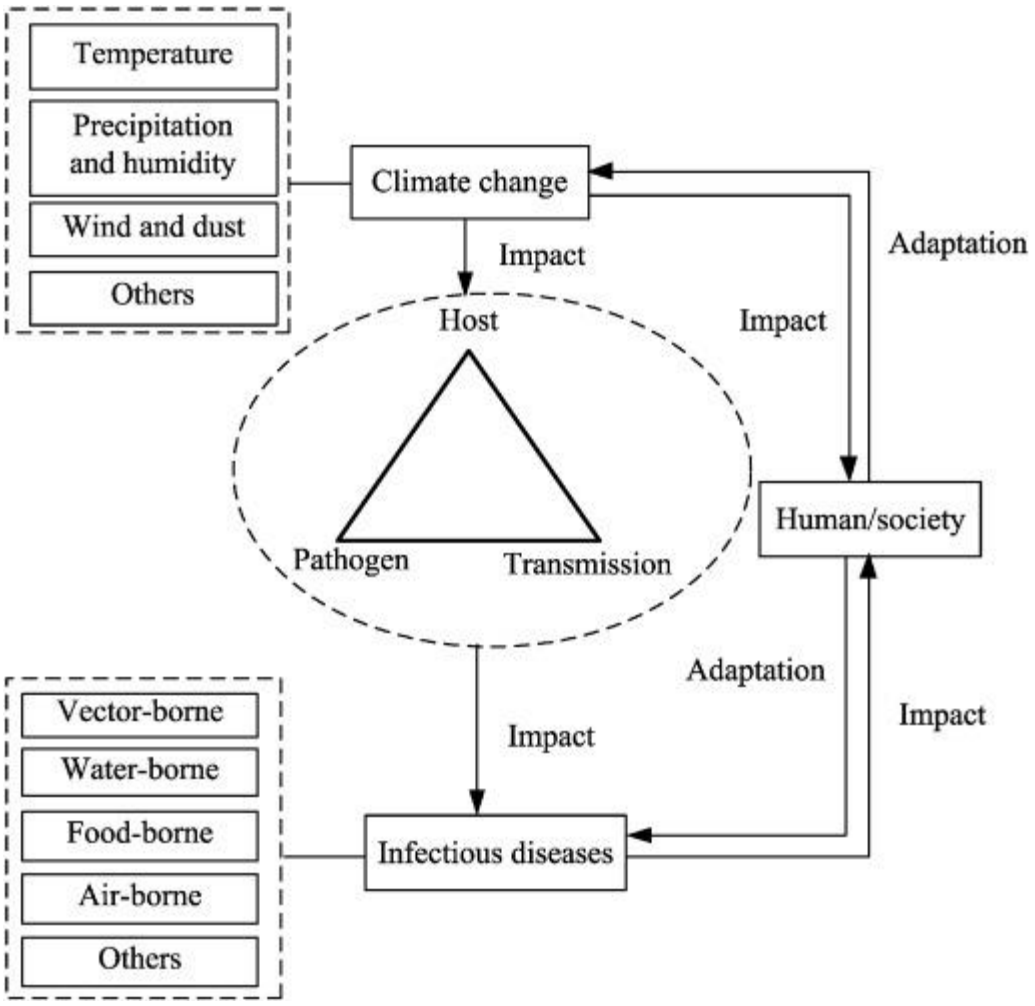

Figure 3. A scheme outlining the impact of climate change, infectious diseases, and society (Shah, 2008)

II. Preliminary studies on vinegar as an antimicrobial treatment

One readily available alternative for antimicrobial treatment is vinegar. Organic acids in vinegars can successfully inhibit the growth of bacteria. According to Figure 2 below, first, they destroy the outer cell membrane of bacteria. Second, they inhibit macromolecular synthesis, and prevent energy production in bacteria. This causes an increase in intracellular osmotic pressure, which could by itself cause cellular lysis. Lastly, this promotes the generation of antibacterial

peptides to exposed bacterial components in host cells. This increase in the generation of antibacterial peptides also facilitates further destruction of bacteria in the host cell.

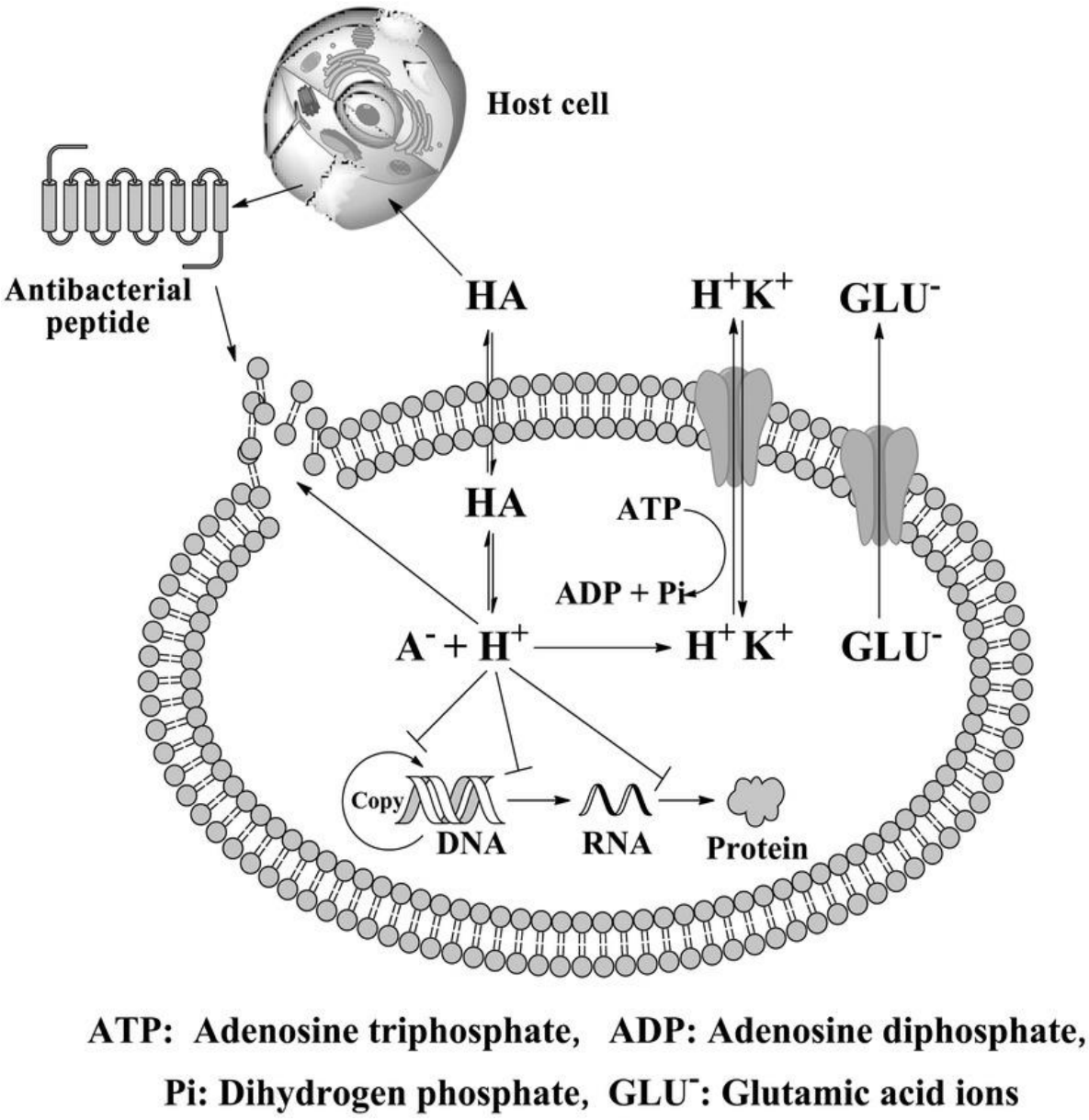

Figure 4. A scheme to show how organic acids in vinegars inhibit the growth of bacteria (Zhang et. al. 2011).

A few studies have been done on specific microorganisms to see if apple cider vinegar has any effect on them. One study tested to see if the induction of apple cider vinegar would have any microbial effects against *Escherichia coli, Staphylococcus aureus,* and *Candida albicans* (Yagnik et. al. 2018). Results were found by comparing the cytokine secretion of *E. coli, S. aureus,* and *C. albicans* that were treated with apple cider vinegar, compared to those that were not treated. The purpose of this study was to see if a conventional remedy could be used to help fight off microorganisms instead of using antimicrobials. This is important and could be useful in the health field because antibiotics are given out to patients so much that antibiotic resistance is a major problem these days. Antibiotics reduce the release of pro-inflammatory cytokines associated with bacteria, and this experiment assessed if apple cider vinegar has a similar reducing effect.

The results on these three microorganisms treated with apple cider vinegar indicated that it has a suppressing effect on microbe growth, cytokine production, and phagocytic responses. The presence of apple cider vinegar suppressed the microorganisms from spreading as they normally would. It also expressed similar characteristics in the microorganisms as anti-pathogenic compounds, such as antimicrobials, would. Apple cider vinegar was shown to increase phagocytic potential of monocytes. This is significant because microbial phagocytosis is important in innate immunity, which is the body's natural response to invading agents and infections. While this study is promising, it was done *in vitro,* and the efficacy of apple cider vinegar in the setting of the host or an animal model will still need to be assessed.

The body's innate immune response is important because sometimes the body does not respond to drug prescriptions or in immunocompromised individuals, it is the sole defense. For example, in a study done by Ozen (2017), the effect of apple cider vinegar was investigated on a

vaginal candidiasis infection caused by the fungus, *C. albicans. Candida* is a microorganism that is naturally found in the vaginal area. High numbers of *Lactobacillus* bacteria keep its growth in check. However, if there is an imbalance of *Candida* and *Lactobacillus*, this microbial antagonism is lost. This leads to an overgrowth of yeast, which causes the symptoms of vaginal yeast infections (Johnson, 2018). When people do not respond to medical treatment prescriptions, this is an alternative remedy may be necessary.

In the aforementioned study, a 32 year old woman was admitted into the facility for a chronic vaginal candidiasis infection. She had recurrent symptoms for five years now, during which time she had been seen by six different physicians and prescribed seven different antifungal regimens. Her last treatment relieved discomfort efficiently; however it only lasted 20 days. This is because of the strong recurrence rate that *C. albicans* exhibits. After having a child, she still had painful vaginal pains and intense foul-smelling discharge. Her treating physician for her delivery recommended a vaginal douche mixed with 20 mL of apple cider vinegar and 1 L of water for application. She used it twice daily for four months. Two years later, she reported no signs of the infection. This was the only treatment that proved to get rid of vaginal candidiasis infection. The researchers proposed that the infection went away from the acetic acid in the apple cider vinegar. Given that this research was based on one subject, and has since not been validated by other investigators, it is difficult to conclude the researchers' claim (Ozen, 2017).

Acetic acid has been shown to be a potential treatment option for various infections. Acetic acid prevents the development and growth of bacteria and fungus, especially in wounds and infections. It is found in vinegar, and the acetic acid is what causes the foul smelling odor that vinegar has. Since acetic acid is the main component in vinegars, it was found that this is the main reason for apple cider vinegar's antimicrobial capabilities. In a study by Mota et. al., it was

found that apple cider vinegar actually inhibited the fungal effect of *Candida* compared to the antifungal prescribed to those diagnosed with denture stomatitis (Mota, 2015).

Denture Stomatitis is the swelling of a person's gums due to the over-wear of dentures. This swelling is caused by *Candida. Candida* is a commensal and normally found in the mouth and is not life-threatening. Besides the mouth, it is also present in the rectum and digestive tracts. The problem occurs when people do not practice good hygiene with the use of their dentures. Without the practice of good hygiene, this allows for uncontrolled growth of this fungus. Swelling, and sometimes red sores can occur on the person's gums, which causes them discomfort, and puts them at risk for other oral diseases. This study was done to see if the use of apple cider vinegar could limit the amount of microbial growth on the dentures, which would prevent the swelling of the gums and the sores from occurring.

This test was done using a microdilution technique, which measured the minimum inhibitory concentration and minimum fungicidal concentration of apple cider vinegar compared to the commonly prescribed antifungal, Nystatin. After about 30 minutes of exposure, their results showed that apple cider vinegar inhibited fungal activity by about four times better than Nystatin, which maintained its same fungicidal effect. Another positive that the apple cider vinegar had on the dentures was that it did not alter the surface roughness of the acrylic resin that is present on dentures. This is a problem with antimicrobials because some corrode this resin, as seen with the Nystatin.

Thus, apple cider vinegar may be potentially used for those suffering from vaginal candidiasis and denture stomatitis, and likely should be considered for other fungal infections, which are on the rise from overuse of antibiotics, and also for which there are not enough developed antifungals.

III. Phenolic and vinegar-based treatments to address the rise in infectious diseases

Studies support that vinegar has many positive effects on health. These effects include antibacterial, anti-infection, antioxidation, blood glucose control, lipid metabolism regulation, weight loss, and anti-cancer activities. These functions on health are due to the presence of organic acids, polyphenols, and melanoidins in vinegar (Chen, 2016). Polyphenols, specifically, act as antioxidants, reducing the risk of diseases, especially type II diabetes and cardiovascular diseases. A study done by Xu et al (2007), demonstrated that melanoidins in vinegar are important for antiradical and antioxidant properties.

A study was done to determine the antioxidant capacity of three apple cider formulations in Poland. This study performed by Kowalczyk (2015) determined antioxidant capacity by measuring each cider's phenolic acid content. Phenolic acid is a polyphenol; polyphenols are found in fruit and plants and help protect them from harsh conditions they may face outdoors. When polyphenol is extracted and ingested by humans, it is shown to have a positive effect on the body by working as an antioxidant. To determine phenolic content, the Folin-Ciocalteu method was used. Phenolic content was measured spectrophotometrically, which measures the transmission properties of a certain material as a wavelength. The three samples (cider A, B, and C) were incubated for 20 minutes at room temperature after they were diluted and then saturated with sodium carbonate and distilled water. They were then centrifuged for five minutes, and the supernatants were used for spectrophotometric determination. The conclusion was that cider B had the highest antioxidant capacity, followed by cider C, and cider A. It was confirmed that the antioxidant capacity of the ciders was due to their polyphenols. The researchers came to the conclusion that the different antioxidant capacities are due to the different apples used in each

cider. Since these ciders were found to have antioxidant capabilities, other ciders will be need to analyzed to further assess their beneficial effect on consumer health.

A study by Valdes (2015) discussed the relationship between phenolic compounds and gut microbiota, and the impact that this relationship has on human health. Gut microbiota plays an essential role in the maintenance of human health. However, it is often altered by external factors, such as the use of medication or dietary patterns, which affect it negatively (Valdes, 2015). Phenolic compounds are said to have antioxidant capabilities, anticarcinogenic capabilities, and antimicrobial actions. They are found in high quantities in many fruits, nuts/seeds, and whole grains, which are often consumed. Imbalances in the composition and function of gut microbiota can be detrimental to health, and possible causes of intestinal, metabolic, and autoimmune disorders (Valdes, 2015). An imbalance of gut microbiota was also found in obese people. Gut microbiota is also important for its ability to fight off pathogenic microorganisms. Phenolic compounds may therefore play an important role in making sure the gut microbiota stays healthy, and improve health and nutrition in people.

There are a sheer number of beneficial and detrimental microorganisms that inhabit body, and at least one study by Pietrangelo (2016) tested the effects of apple cider vinegar on some of these microorganisms. Specifically, the study looked at *Lactobacillus casei* in a common carp fish diet. *L. casei* is one of the many beneficial microorganisms found in our gut, and has a positive effect on digestive disorders, such as constipation, Crohn's disease, Inflammatory Bowel Disease (IBD), Irritable Bowel Syndrome (IBS), lactose intolerance, and ulcerative colitis (Pietrangelo, 2016). Apple cider vinegar contains acetic acid, polyphenolic compound, minerals, vitamins, and amino acids that are said to have immuno-stimulant and antimicrobial properties.

The aforementioned study was performed on 360 common carp (*Cyprinus carpio*) fish that were on six different feeding diets. The six diets were: control diet, *L. casei*, 1% apple cider vinegar, 2% apple cider vinegar, *L. casei* with 1% apple cider vinegar, and the *L. casei* with 2% apple cider vinegar. A few different effects on the immune system were observed in these fish compared to the experimental group diets. First, with regard to the antimicrobial chemicals present on skin mucus, the highest lysozyme activity was found in those fed the combinations of *L. casei* with apple cider vinegar compared to the control group. Also, the highest serum lysozyme activity was recorded in those fed the *L. casei* and 2% apple cider vinegar diet compared to the rest of the groups. Another important result was that the highest mRNA expression of immune-related genes was found in the fish supplemented with the *L. casei* and apple cider vinegar diets, and the lowest was found in the control group. Further, the highest antioxidant enzymes gene expression was found in those fed the *L. casei* and apple cider vinegar diet. This study is important because it shows the immuno-stimulant properties from a diet containing apple cider vinegar and *L. casei* on common carp fish, and this approach could be used in the future for health promoting reasons in humans.

In a study by Chen et. al. (2016), several conclusions were made about the effect of different types of vinegars, including fruit, grain, and apple-based, on pathogens. By soaking vegetables in fruit or grain vinegar for a short period of time, it was found that pathogenic bacteria were successfully eliminated. The study also concluded that fruit vinegars, which contained 1% acetic acid, effectively inhibited growth of food-borne pathogens. These pathogens included *Escherichia coli, Salmonella enteritidis, Salmonella typhimurium, Vibrio parahaemolyticus, Staphylococcus aureus, Aeromonas hydrophila,* and *Bacillus cereus.* Grain vinegars were found to successfully destroy respiratory pathogens, including *Micrococcus*

catarrhalis, *Staphylococcus albus*, *Diplococcus pneumonia*, and *Alpha streptococcus.* And lastly, apple cider vinegar was found to strongly inhibit growth of other pathogenic bacteria, including *Staphylococcus epidermidis, Pseudomonas aeruginosa, Proteus mirabilis,* and *Klebsiella pneumoniae* (Chen et. al., 2016).

The aforementioned study also looked at the effect of vinegar on cancer cells. It explained how the rapid growth of cancer cells was inhibited by the ethyl acetate extracted from Shanxi aged vinegar and Japanese black vinegar. Ethyl acetate is the acetate ester formed between acetic acid and ethanol. The experiments in the study were performed *in vitro*, and while results will need to be validated *in vivo,* they are nonetheless promising. The authors concluded that the ethyl acetate extracts from the Japanese black vinegar specifically increased the expression of p21 genes, and facilitated human colon cancer cells that were in the G0/G1 phase to undergo apoptosis, which is programmed cell death. Also enabling apoptosis was seen in oral cancer cells by receptor binding of a serine threonine kinase 3 (Nanda et. al. 2004; Baba et. al. 2013). Thus, the article established the mechanism behind the observation. It was also mentioned that research has been done on fruit vinegars' polyphenols, and their anticancer activities. When ingested in the long-term, these fruit vinegars may have a positive anticancer effect, but no follow-up experiments have been performed.

IV. Effects of apple cider vinegar on glucose levels and glycemic index

Given that obesity is on the rise in the United States, research has to be done on helping individuals maintain a healthy weight beyond. According to the textbook, Nutrition: Concepts and Controversies, the average body weight of males and females from 1980 to 2010 has increased by 20 pounds. This is partly due to added sugars in processed foods, including sugary desserts and sugar-sweetened soft drinks. The daily caloric intake from 1980 to 2010 has also increased by 3,000 calories. A limited number of studies point to apple cider vinegar as being able to positively affect our blood, glucose, and lipid levels, although it is difficult to conclude based on these alone whether that is enough to counter obesity. Most literature still supports a healthy diet and exercise to maintain health (Centers of Disease Control and Prevention).

Blood glucose levels change after a meal, and in a few studies, it was proven that apple cider vinegar positively affected this change in levels. After ingestion of a meal, first glucose levels rise, then the pancreas secretes the hormone insulin, which stimulates tissues to take up glucose from blood, and this also stimulates glycogen storage from liver. Blood glucose goes back to normal, and then it declines as it is broken down in the process of glycolysis. When energy is needed, the pancreas releases the hormone glucagon, which causes the liver to break down the stored glycogen in a process known as gluconeogenesis to release glucose into the bloodstream. The blood glucose levels then rise back to normal (Sizer, 2017). It is important to know the process of how glucose levels work, especially in people with diabetes, where the process is not the same. People with type II diabetes are resistant to insulin, and may get it from lack of exercise, poor diet, or genetics. In people with type II diabetes, the blood glucose levels rise to abnormally high levels in a condition known as hyperglycemia. A study was done on people with type II diabetes to see if the ingestion of apple cider vinegar at night time would

reduce glucose levels in the morning (Centers of Disease Control and Prevention). If this remedy could be helpful in decreasing fasting glucose levels, this would be another potential treatment for adults with diabetes.

A study done by Andrea White and Carol Johnston was conducted on four men and seven women with type II diabetes, who were not taking insulin. It is important to know that they are not taking insulin because insulin helps control blood sugar levels, and this confounding variable was eliminated, and showed whether apple cider vinegar has any effect on their glucose levels without the influence of any insulin. The food intake was identical for each adult. Each subject's fasting glucose levels were measured by a glucometer, which is a test strip that measures glucose levels on a small blood sample. For two days, all of the participants were required to have the same diet. Due to a randomized sample, subjects were required to drink 2 tablespoons of apple cider vinegar or water at bedtime with 1 ounce of cheese. The purpose of the cheese was to make the ingestion of apple cider vinegar easier. Blood glucose levels were measured before and after the study began. The results of the study were that fasting blood glucose levels decreased in adults who took a placebo as well as the adults who drank apple cider vinegar. Specifically, in adults that received the placebo, glucose levels decreased by 2%, and in adults who drank vinegar, they decreased by 4%. It was determined that the decrease in glucose levels in the adults that received placebo was due to a change in diet. It was also determined that the acetic acid in apple cider vinegar alters glycolysis and the gluconeogenic cycle that occurs in the liver. While this finding may not be a substantial treatment yet, it may benefit those individuals who have metabolic disturbances in their body, or those who may be predisposed to diabetes (White, 2007).

Another important area associated with blood glucose homeostasis that should be

investigated is blood lipid levels since both metabolic processes share key molecules. Blood lipid profiles can be tested and measure the amount of cholesterol and fats in the blood called triglycerides. There are four types of lipoproteins: chylomicrons, very-low-density lipoproteins (VLDL), low-density lipoproteins (LDL), and high-density lipoproteins (HDL). LDLs have more lipid, and less protein, which means more triglycerides, phospholipids, and cholesterol compared to the other proteins. HDLs contain fewer lipids and more protein, making the presence of HDLs in the bloodstream better for health compared to LDLs. Some recommendations from Nutrition: Concepts and Controversies, are to lower LDL levels by reducing the amount of saturated and trans fats in one's diet, and to raise HDL levels by certain foods and physical activity.

A study done by Shishehbor (2008) used a rodent model to determine if apple cider vinegar is more effective at inducing hypoglycemia (lowering glucose levels in bloodstream) and hypolipidemia (reduce level of lipids and lipoproteins in blood) instead of pharmaceutical products that do the same. The subjects of the experiment were normal and diabetic rats. The investigators observed the effects of apple cider vinegar on fasting blood glucose, lipid profiles and HbA1-c in these rats. HbA1-c is a better indicator of blood glucose levels since it quantitates average blood glucose sugar levels in the last two to three months. In order to obtain diabetic rats, diabetes was induced by Streptozotocin. The rats were split into 4 groups: healthy control, healthy apple cider vinegar, diabetic control, and diabetic apple cider vinegar.

After four weeks, the results concluded that fasting blood glucose level was not affected by apple cider vinegar. However, diabetic rats that were given apple cider vinegar showed a significant decrease in HbA1-c of about 18.8%. High density lipoprotein was also significantly reduced in diabetic control rats after the four weeks. On the other hand, the diabetic rats who consumed apple cider vinegar high density had significantly increased lipoproteins by 18%.

These results indicate that diets containing apple cider vinegar have a beneficial effect on serum lipid profiles, but not necessarily blood glucose profiles, of both the healthy and diabetic rats, as well as reduction of their HbA1-c levels. These decreased HbA1-c levels could be the result of the acetic acid in apple cider vinegar in lowering glycemic index. Further studies will need to be done in human trials to validate these findings.

	FBG (mg dL^{-1})		HbA1-c (%)	
Groups	Before treatment	After treatment	Before treatment	After treatment
Normal (n = 8)	98±13	94±14	2.9±0.3	2.8±0.2
Normal+vinegar (n = 10)	92±15	75±24	2.9±0.3	3.2±0.4
Diabetic control (n = 6)	239±68	236±80	6.0±0.8	6.0±0.9
Diabetic+vinegar (n = 7)	249±84	200±69	6.4±0.9	5.2±0.8[ab]

Table 1: Concentrations of Fasting Blood Glucose (FBG) and HbA1-c before and after four weeks treatment with apple cider vinegar in normal and diabetic rats.

	Normal (n = 8)		Normal+vinegar (n = 10)	
Variables (mg dL^{-1})	Before treatment	After treatment	Before treatment	After treatment
TG	33±10	34±8	31±8	27±9
TC	70±14	70±11	73±14	70±9
LDL-c	36±6	36±7	36±8	19±7[ab]
HDL-c	27±7	27±6	29±6	44±08[ab]

Table 2: Concentrations of serum triglyceride (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-c) and low density lipoprotein cholesterol (LDL-c) before and after four weeks treatment with apple cider vinegar in normal rats.

Variables (mg dL^{-1})	Diabetic control (n = 6)		Diabetic+vinegar (n = 7)	
	Before treatment	After treatment	Before treatment	After treatment
TG	36±8	65±15[a]	39±21	28±17[b]
TC	68±5	74±8	72±15	63±13
LDL-c	25±7	36±9	37±10	26±9
HDL-c	36±3	28±4[c]	27±7	33±3[c]

Table 3: Concentrations of serum triglyceride (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-c) and low density lipoprotein cholesterol (LDL-c) before and after four weeks treatment with apple cider vinegar in diabetic rats.

Glycemic Index (GI) is a scale that ranks food according to what causes the fasted rise in blood sugar levels. It is specifically a ratio of the blood glucose-raising potential of carbohydrate foods relative to glucose. There are three groups of glycemic indices based on their GI rated on a scale from 1-100: The high-GI foods have an index greater than 70, the intermediate-GI foods have an index greater than 55, but less than 70, and low-GI foods have an index less than 55 (Eleazu, 2016). A GI score of 55 and under means that the food is digested more slowly, which causes a slower spike in blood glucose and insulin levels. The glycemic response refers to the effect the food one just ate, and does not represent HbA1-c levels.

A study done by Otsman in 2005 found that vinegar supplementation lowers glucose and insulin responses after a bread-filled meal in healthy subjects. It would be beneficial to lower one's glycemic index after a meal because then one will not have a large increase in their blood sugar levels. Having high blood sugar levels may increase the risk of cardiovascular diseases, such as diabetes and atherosclerosis. In this study, 12 healthy subjects had to fast overnight, and were then given 50 grams of white bread on the morning after as their breakfast. These subjects were separated into four groups: control group was given no vinegar, one group was given 18 mmol of vinegar, another group was given 23 mmol of vinegar, and the last group was given 28

mmol of vinegar. Each group was given the vinegar at the same time with the bread. Blood samples were taken periodically to measure the glucose and insulin levels after ingestion (Otsman, 2005).

The results found that after 30 minutes, the higher the acidic level in subjects, the lower their metabolic responses (Figure 5). This meant that the GI was lowest after 30 minutes of ingestion for subjects who ingested the 28 mmol of vinegar with the bread. After 90 minutes, the metabolic response rates were still much slower. However, after 120 minutes, the researchers found that the GI values did not differ from the control group. This was interesting because the results showed a slower metabolic response rate with subjects that ingested vinegar compared to the control group, but only up to 120 minutes after ingestion. When the levels were measured at 120 minutes, GI seemed to be equivalent in all four groups. These results indicate that vinegar could have a possible effect to lower GI and maintain blood sugar levels, potentially suggesting that the continuation of vinegar ingestion must be necessary to keep levels low after a high carbohydrate-filled meal. The long-term consequences for the body's pH homeostasis from such ingestion of vinegar will still need to be investigated.

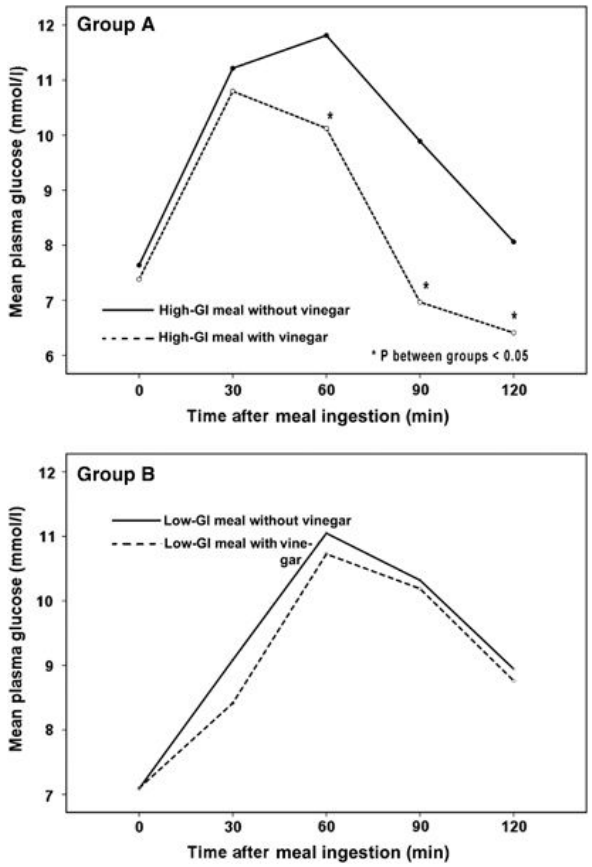

Figure 5. Graph shows the lower glucose levels after meal with vinegar compared to meal without vinegar in two groups.

According to Dr. Gregory Moneta, hyperlipidemia is defined as an acquired or genetic disorder that results in a high amount of lipids, such as fats, cholesterol, and triglycerides in the blood. This is a dangerous disorder because the lipids can enter the walls of one's arteries and can lead atherosclerosis, which is the hardening of your arteries. Atherosclerosis is dangerous because it can lead to strokes and heart attacks. Hyperlipidemia is extremely common in the United States and Europe. Over 3 million people have this disorder due to the high-fat diets associated with these countries. Hyperlipidemia is a chronic disorder that requires lifelong treatment, usually by anti-cholesterol medications taken orally. These are extremely effective in lowering LDL and VLDL cholesterol levels. Sometimes these medications have negative side

effects, such as headaches, difficulty sleeping, drowsiness, muscle aches, nausea, and vomiting. If an alternative remedy could be used to help lower lipid levels, then this would be a beneficial alternative to medications with negative side effects.

Regarding the effects and mechanisms of the action of vinegar on lipid levels, vinegar ingestion has been found to decrease lipid levels in at least one study. A study done by Petsiou, was performed on 19 subjects with hyperlipidemia. The subjects consumed 30 mL of apple cider vinegar twice a day for eight weeks. At the end of this period, the researchers found that the serum levels of total cholesterol, triglycerides, and LDL levels were all reduced. On the other hand, they found a non-significant increase of HDL levels. This fact for HDL levels is less worrisome since HDLs are good to have because they contain more protein than fats. It is positive that LDL's were reduced because having a high amount of LDLs means one is at a higher risk for heart attack and stroke. The researchers also attributed the hypolipidemic effects of acetic acid on the total cholesterol and triglycerides to the inhibition of metabolic pathways of cholesterol and lipids (Petsiou, 2014). Since hypolipidemic effect can also be caused by the effects of polyphenols and flavonoids in vinegar, this is an important area for further investigation.

V. Anti-Obesogenic Effect and Weight Loss

In the United States, more than ⅓ of adults suffer from obesity. Globally, more than 400 million people are obese, and in America, 36% of Americans are obese. Obesity is exacerbated by the high calorie, non-nutrient dense foods ingested by Americans with a low energy expenditure. This causes an abnormal amount of fat to be stored, which can increase the risk for diabetes. Diabetes is one of the leading causes of death in the United States, requiring more research to be done and alternative methods to be researched to help prevent its incidence. Obesity results from the establishment of an elevated fat mass that is maintained through an abnormal amount of energy homeostasis (Corey, 2014). Energy homeostasis is the process between food intake and energy expenditure. It is controlled by a variety of organs including the pancreas, stomach, intestine, brain and liver (Figure 6).

Obesity can lead to many other diseases in the body, which can be life-threatening. By examining the figure below, one can see many of the diseases that obesity may cause.

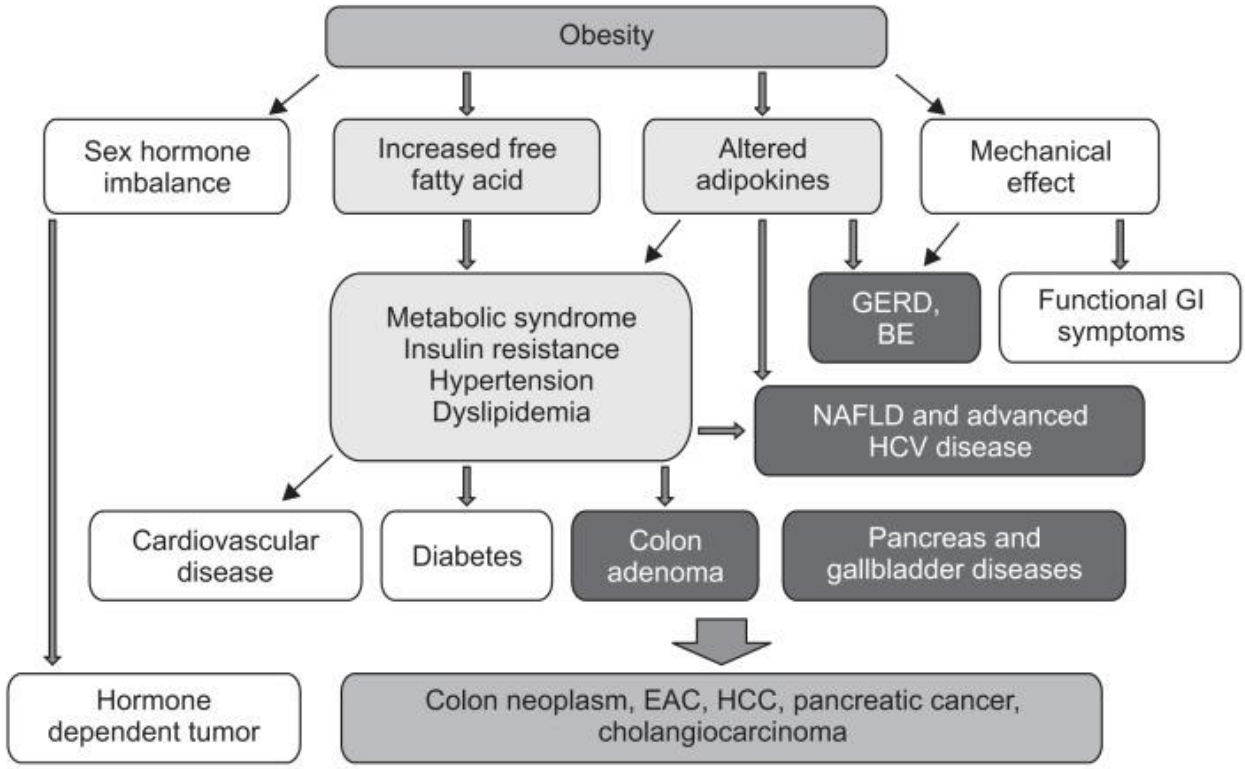

Figure 6. GERD, gastroesophageal reflux disease; BE, Barrett's esophagus; GI, gastrointestinal; NAFLD, non-alcoholic fatty liver disease; HCV, hepatitis C virus; EAC, esophageal adenocarcinoma; HCC, hepatocellular carcinoma (Nam, 2017).

Obesity is a serious issue in America. Diet and exercise are extremely important to curb this issue, and many individuals seem to have a poor diet, filled with fats and cholesterol, and do not exercise enough. The aim of one study (Zubaidah, 2017) was to see if the ingestion of apple cider vinegar would have any effect on hyperlipid/hyperglycemic rats, as well as on the lipid profiles of these rats. The study included 18, 2 month old, male Wistar rats that weighed about 140 grams $\pm$ 5 grams. The rats were separated into 3 groups: the first group of six rats were given a standard diet, the second group were given a hyperlipidic diet, meaning it was high in cholesterol, as well as rich in fat and calories, and the third group was given the same

hyperlipidic diet, and were also given apple cider vinegar at a rate of 7 mL/kg. All rats were measured at beginning of the experiment for weight, body mass index (BMI), and lipid levels. The rats were all housed in the same living conditions for the experiment.

After the 30 days, weight gain was the highest in the second group that was fed a high cholesterol diet with no apple cider vinegar. This was followed by the first group that received the standard diet. Rats in the third group had the highest weight decrease and had received apple cider vinegar supplementation. BMI decreased the most in this group as well. The researchers also observed that the LDL levels decreased the most in this group. Additionally, the HDL levels increased the most in the third group. This study concluded that the ingestion of apple cider vinegar has a positive effect on body weight by reducing both hyperglycemia and hypercholesterolemia. This study as most studies cited so far will need to be validated with higher groups and in human clinical trials, but it sheds some light on alternatives to preventing cardiovascular diseases.

The pancreas is one of the most important organs to in maintaining energy homeostasis because it secretes the antagonistic hormones, insulin and glucagon, which regulate the uptake and release of glucose. Type I diabetes is an autoimmune disorder that results in the destruction of B-cells of the pancreas, which prevents the body from producing enough insulin to maintain energy homeostasis (Figure 6). Therapy involves insulin intake externally since the body cannot make enough or any by itself.

A study done by Zubaidah (2017) on the effectiveness of Salacca vinegars as a therapeutic agent on diabetes-induced rats found an improvement in the functioning of pancreatic cells. The test was done on 35 rats, who were split up into an untreated group that received no vinegar, a diabetes-induced group that received no vinegar treatment, and a third group of

diabetes-induced rats that received vinegar treatment. At the beginning of the experiment, glucose levels and other vital levels, including total cholesterol, and LDL levels, were measured in rats that were made to fast for 10-12 days. After 28 days of the treatment, all vitals were measured again and the effectiveness of pancreatic cells was determined.

At the end of the 28 day period, the researchers found that in diabetic rats receiving the vinegar treatment most vitals were improved. Specifically, blood glucose levels, total cholesterol, and LDL levels had decreased, and there was an improvement on pancreatic cell function. The improvement on cell function was attributed to the vinegar resulting in the regeneration of endocrine cells. This is important in diabetic patients because those with this condition have trouble producing insulin, which is secreted by the pancreas. Since vinegar was found to improve pancreatic function, this could be be useful in these patients, and could help control blood sugar levels. These results are helpful because they could also potentially help diabetics who have hyperglycemia and hyperlipidemia since at least in the rats, vinegar was found to lower these levels. Compared to earlier cited studies, this study had a sizeable number of subjects and better statistical analysis. Further studies will need to be done to validate these studies.

Compared to Type I, Type II diabetes is when one loses sensitivity to insulin, often caused by body fat accumulation, genetic inheritance, and physical inactivity (Figure 7). This causes the levels of glucose in the body to increase because body desensitization to insulin prevents glucose uptake into the cells. This is the more well-known and prevalent type of diabetes. Not surprisingly, according to Nutrition: Concepts and Controversies, Type II diabetes has the higher number of cases, which have increased by 60% since 1991. This number is

expected to double in 2025, showing how diet and lifestyle choices are affecting the United States population negatively.

Diabetes affects almost every cell in the body by altering the metabolism of these cells. Some examples of how diabetes affects the cells include: some cells convert extra glucose to toxic alcohols causing the cells to swell, blood vessels and nerves are damaged causing loss of circulation and nerve function, kidneys are damaged from loss of blood flow (dialysis), and there is an increased risk of infections, and possibly tissue death (necrosis) leading to amputation. Diabetes is a serious disease and one of the main reasons it occurs is from obesity. To be considered obese, one must be above a certain BMI, which is the ratio of body weight over the square of one's height. A healthy BMI range is between 18.5 and 24.9, whereas a range between 25-29.9 is considered overweight, between 30-34.9 is considered class 1 obesity, between 35-39.9 is considered class 2 obesity, and anything equal to or above 40 is considered class 3 obesity (Peterson, 2016). The higher the class of obesity, the higher one is at risk for obesity-related diseases, and other cardiovascular anomalies.

	Type 1 Diabetes	Type 2 Diabetes
AGE OF ONSET	Usually during childhood or puberty; symptoms develop rapidly	Frequently after age 35; symptoms develop gradually
NUTRITIONAL STATUS AT TIME OF DISEASE ONSET	Frequently undernourished	Obesity usually present
PREVALENCE	10% of diagnosed diabetics	90% of diagnosed diabetics
GENETIC PREDISPOSITION	Moderate	Very strong
DEFECT OR DEFICIENCY	β Cells are destroyed, eliminating production of insulin	Insulin resistance combined with inability of β cells to produce appropriate quantities of insulin
FREQUENCY OF KETOSIS	Common	Rare
PLASMA INSULIN	Low to absent	High early in disease; low in disease of long duration
ACUTE COMPLICATIONS	Ketoacidosis	Hyperosmolar state
RESPONSE TO ORAL HYPOGLYCEMIC DRUGS	Unresponsive	Responsive
TREATMENT	Insulin is always necessary	Diet, exercise, oral hypoglycemic drugs; insulin may or may not be necessary. Reduction of risk factors (smoking cessation, blood pressure control, treatment of dyslipidemia) is essential to therapy.

Figure 7. Comparison of Type I and Type II Diabetes (White et. al, 2007).

In a study done by Kondo et. al. (2009), the researchers found that the ingestion of vinegar caused a decrease in body fat accumulation. This study investigated the effect of the intake of vinegar on body weight, abdominal fat areas, and serum triglyceride levels in 175 obese individuals. All subjects had consistent body weights for at least a month before the study was done, and were between the ages of 25-60. Other than being obese, they did not have any other major health problems and were not taking any medications. Thus, the researchers controlled for a lot of confounding variables. For the experiment, three different 500 ml test beverages were assigned randomly to three groups. One group received the placebo beverage with no apple cider vinegar in it, the next group received a beverage containing 15 ml of apple cider vinegar, and the last group received a beverage containing 30 ml of apple cider vinegar. The study was a randomized double-blind experiment. In order for all three beverages to have the same vinegar

taste, lactase was added to the placebo group. During the treatment period of 12 weeks, the subjects drank 500 ml of the beverage after breakfast and 250 ml after dinner.

The specific study regarding body weight was done on 155 obese people over a period of 12 weeks. After the 12 week period, the researchers found a decrease in body weight, body fat mass, waist circumference, and body mass index in the subjects. Although the degree of reduction was not very high, it was found to be beneficial for the mildly obese. The researchers also found that 4 weeks after the study period, body weight and body mass index of the subjects returned to healthy levels. This means that the continued use of apple cider vinegar may be beneficial for consistent weight loss. It would be beneficial to see if these effects were maintained or improved over an even longer period.

Table 4. Anthropometric Variables and Body Composition[1]

	Treatment period				Post-treatment period
	week 0	week 4	week 8	week 12	week +4
Body weight (kg)					
Placebo	74.2 ± 11.0	74.3 ± 11.0	74.4 ± 11.2	74.6 ± 11.3#^{2}	74.5 ± 11.4
Low-dose	74.9 ± 10.1	74.5 ± 10.1a^{3}#^{2}	74.0 ± 10.2a^{3}#^{3}	73.7 ± 10.3a^{3}#^{3}	74.9 ± 10.5
High-dose	73.1 ± 8.6	72.6 ± 8.5a^{3}b^{3}#^{2}	71.4 ± 8.3a^{3}b^{3}#^{3}	71.2 ± 8.3a^{3}b^{2}#^{3}	72.7 ± 8.3a^{3}b^{3}#^{1}
BMI (kg/m^{2})					
Placebo	26.9 ± 1.6	27.0 ± 1.7	27.0 ± 1.7	27.1 ± 1.8#^{1}	27.0 ± 1.8
Low-dose	27.2 ± 1.8	27.1 ± 1.9a^{2}#^{2}	26.9 ± 1.9a^{3}#^{3}	26.8 ± 2.0a^{3}#^{3}	27.2 ± 2.0
High-dose	27.0 ± 1.7	26.8 ± 1.6a^{3}#^{3}	26.4 ± 1.6a^{3}b^{3}#^{3}	26.3 ± 1.6a^{3}b^{2}#^{3}	26.8 ± 1.7#^{1}
BFR (%)					
Placebo	29.9 ± 6.8	29.9 ± 6.9	29.9 ± 7.0	29.9 ± 6.9	30.0 ± 7.0
Low-dose	30.3 ± 7.2	30.0 ± 7.2a^{1}#^{2}	29.8 ± 7.1a^{2}#^{3}	29.6 ± 7.1a^{3}#^{3}	30.2 ± 7.1
High-dose	30.2 ± 7.6	29.8 ± 7.5a^{2}#^{3}	29.6 ± 7.6a^{3}#^{3}	29.3 ± 7.5a^{3}#^{3}	29.8 ± 7.5a^{1}#^{3}
Waist (cm)					
Placebo	90.2 ± 6.8	90.2 ± 6.9	90.4 ± 7.0	90.4 ± 6.9	90.6 ± 7.1
Low-dose	90.8 ± 6.4	90.4 ± 6.5	89.7 ± 6.5a^{3}#^{3}	89.4 ± 6.5a^{3}#^{3}	90.1 ± 6.5a^{1}#^{3}
High-dose	90.5 ± 6.5	89.9 ± 6.7#^{1}	89.3 ± 6.3a^{3}#^{3}	88.6 ± 6.3a^{3}#^{3}	89.8 ± 6.1a^{2}#^{2}
Hip (cm)					
Placebo	99.9 ± 4.9	99.7 ± 4.8	99.8 ± 4.8	99.7 ± 4.8	100.1 ± 5.0
Low-dose	100.7 ± 6.1	100.3 ± 6.2	99.9 ± 6.0a^{1}#^{3}	99.6 ± 6.2a^{2}#^{3}	100.2 ± 6.1#^{1}
High-dose	100.1 ± 5.3	99.5 ± 5.3#^{3}	99.0 ± 5.3a^{3}#^{3}	98.7 ± 5.2a^{3}#^{3}	99.4 ± 5.0a^{2}#^{3}
Waist-hip ratio					
Placebo	0.903 ± 0.042	0.904 ± 0.045	0.905 ± 0.042	0.906 ± 0.043	0.905 ± 0.045
Low-dose	0.903 ± 0.052	0.903 ± 0.051	0.899 ± 0.049	0.898 ± 0.052a^{1}	0.900 ± 0.051
High-dose	0.904 ± 0.041	0.903 ± 0.044	0.902 ± 0.042	0.898 ± 0.042a^{2}#^{1}	0.903 ± 0.038

[1]All values are mean ± SD.
a Significantly different from placebo, a^{1} $p < 0.05$, a^{2} $p < 0.01$, a^{3} $p < 0.001$ (ANCOVA followed by the Bonferroni test).
b Significantly different between low-dose and high-dose, b^{1} $p < 0.05$, b^{2} $p < 0.01$, b^{3} $p < 0.001$ (ANCOVA followed by the Bonferroni test).
Significantly different from the value at week 0, #^{1} $p < 0.05$, #^{2} $p < 0.01$, #^{3} $p < 0.001$ (one-way repeated ANOVA followed by the Dunnett test).

Figure 8. Study results of ingestion of vinegar (Kondo et. al., 2009)

Figure 8 is a visual representation of the results of the experiment described above. One can see how body weight, BMI, waist circumference, hip circumference and waist-hip ratio all decreased significantly in the subjects that ingested the high dose of vinegar. It is also interesting to look at how the values started rising again in the post treatment period. This indicates that the continuation of ingestion of vinegar may be necessary to sustain the changes observed in these subjects.

Another study (Chen, 2016) revealed weight loss, a decrease in glucose levels, a decrease in triglycerides, and total cholesterol levels from the ingestion of vinegar. In this study, 20 male Wistar Rats who were 8-9 weeks old were used to investigate the effect of vinegar on their bodies. Of these rats, 10 were obese based on the BMI values described earlier, and were fed a high-caloric diet, and the rest were healthy and fed a conventional caloric diet. The rats, who were fed a high-caloric diet ingested the same type of food as the healthy rats; however their food was saturated with coconut oil, which gave them a higher caloric intake. The rats were randomly assigned to either ingest the vinegar or a placebo. The vinegar was orally ingested twice daily by an esophageal tube inserted into the rats assigned to the experimental group. The study lasted four weeks long, and all vitals were measured at the beginning of the study, and compared post treatment.

After the four weeks, the researchers determined that for both the healthy and obese rats on the vinegar treatment plan, the total and average weight gain decreased significantly compared to the control groups. At the fourth week, plasma glucose levels also decreased for the rats that ingested vinegar; however this only decreased in the obese group of rats. Triglyceride and total cholesterol levels were also reduced by vinegar, only in the obese rats. However, LDL and HDL levels did not change in the vinegar treatment group. The changes that were observed

were attributed to acetic acid, the major component of vinegar. Acetic acid reduces cholesterol and triglyceride levels through the disruption of metabolic pathways causing cholesterogenesis and lipogenesis in the liver. In conclusion, vinegar can be used to prevent excessive weight gain, high plasma concentrations of glucose, triglycerides and cholesterol in obese patients who are eating a lot of calories; however its effect on LDL and HDL levels will need to investigated. As is the case with many of these preliminary studies, human clinical trials will need to be done to validated what was found in animals.

Discussion

While limited in the length and breadth of studies, the positive effect of vinegar on body metabolism and infectious diseases is evident. More research should therefore be done to validate many of the studies that are limited in their number and animal models, as well concentrations and types of vinegars. With growing numbers of public health issues due to factors, such as climate change and antimicrobial resistance, infectious diseases need to be handled differently. The use of vinegar was found to suppress the growth and spread of bacteria and fungi that could lead to these infectious diseases. A few examples of bacteria that vinegar successfully inhibited were *E. coli, S. aureus, and C. albicans.* This is beneficial because antimicrobials are over-prescribed, which has contributed to antimicrobial resistance.

Antimicrobial resistance is dangerous because the bacteria adapt to the antimicrobials, which causes the antimicrobials to be ineffective. The re-emergence of infectious diseases that were once successfully destroyed is an issue as well. In 2016, one of the top ten reasons for death was due to infectious diseases. They are extremely dangerous because due to travel availability, these diseases can spread globally. This can cause global epidemics, killing an abundance of people at a time. The antioxidant activities of vinegar are said to be due to the polyphenols that vinegar contains. Also, a number of studies have shown that polyphenols exert a protective effect against hypertension, dyslipidemias, inflammation, endothelial function and atherosclerosis. Thus, approaches involving vinegar may help circumvent the inefficacy posed by a purely antimicrobial-based treatment.

Concerning one's body metabolisms, ingestion of vinegar in the diet was found to positively affect diabetic subjects in a few studies and in rodent models in several studies. Specifically, vinegar was shown to decrease LDL levels, and in several studies also increase

HDL levels. It is beneficial to have a decrease in LDL levels because they contain more fat and triglycerides because they increase one's risk of cardiovascular diseases, which remains to this day as the number one cause of death in the United States. The added benefit of increased HDL levels from vinegar treatment may also help curb this issue. Vinegar was also found to decrease HbA1-c levels in diabetic subjects, which is a more reliable indicator of blood glucose levels. The implications of all studies will be complicated in human subjects, where diet varies quite a bit in calorie intake and nature of foods, for example high or low GI foods. These factors may affect the viability of a vinegar-based treatment.

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