FIRAT UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
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SOME PHYTOCHEMICAL PROPERTIES AND ANTIMICROBIAL ACTIVITY OF *ALOE VERA* (L.) BURM. F.

Heleen Tahseen YASEEN

Master's Thesis

DEPARTMENT OF BIOLOGY

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Author
Heleen Tahseen YASEEN

Supervisor
Prof. Dr. Sevda KIRBAĞ

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THESIS APPROVAL

This thesis, which was prepared according to the thesis writing rules of the Graduate School of Natural and Applied Sciences, Fırat University, was evaluated by the committee members who have signed the following signatures and was unanimously approved after the defense exam made open to the academic audience.

		Signature
Supervisor:	Prof. Dr. Sevda KIRBAĞ Firat University, Faculty of Science	Approved
Chair:	Prof. Dr. Şemsettin CİVELEK Firat University, Faculty of Science	Approved
Member:	Assist. Prof. Dr Burak BİRCAN Osmaniye Korkut Ata University, Vocational School of Health Services	Approved

This thesis was approved by the Administrative Board of the Graduate School on

..... / ..... / 20 .....

Signature

Prof. Dr. Burhan ERGEN
Director of the Graduate School

DECLARATION

I hereby declare that I wrote this Master's Thesis titled “Some phytochemical properties and antimicrobial activity of *Aloe vera* (L.) Burm. f. ” in consistent with the thesis writing guide of the Graduate School of Natural and Applied Sciences, Firat University. I also declare that all information in it is correct, that I acted according to scientific ethics in producing and presenting the findings, cited all the references I used, express all institutions or organizations or persons who supported the thesis financially. I have never used the data and information I provide here in order to get a degree in any way.

05 June 2024

Heleen Tahseen YASEEN

PREFACE

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ABSTRACT

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Department of Biology

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Aloe vera (L.) Burm. f. known as a perennial and succulent that is called the plant of immortality, has been used for beneficial effects over the centuries. In this study, some phytochemical characteristics and antimicrobial activities of the gel and green leaf part of *Aloe vera* were tested. Water and fat-soluble vitamins, β-carotene, lycopene, and 4-HNE were determined by HPLC, and total phenolics and flavonoids, ABTS, and DPPH radical scavenging activity were determined using a UV-Vis spectrophotometer. The antimicrobial activities of *Aloe vera* was determined by the disc-diffusion method. According to the results, the highest amounts of thiamine, riboflavin, pyridoxal, and vitamin B12 were determined in the green leaf part of *Aloe vera* with values of 1.86±0.07 µg/g, 4.71±0.11 µg/g, 3.67±0.16 µg/g, 4.96±0.13 µg/g, and 22.56±1.03 µg/g, respectively. On the other hand, the highest concentration of ascorbic acid, nicotinic acid, nicotinamide, pantothenic acid, pyridoxine, and folic acid was observed in the gel with values of: 3.17±0.14 µg/g, 90.55±2.63 µg/g, 39.8±0.99, 5.42±0.36 µg/g, 14.93±0.30 µg/g, 12.72±0.49 µg/g, and 0.23±0.01 µg/g, respectively. In the green leaf part of *Aloe vera*, the amounts of vitamin A, E, lycopene, β-carotene, and 4-HNE were found to be 0.17±0.03, 3.6±0.57, 7.6±1.50, 0.63±0.14, and 5.6±1.07 µg/g, respectively. On the other hand, were 0.26±0.05, 1.1±0.09, 0.07±0.01, and 3.68±0.74 µg/g, respectively, in the gel. The obtained results detected that the amounts of total phenolic content (µg GAE/g), total flavonoid content (µg QE/g), DPPH (IC50 (µg/mL)), and ABTS (µmol trolox/g) were 0.17±0.01, 0.96±0.15, 133.9±7.08, and 25.1±2.28, respectively, in the green leaf part of *Aloe vera*. While in the gel found to be 407.95±9.42, 0.95±0.67, 0.04±0.00, and 0.26±0.05, respectively. It was determined that the green leaf part of *Aloe vera* had the highest antimicrobial efficacy against *Bacillus megaterium*, with a diameter of 11.6±0.32 mm of inhibition zone, while demonstrating the lowest efficacy against *Escherichia coli* (8.3±0.30 mm). The gel exhibited the greatest antimicrobial activity against *Staphylococcus aureus* (20.0±0.29 mm), while showing the weakest efficacy against *Pseudomonas aeruginosa* and *Proteus vulgaris* (15.5±0.29 mm). As a result, it can be said that *Aloe vera* is a good source of antioxidant and antimicrobial activity that can be used for medicinal and cosmetic purposes.

Keywords: *Aloe vera*, Phytochemical, Antimicrobial, Vitamins

ÖZET

Aloe vera (L.) Burm. f' un Bazı Fitokımyasal Özellikleri ve Antimikrobiyal aktivitesi

Heleen Tahseen YASEEN

Yüksek Lisans Tezi

FIRAT ÜNİVERSİTESİ
Fen Bilimleri Enstitüsü

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Aloe vera (L.) Burm.f. Ölümsüzlük bitkisi olarak adlandırılan çok yıllık ve sukulent bir bitki olarak bilinen bitki, yüzyıllar boyunca faydalı etkileri nedeniyle kullanılmıştır. Bu çalışmada *Aloe vera*'nın jel ve yeşil yaprak kısmının bazı fitokimyasal özellikleri ve antimikrobiyal aktiviteleri test edilmiştir. Suda ve yağda çözünen vitaminler, β-karoten, likopen ve 4-HNE, HPLC ile ve toplam fenolikler ve flavonoidler, ABTS ve DPPH radikal temizleme aktivitesi UV-Vis spektrofotometresi kullanılarak belirlendi. Bitkinin antimikrobiyal aktivitesi disk difüzyon yöntemiyle belirlendi. Sonuçlara göre en fazla tiamin, riboflavin, piridoksal ve B12 vitamini miktarı sırasıyla 1,86±0,07 µg/g, 4,71±0,11 µg/g, 3,67±0,16 µg/g, 4,96±0,13 µg/g ve22,56±1,03 µg/g *Aloe vera*'nın yeşil yaprak kısmında belirlendi. Askorbik asit, nikotinik asit, nikotinamid, pantotenik asit, piridoksin ve folik asitin en yüksek konsantrasyonu sırasıyla 3,17±0,14 µg/g, 90,55±2,63 µg/g, 39,8±0,99, 5,42±0,36 değerleriyle jelde tespit edildi. *Aloe vera*'nın yeşil yaprak kısmında A, E vitamini, likopen, β-karoten ve 4-HNE miktarları sırasıyla 0,17±0,03, 3,6±0,57, 7,6±1,50, 0,63 olarak belirlenmiştir. Jelde ise sırasıyla 0,26±0,05, 1,1±0,09, 0,07±0,01 ve 3,68±0,74 µg/g seviyelerinde belirlenmiştir. Elde edilen sonuçlarda, *Aloe vera*'nın yeşil yaprak kısmında toplam fenolik içerik (µg GAE/g), toplam flavonoid içeriği (µg QE/g), DPPH (IC50 (µg/mL)) ve ABTS (µmol trolox/g) miktarlarının sırasıyla 0,17±0,01, 0,96±0,15, 133,9±7,08 ve 25,1±2,28 olduğunu gösterdi. Jel sırasıyla 407,95±9,42, 0,95±0,67, 0,04±0,00 ve 0,26±0,05 bulunmuştur. *Aloe vera*'nın yeşil yaprak kısmı en yüksek antimikrobiyal etkiye 11,6±0,32 mm *Bacillus megaterium*'a karşı sahipken, *Escherichia coli*'ye karşı en düşük etkinliği gösterdi belirlendi (8,3±0,30 mm). Bununla birlikte jel, *Staphylococcus aureus*'a karşı en büyük antimikrobiyal aktiviteyi sergilerken (20,0±0,29 mm), *Pseudomonas aeruginosa* ve *Proteus vulgaris* üzerinde en az etkiye gösterdi tepit edildi (15,5±0,29) mm. Sonuç olarak *Aloe vera*'nın tıbbi ve kozmetik amaçlı kullanılabilecek iyi bir antioksidan ve antimikrobiyal aktivite sahip olduğu söylenebilir.

Anahtar Kelimeler: *Aloe vera*, Fitokimyasal, Antimikrobiyal, Vitaminler

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SYMBOLS AND ABBREVIATIONS

Abbreviations

4-HNE : 4-Hydroxyneonal

QE : Quercetin

GAE : Gallic acid equivalents

DPPH : 2,2-Diphenyl-1-picrylhydrazyl

ABTS : 2,2'Azino-bis-3-ethylbenzothiazoline-6-sulfonic

HPLC : High Performance Liquid Chromatograph

TFC : Total Flavonoid Content

TPC : Total Phenolic Content

dd H_2O : Double-distilled water

PDA : Photo diode array

$HClO_4$: Perchloric acid

C_2H_5OH : Ethanol

CH_3OH : Methanol

IC_{50} : Half-maximal inhibitory concentration

WSVs : Water-soluble vitamins

FSVs : Fat-soluble vitamins

MIC : Minimum inhibitory concentration

NAD : Nicotine amide adenine dinucleotide

NADP : Nicotine amide adenine dinucleotide phosphate

1. INTRODUCTION

Plant parts (leaves, wood, fibers) and storage sections (fruits, tubers) have been used by people for generations to generate or manufacture necessities like food, clothing, and shelter. Plants have also been used for a variety of other reasons, such as arrow and dart poisons, hallucinogens for use in rituals, and stimulants to increase stamina and decrease appetite. Humans have been exploring the natural world for medicine ever since ancient time. The initial use of plants was based purely on instincts. Everything was based on experience since there was not enough knowledge available at the time to determine the causes of the diseases or the specific plant and how it might be used as a remedy [1].

Humans rely on plants for a wide variety of nutrients, including water, carbohydrates, proteins, minerals, oils, vitamins, and minerals. Throughout history, plants have provided humans with a vast majority of essential elements for maintaining a healthy diet and way of life [2].

The main direct and indirect products of the industry are plant-based metabolites, which include both primary and secondary metabolites. Plants transform soil, water, minerals, and some elements into substances that individuals may absorb. Carbohydrates, proteins, lipids, vitamins, and minerals are among the most fundamental nutrients. Plant metabolism primarily uses active compounds, such as essential oils, alkaloids, tannins, and bitter chemicals. They aid in the proper functioning of organs, speed up the healing process, and boost the body's defenses. Consequently, they improve the efficiency with which certain organs and tissues in the body perform their duties [3].

Plants play a significant role in the ecosystem by providing crucial functions. Plants are essential for all forms of life and function as they should. Herbs in general and therapeutic herbs in particular have always served as reliable barometers of ecosystem vitality [1] People have been trying to heal themselves naturally since the beginning of time. The first uses of animals were instinctual, and the same was true of the first uses of plants [4].

Plants with therapeutic properties are included in the broad category known as "medicinal plants," which are employed in herbalism. The "backbone" of alternative medicine is medicinal plants, which are also a valuable resource for the creation of new drugs [5]. The term "medicinal plants" refers to a wide range of plants, not all of which are used for medicinal purposes. As the "backbone" of traditional medicine, medicinal plants are used regularly by more than 3.3 billion people in developing nations [6]. It is estimated that at least 13,000 plant species have been used worldwide for medicinal purposes around the globe for at least a century. Over 20,000 medicinal plants have been documented, and there are certainly many more that have yet to be discovered. Medicinal uses have been found in many flowering plant species worldwide. A total of 70,000

therapeutic plant species are often mentioned; however, this number includes several algae, fungi, and microorganisms that are not true plants, as botanists use the term [7]. The Indian sub-continent has an enormous number of plant species, showing amazing variation and existing in a wide variety of environments. There are roughly 17,000 species of higher plants, of which about 8,000 are employed for medicinal purposes by rural dwellers and indigenous peoples alike, whether via modern Western medicine or more ancient practices like Ayurveda. UNESCO (1996), reported that traditional medicine and the use of medicinal plants are crucial to the health of people in the majority of poor nations. The materials used in the creation of drugs have traditionally come from medicinal plants. In addition, these plants are essential for the development of human civilization everywhere. Plant species diversity in the Indian subcontinent is very high [8]. Over 50,000 plant species are cultivated for their medicinal and aesthetic value. However, medicinal plants do not exhibit a consistent global distribution [9,10]. The chemicals found in plants have made them useful in the treatment of several ailments throughout human history [11]. Its documented history of use in medicine and ceremonial practices includes many cultures and time periods, including Roman Empire, Byzantine Empire, Arab world, Ottoman Empire, and even mediaeval Europe [12]. Almost 5000 years ago, in India, China, and Egypt, and at least 2500 years ago in Greece and Central Asia, there were scripts written on medicinal herbs [13] . The cultural frameworks, religious convictions, ideologies, and life experiences of a society influence these therapeutic modalities, which are distinct from contemporary medical medicine. There have always been Traditional medical procedures have been passed down through the generations, either verbally or in writing [14,15]. The second half of the twentieth century saw a dramatic increase in the use of herbal medicines in industrialized nations. Several organizations, such as the European Scientific Cooperative on Phytotherapy, publish monographs on certain plants [16].Before the development of iatrochemistry(pharmaceutical chemistry) in the 16th century, medicinal and preventative measures were derived from plants [17].

Undoubtedly, people have thought about plants for their medicinal properties since the prehistoric times. It is safe to assume that, long before written history was created, early people had some concept of the useful attributes of the plants they encountered. Countries such as China, Greece, Egypt, and India have elevated the study of medicinal herbs to the ancient science level. Plants have been widely employed in ancient Persia as medicines, disinfectants, and fragrances [18].

The majority of herbs used in traditional medicine come from wild plants. Indeed, in recent decades, the annual increase in demand for animal supplies in Europe, North America, and Asia has averaged between 8% and 15% [19] while in underdeveloped nations, the consumption rate of herbal medications is 75%, compared to 25% in wealthy countries [20].

The World Health Organization (WHO) conducted research based on studies of medicinal plants in 91 countries and found that approximately 20,000 plants are used for therapy worldwide. Natural plant parts, such as stems, leaves, seeds, and roots, have been investigated for compounds that prevent the development of numerous bacteria; these chemicals have been isolated and their actions documented [3].

More than one-third of Americans use complementary or alternative medicine, and this percentage is rapidly growing [21]. Herbal remedies are the most widely used alternative medicines in the United States, with over 38 million people (approximately 20% of the adult population) [22].

For general health maintenance or targeted relief of particular ailments, people turn to herbal medicines administered topically or in the form of food supplements [23]. It is impossible to identify a specific epoch of drug use in plants. About 60,000 years ago, there was evidence of narcotic plant cultivation [24].

Plants used in medicine have unique structural forms of several important medicinal chemicals. Many pharmaceuticals in current Western medicine originate from plants or other elements of the natural world. The active compounds in medicinal plants are traded. Traditional remedies for bacterial, fungal, and viral illnesses have been evaluated in plants [25]. Researchers have a pressing need to study, collect, and chronicle our medicinal cultural resources for the benefit of all Africans and indeed the whole human race before the woods are gone and the aging TMPs die out. Given their size and sway in primary care, TMPs must be included in national healthcare systems for the sake of teaching and assessing the efficacy of treatments [26,27].

As a result of advancements in chemistry, synthetic versions of traditional medicines are being increasingly used. Despite this, a sizable portion of the global population continue to receive treatment with medicinal plants. Some drug precursors obtained from herbal drugs are cheaper and easier to obtain than synthetic ones, and because the drugs have multiple effects at once, there has been an uptick in research on the efficacy of medicinal plants and the active substances obtained from them in recent years [28].

It has been estimated that there are 8,000 unique phytochemicals present in fruits, vegetables, and grains that humans eat. [29]. Thus far, more than 150 studies have been extensively conducted. The antioxidant properties of dietary phytochemicals have been receiving increasing attention. [30].

1.1. Antioxidants

Antioxidants, as is well known, are substances that prevent cellular damage from free radicals [31]. Diseases caused by free radical oxidation can be mitigated by the use of antioxidants. It inhibits the production of reactive oxygen species or reduces their concentration at subcellular

and molecular levels. Antioxidant capabilities and beneficial effects on human health have piqued interest in phytochemical substances found in many plant, fruit, and spice species [32,33].

The body has defenses to prevent harm from oxidative chemicals. The oxidant concentration and the antioxidant defense system are in equilibrium. This equilibrium is disrupted when there is an excess of oxidants and a deficiency of antioxidants, and the resulting oxidant molecules from various cellular components (proteins, lipids, carbohydrates, nucleic acids, and enzymes) harm the cells [34,35].

Antioxidants help prevent further free radical production, interrupt chain reactions in biochemical pathways, remove any existing free radicals, and restore and cleanse any damaged molecules [36].

This research on phytochemicals has led to one conclusion: "phytochemical nutrient" highlight the connection between what we eat and how we feel. Phytochemicals in vegetables and fruits have antibacterial and antiviral effects, as well as effects on gene expression, hormone metabolism, immune system stimulation, cell proliferation, apoptosis, and the capture of oxidants [37].

Vitamins, polyphenols, carotenes, and several phytochemicals derived from plants, as well as different enzyme and thiol compounds, are examples of antioxidants. Polyphenols are a group of antioxidants that include a wide variety of bioactive compounds such as anthocyanins, phenolic acids, lignans, flavonoids, and stilbenes. Plant polyphenols are powerful antioxidants and radical scavengers owing to their secondary metabolites [38,39].

A recent study has shown that phytochemicals, more specifically phenolics, which are abundant in fruits and vegetables, are the key bioactive substances that have been discovered to have favorable impacts on human wellness. An extensive range of foods, including fruits, vegetables and plants, is known to contain phenolic compounds, which belong to a category of molecules that possess antioxidant capabilities. There was a clear correlation between the total phenolic content of vegetables and fruits and the antioxidant capacity of these fresh produce items [40].

In very small doses, vitamins are essential for the proper functioning and development of all living things. Some disorders or symptoms caused by a lack of these vitamins require a particular treatment: vitamin intake. Many microbes and plants, with the exception of humans and a few other animals, produce vitamins; that are necessary for human health. Thus, the human body can't produce them on its own and must rely on food as a source [41].

Vitamins are a vast class of critical micronutrients that can be broken down into two categories: water-soluble (WSVs) and fat-soluble (FSVs). Vitamin C (VC) and the B vitamins (thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), pantothenic acid (vitamin B5), pyridoxine (vitamin B6), biotin (vitamin B7), folic acid (vitamin B9), and cobalamins (vitamin

B12)) are examples of (WSVs). Each WSV has a unique chemical makeup, structural complexity, stability, and a set of physical characteristics. WSVs have a unique function in energy metabolism and in maintaining the muscles, skin, eyes, hair, and liver in good shape. As precursors to coenzymes and enzyme cofactors, they participate in a wide variety of metabolic activities, including those involved in lipid, carbohydrate, and protein synthesis. Beriberi, anemia, neurological illnesses, oral lesions, and pellagra are only some of the metabolic and other health issues that may result from not getting enough or getting too much of them [42]. Ascorbic acid, often referred to as an antioxidant, is necessary for maintaining healthy body tissue, promoting development, supporting a strong immune system, and playing a crucial part in the production of collagen and norepinephrine [43]. In addition, several WSVs, most notably VC, have antioxidant activity, making them popular food additives [44]. The human body can only store and synthesize VB12; thus, it is vital for optimal health to obtain other WSVs on a regular basis through diet [45]. Vitamins K, E, D, and A are the fat-soluble vitamins. The body stores fat-soluble vitamins in the adipose tissue and hepatic fat [46]. A lack of fat-soluble vitamins can potentially affect several body systems, including the immune system. A lack of fat-soluble vitamins, which play important functions in the immune system, might affect a person's general health [47].

In order to be absorbed by the body, fat-soluble vitamins need to go through a metabolic pathway that involves fat. The immune system is only one of several factors that may be negatively affected by a lack of fat-soluble vitamins. Deficiencies in fat-soluble vitamins may have serious consequences for health and well-being because of their vital functions in the immune system [48].

The fat-soluble antioxidant vitamin A is characterized by its yellow color. Lycopene, β-carotene, lutein, and other carotenoids found in plants are examples of provitamin A molecules [49]. Vitamin A's traditional function in low-light vision is well-established, and its significance in immunological function is also obvious. Additionally, it plays a crucial role in preventing the oxidation and esterification of vitamin A [50].

Approximately 50 years ago, vitamin E became an object of inquiry in the fields of chemistry and biology [51]. Vitamin E, as shown in these experiments, prevents reactive chemicals from doing any harm [52]. Analyses conducted on rabbits fed a high-fat atherogenic diet revealed that the groups provided with vitamin E had significantly lower plasma TBARS levels and aortic plaque development compared to the group not given vitamin E [53].

Vitamins have been shown to reduce the risk of cancer development. β-carotene and the antioxidant vitamins A, C, and E have recently risen to the forefront of public attention because of their ability to protect against degenerative diseases such as cancer at the same time. A number of studies have shown that β-carotene, together with the antioxidant vitamins A, C, and E, may shield the body from the harmful effects of free radicals and reactive oxygen molecules, thereby reducing the likelihood of developing cancer [54].

Phenolic chemicals, which are found in every plant and serve as defense mechanisms against insects, are the most abundant class of secondary metabolites. Plant phenolic compounds are believed to play a crucial role in shielding plants from environmental challenges that lead to the production of more free radicals and other oxidative species [55]. The type and variety of phenolic compounds that are compatible with the antioxidant potential determine the quantity and reducing power of these substances. Consequently, phenolic compounds found in plant extracts are generally believed to be a source of antioxidant action [56].

Chemical flavonoids are widely distributed in plant diets. It is a plant compound known as a secondary metabolite. Flavonoids have been shown to offer several health benefits, including antioxidant, anti-inflammatory, antiviral, antiallergic, and antithrombotic effects. Flavonoids can mitigate the effects of free radicals by halting their chain reactions. As a result, vitamin C absorption was boosted. Tea, apples, onions, beans, and tomatoes are particularly rich in flavonoids, and the total amount may exceed 4000 [57].

Currently, 25% of the raw pharmaceutical ingredients are derived from plants and herbal medicines. The need to use natural goods has grown in recent years owing to the inadequacy of synthetic pharmaceuticals in the face of rising illness rates and the discovery of their negative effects. Therefore, many plants have been studied in recent years, when biological warfare is a top priority, in terms of microbiological and pharmacological aspects and even in terms of plant defense systems. Since 1926, scientists have studied the antibacterial properties of plants and determined their significance for human health [58].

The effectiveness of phytochemicals found in plants as antimicrobial agents has been the subject of a great deal of recent research, both in the laboratory and living organisms [59].

1.2. Antimicrobial

Antimicrobial activity occurs when microbes possess characteristics that prevent their multiplication or elimination. plants secrete antimicrobial chemicals as a defense mechanisms against microbial infections. Phenolics, terpenoids, essential oils, alkaloids, lectins, polypeptides, and polyacetylenes the antimicrobial compounds found in plants. Therefore, investigations of the antimicrobial effects of plants and herbal remedies are common [60].

Chemical or biological chemicals that regulate disease agents, restrict the development of germs, halt them, or kill them are known as antimicrobial substances because of their detrimental impact on microbial viability. The development of antibiotic resistance in pathogenic microorganisms has been one of the most pressing issues in recent years. Resistance to antimicrobials is on the rise owing to their misuse and overuse, particularly in poor nations. Due to

antibiotic resistance and its negative consequences, researchers are looking for novel antimicrobial compounds, such as medicinal plants, to develop into antibiotics [61].

Antibiotic-resistant bacteria are becoming a major public health problem. The emergence of antibiotic-resistant microorganisms has rendered many of the currently available treatments ineffective. Researchers have been looking for novel antimicrobials, either by designing and synthesizing new compounds or by exploring natural sources. In particular, herbal treatments have had a renaissance in popularity, since it is widely believed that plant preparations have a reduced rate of adverse reactions compared to synthetic antibacterial agents. This, along with the low cost of herbal remedies, makes investigating plant-based treatments more desirable [62].

Substances that inhibit the development of microorganisms even at low doses; they are secondary metabolites of biological origin. Natural or synthetic compounds derived from microbes that kill other microorganisms in modest quantities but have no impact on the human body are also included in this definition [63].

These include compounds like bacteriocids and fungicides, which kill microorganisms, and bacteriostatics and fungistatics, which stop their reproduction [64].

There are four recognised classes of antibacterial mechanisms of action, each targeting a different set of cellular processes: The production of the cell wall, the function of the cell membrane, protein synthesis, and nucleic acid synthesis are all inhibited [63].

In this study, we investigated the phytochemical and antimicrobial properties of *Aloe vera*. *A. vera* is a popular plant owing to its medicinal properties. In the last few decades, it has been used in a wide variety of applications (including medicine, cosmetics, and food).

1.3. *Aloe vera* (L.)

There are around 420 species of the genus *Aloe*, and they have been placed in the, Aloaceae families, including *Aloe vera* (L.) Burm. f. [65]. Although *Aloe barbadensis* Miller is the more common name, *Aloe vera* (L.) Burm. f. is the correct name according to international regulations of botanical nomenclature [66].

The leaves of the plant are tall and pointed. There is a green shell and a transparent pulp within each leaf. The pulp, which makes up the bulk of the leaf, seems to be both transparent and mucilaginous. For medicinal reasons, this portion of the plant is most often used [67].

Light green in color; this perennial plant resembles both shrubs and trees. It is xeric and succulent [68]. It is believed that the Arabic words "alloeh" or "alloek" and the Hebrew word "allal," meaning "bitter" are the origins of the Greek word "aloe" (aloi). Arabic "wahre" means "real" or "genuine," and the Latin word "vera" comes from this source. In Anatolia, it is called "sari sabre" because of its typically yellow petals, and its name in common use is derived from the Arabic word

"sabre" meaning "sword" in reference to its sword-shaped leaves. Its native habitats in Turkey are the southern Turkish coast and Antalya's Demre area [69,70].

It is thought that the plant *A. vera* originated in Sudan and was later transferred to the Mediterranean and other warm regions of the globe. A clay tablet from 2100 BC in Mesopotamia is the first known written evidence of the medicinal power of *Aloe*. Papyrus Ebers, an Egyptian record from 1550 BC, provide the earliest extensive description of the plant's medical significance, including several *Aloe*-containing concoctions for the treatment of exterior and interior illnesses. The Greek herbalist Dioscorides (ca. Seventy AD) described the *A. vera* plant and advocated its use in treating wounds, hair loss, vaginal ulcers, and hemorrhoids [71].

Alexander the Great and Christopher Columbus both employed *A. vera* to heal wounds sustained by troops during battles, while Egyptian princesses Nefertiti and Cleopatra used it in their beauty regimens. Although Americans began using *A. vera* as a laxative in the early 1800s, it wasn't until the mid-1930s that it was effectively used to treat severe and chronic radiation dermatitis [72]. According to a variety of recent study, this species not only protects teeth from UV rays but also reduces inflammation, fights germs and fungi, modulates the immune system, and inhibits the growth of cancer cells [73–77].

In 1820, the United States Pharmacopoeia recognized *A. vera* for its purgative and skin-protecting properties [78]. Its first therapeutic use was in the 1930s, when it was used to treat skin and mucosal burns caused by radiation [79]. To date, *A. vera* has been revered as a medicinal plant in several nations, including but not limited to China, India, the West Indies, South Africa, and Japan [66]. Despite its widespread cultivation today, the *Aloe barbadensis* Miller plant—the "plant of immortality"—actually originates from Africa, the Arabian Peninsula, and the islands of the Indian Ocean. This plant is a member of the Asphodelaceae family [80].

The passage of the Dietary Supplement and Health Education Act (DSHEA) in 1994 may have contributed to the rise in the popularity of *A. vera's* during the previous decade. Multiple *A. vera* components may have biological activity [81].

Over 2000 years ago, Egyptian scientists dubbed *A. vera* "the herb of immortality," while Greeks called it "the universal panacea". Approximately 99.0–99.5% of the substance is water. Since it can hold a lot of water, it may be used to keep the skin hydrated, and its gel can be used to treat skin injuries since it aids in wound healing and promotes cell reproduction. Several properties of *A. vera* contribute to its capacity to hasten wound healing, including moistening effects, increased cell motility, and enhanced collagen production [82].

In addition, it is used to treat a wide variety of illnesses, including inflammation, digestive issues, constipation, thermal burns, sunburns, radiation damage, skin diseases, diabetes, and ulcers. Nearly 200 active substances and 75 nutrients, including water- and fat-soluble vitamins, minerals,

enzymes, simple and complex polysaccharides, phenolic compounds, and organic acids, have been reported to make up the remaining 0.5–1.0% instead of the typical 99.0-99.5% water [83].

The medicinal properties of *A. vera* gel may be attributed to the presence of molecules with a high molecular weight [84]. The plant has an exterior covering that is visible from the outside and a parenchyma *Aloe* gel that is visible from the inside of the same covering. Both *in vivo* and *in vitro* studies have shown that these two constituents have therapeutic effects. Antibacterial, antifungal, anti-inflammatory, and anti-arthritic properties have been shown in studies of the plant's entire extract [85]. By preventing the production of oxygen radicals, *A. vera* is thought to have immunomodulatory effects [86]. Different *A. vera* fractions, as well as the unfractionated entire gel, have been claimed to have antioxidant benefits by a number of writers. The antioxidant properties of the *A. vera* gel may stem from the presence of glutathione peroxidase activity, superoxide dismutase, and phenolic antioxidant.

A. vera gel was shown to have a dose-dependent antioxidant impact in two cell-free *in vitro* systems and by incubation with inflamed colon mucosal biopsies. In this study, both superoxide and peroxyl radical-scavenging activities were evaluated using cell-free methods. Prostaglandin E2 production from inflammatory colorectal biopsies was likewise suppressed by the *A. vera* gel at a 1 in 50 concentration, whereas thromboxane B2 release was unaffected [87].

There are several components of *A. vera* that are responsible for its antioxidant properties. These components include α-tocopherol, carotenoids, ascorbic acid, flavonoids, tannins and vitamin E [88].

Many different types of bacteria, including *Escherichia coli*, *Klebsiella pneumonia*, *Streptococcus pyogenes*, and *Staphylococcus aureus*, are inhibited by *A. vera* when tested *in vitro* [89]. Recent studies have shown antimicrobial activity against *Shigella flexneri*, methicillin-resistant *Staphylococcus aureus*, *Enterobacter cloacae*, and *Enterococcus bovis* has been shown in recent studies [90]. Extracts of *A. vera* leaves in water, methanol, and acetone were tested for their ability to halt the development of *Staphylococcus aureus* and *Escherichia coli*, and it was found that the acetone extract was the most effective [91].

At the same time, another study compared 14 patient-derived and one reference strain of *Helicobacter pylori* to the gel found within the leaves of a 5-year-old *A. vera* plant. When compared to other bactericidal species, the MIC values for *A. vera* inner gel against these 14 bacteria ranged from 6.25 mg mL^{-1} to 800 mg mL^{-1}. [92].

Because of its ability to alter drug-resistant behavior *Helicobacter pylori*, *A. vera* gel may be useful in combination with antibiotics for treating *Helicobacter pylori* infections [91].

Furthermore, anthraquinones in *A. vera* might hinder the development of microorganisms by preventing the production of proteins. *A. vera* leaf polysaccharides also have antibacterial properties by stimulating phagocytic cells, which consume germs [93].

Multiple components of *A. vera* leaves have been shown to have antibacterial activity in separate investigations that employed extracts of these components. Concentrations of 100 mg of *A. vera* gel per mL were effective in inhibiting growth for up to 24 h. Although the antimicrobial activity of *A. vera* gel was minimal compared to that of ampicillin and nalidixic, its direct impact on easily accessible parts of the body led some to argue that it may be useful as a component of antimicrobial goods [94].

Due to its interference with DNA synthesis, *A. vera* has been shown to have antiviral action in *in vitro* experiments [95]. Subsequent *in vivo* experiments by Kim and Lee (1997) verified this [96]. Furthermore, *Aloe's* anthraquinones have been proven to be virucidal against herpes simplex viruses 1 and 2, vaccine virus, para-influenza virus, and vasospastic stomatitis virus in *in vitro* investigations [97].

2. MATERIALS AND METHODS

2.1. Sample preparation

Plant samples were obtained from Planet Shop in Elazığ City, Türkiye (Figure 2.1). The plant leaves were rinsed under running water to eliminate dust and insect larvae. The gel was manually extracted from fresh *A. vera* leaves after they were chopped using a knife. One gram of the gel and one gram of the green leaf part were used for testing water soluble vitamins, vitamins A, E, β-carotene, lycopene and 4-HNE. While 15 grams of samples were extracted using methanol in Soxhlet to prepare for antioxidant tests.

Figure 2.1 *Aloe vera* picture

2.2. Chemicals and equipments

Standard and chemical reagents, including butylated hydroxy toluene, flavone, perchloric acid, gallic acid, aluminum chloride, quercetin (dehydrate), potassium persulfate, sodium nitrate, aluminum chloride, gallic acid, and perchloric acid, were acquired from Sigma-Aldrich or Merck, respectively. All the water used in the process was double-distilled (dd H_2O).

Because of the potential for contaminants in the solvent to obscure the sample peak in the HPLC chromatogram, only analytical-grade solvents were used for the sample preparation. The liquid chromatography solvents were of the HPLC kind. For HPLC, the mobile phase always consists of a solvent that has been filtered via a membrane filter and degassed in an ultrasonic bath. The SHIMADZU Prominence-LC-2020C 3D Model was used for HPLC analysis together with a PDA detector. A UV-VIS spectrophotometer was used for the spectrophotometric measurements

2.3. Analysis of Water-Soluble Vitamins

One gram of material was mixed with 1mL of 0.5 M $HClO_4$ in a vortex mixer for 1 min. Sonication (Wise Clean, WUC-AO3H, 170 W) was performed for 10 min. after the volume was brought to 5.0 mL with distilled water. After that, 1.0 mL HPLC vials were filled with the supernatant obtained after centrifugation at 4500 rpm for 10 min. The water-soluble vitamin content of each sample was determined using a gradient program on an Inter Sustain AQ-C18 (5 m, 150 4.6 mm I.D.) column and a SHIMADZU Prominence-I LC-2030C 3D Model HPLC fitted with a PDA detector. The maximum absorbance wavelength and retention period of each vitamin were calculated using stock solutions. The chromatogram found in the literature was compared to the retention periods and was found to be consistent [98].

2.4. Determination of vitamins A, E, β-carotene, lycopene and 4-HNE

After adding 1.0 g of sample to a tube, 5.0 mL of C_2H_5OH was added, and the mixture was sonicated for 10 min then vortexed and centrifuged for 6 min at 7,500 rpm. After that, we added 1.0 mL of n-hexane to the sample, gave it a good vortex, and then extracted the n-hexane phase twice. The n-hexane phases were collected, evaporated in a vacuum, and diluted in 1.0 mL of methanol before being analyzed using a combination of methanol and water (95:5) as the mobile phase. An Inertsil ODS-3 column with dimensions of 25.0 cm x 4.6 mm x 5.0 μm was designed for analysis [99].

2.5. Extraction of samples

The samples were being extracted using 15 g of sample and 250 mL of methanol in a Soxhlet device for 6 h (Figure 2.2). Methanol was then extracted using a rotating evaporator operating at 40 °C under vacuum. After drying the extract, it was weighed before dissolving it in 10 mL of CH_3OH and storing the resulting solution at 4 °C in a refrigerator [100].

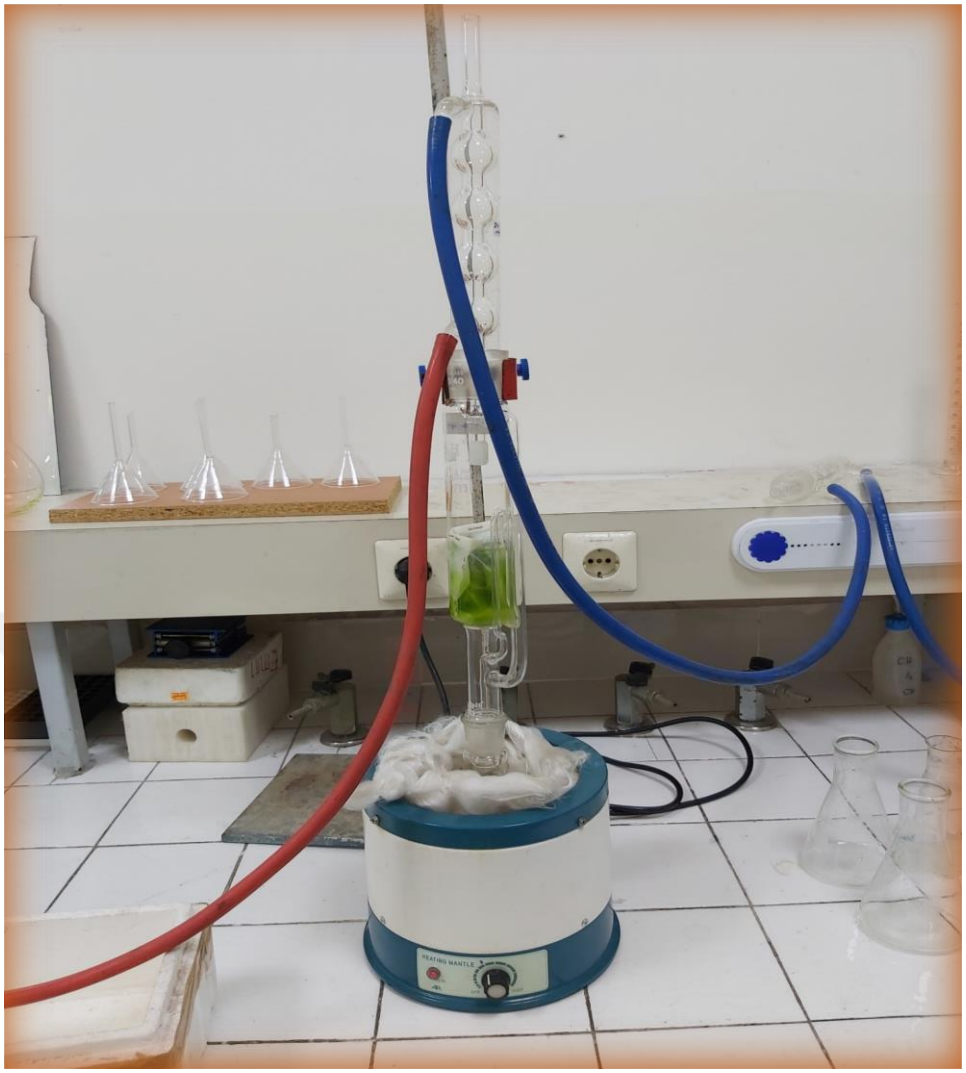

Figure 2.2 Extract preparation using Soxhlet

2.6. Determination of Total phenolic content

The spectrophotometric determination of total phenolic material followed the Folin-Ciocalteu technique with adjustments made by Dewanto et al. The following was combined and shaken: 0.50 mL of distilled water, 0.250 mL of sample or gallic acid, and 0.125 mL of Folin-Ciocalteu reagent. To achieve volume of 3.00 mL, distilled water was added after 6 min, and 1.250 mL of 7% sodium carbonate solution was added. After 90 min, the ultraviolet-visible spectrophotometer read the absorption at 760 nm. It was determined how varied quantities of gallic acid would affect the graph. The TPC of the samples was calculated, and the findings were reported in micrograms of gallic acid equivalents per gram (µg GAE/g) [101].

2.7. Determination of total flavonoids

Spectrophotometric analysis, as reported by Dewanto et al. (2002), was used to calculate total flavonoid content. The absorbance at 510 nm was measured after mixing a 0.025 mL sample of quercetin with 1,250 mL of distilled water, 0.075 mL of a 5% sodium nitrite solution, and 0.150 mL of a 10% solution of aluminum chloride; the mixture was allowed to stand for 5 min. Then, 0.500 mL of a 1.0 M sodium hydroxide solution was added. Different amounts of quercetin were used to create a usable graph. Total flavonoids content was calculated using the working graph, and the findings were expressed as micrograms of quercetin compounds per gram [101].

2.8. Total antioxidant capacity DPPH method

Antioxidant capacity was determined using the approach published by Nile et al. (2013), which is based on the scavenging activity of the stable DPPH free radical. The absorption of a DPPH solution made by dissolving 25 µg/mL of DPPH in methyl alcohol was measured at 510 nm. The, absorbance at 510 nm was measured after the DPPH solution had been in the dark for 30 min with varying concentrations of sample extracts. IC_{50} (µg/mL) values were reported, which represent the concentration of the antioxidant chemical that inhibits 50% of the DPPH radical in the medium. High antioxidant activity is shown by low IC_{50} values [102].

2.9. Total antioxidant capacity ABTS method

Re et al. (1999) provided a technique for measuring the free radical-scavenging activity of ABTS. Stock solutions consisting of 7.0 mM ABTS solution and 2.4 mM potassium persulfate were kept in the dark for 12–16 h at room temperature. To obtain an absorbance of 0.8 at 734 nm, phosphate buffer (pH = 7.4) was added to the ABTS•+ solution. After letting a 2.0 mL ABTS•+ solution at room temperature for 15 min, the absorbance was measured at 734 nm after 25, 50, 75, and 100 microliters of diluted sample or Trolox standard was added. The control was an ABTS+ solution that had been prepared beforehand. The antioxidant capacity of the sample was determined by measuring its Trolox equivalence in micromoles per gram [103].

2.10. Screening of antimicrobial activities

2.10.1. Test microorganisms

Six bacteria viz., *Bacillus megaterium* DMS 32, *Pseudomonas aeruginosa* DMS 50071 SCOTTA, *Escherichia coli* ATCC 25922, *Klebsiella pneumoniae* FMC 5, *Proteus vulgaris* FMC 1, *Staphylococcus aureus* COWAN 1 FMC 16, and as yeasts viz., *Candida albicans* FMC 17, C

used as test organisms. Microorganisms were provided by Firat University, Department of Biology, Microbiology Laboratory Culture Collection.

2.10.2. Extract preparation

Fresh and powdered plant materials (10 g) were used. Was extracted in 150 mL solvent by keeping on a rotary shaker for 24 h. Then, it was filtered through Whatman No. 1 filter paper. The sample was further concentrated to dryness under reduced pressure at 37 ºC using a rotary evaporator. It was dissolved in dimethyl sulfoxide and stored at 4 ºC for further studies. All extracts thus obtained were injected into an empty sterilized antibiotic disc with a diameter of 6 mm in a volume of 20 µL (Schleicher&Shüll No: 2668, Germany). The amount of solvent to be injected in to the disc is regulated by controls, which stipulate that only 20 µL of solvent will be administered. Streptomycin sulfate and nystatin are the standard substances used in this process.

2.10.3. Preparation of microbial cultures and test

After 24 h in nutrient broth and 48 h in malt extract broth, bacterial and yeast strains were inoculated. To use the disc-diffusion method, the test bacteria and yeasts were placed on Mueller Hinton agar (for bacteria) and Malt extract agar (for yeast) at concentrations of 10^5 bacteria/mL and 10^4 yeast/mL, respectively. The solid agar medium was covered with the disc by gently pushing it down. After 2 h at 4 ºC, the petri dishes were incubated at 35±0.1 ºC for 24 h, while the yeast was incubated at 25±0.1 ºC for 3 days. The inhibitory zones were measured in millimeters at the beginning of the period [104].

2.11. Statistical Analysis

The analyses were replicated three times, and the findings are reported as the mean ± error. The findings were subjected to one-way ANOVA analysis using SPSS 26.0 for MS Windows. The significance of differences between group means was assessed using the Tukey HSD test, and statistical significance was indicated by a $p \leq 0.05$. Different letters were used to highlight significant differences between table rows, whereas similar letters imply that there is no statistical difference between groups.

3. RESULTS

3.1. Water-soluble vitamin content

This investigation also focused on *A. vera's* water-soluble vitamins. Because *A. vera* include 99% of water in their structure, it follows that they include water-soluble vitamins. Research has shown that various parts of *A. vera* contain water-soluble vitamins. There were vitamin C, thiamine, riboflavin, nicotinic acid, pyridoxal, nicotinamide, pyridoxine, pantothenic acid, folic acid, and vitamin B12 at concentrations of 1.16±0.03 μg/g, 1.86±0.07 μg/g, 4.71±0.11 μg/g, 9.34±0.38 μg/g, 3.67±0.16 μg/g, 12.1±0.47 μg/g, 3.53±0.15 μg/g, 4.96±0.13 μg/g, 10.8±0.56 μg/g, and 22.56±1.03 μg/g, respectively, in the green leaf part of the plant. Vitamin B12 has the highest level of water-soluble vitamin in the green leaf part of *A. vera* (Table 3.1). However, the gel of *A. vera* included each one of vitamin C, thiamine, riboflavin, nicotinic acid, pyridoxal, nicotinamide, pyridoxine, pantothenic acid, folic acid, and vitamin B12 at concentrations of 3.17±0.14 μg/g, 1.61±0.06 μg/g, 1.9±0.09 μg/g, 90.55±2.63 μg/g, 2.13±0.1 μg/g, 39.8±0.99 μg/g, 14.93±0.30 μg/g, 5.42±0.36 μg/g, 12.72±0.49 μg /g and 0.23±0.01 μg/g, respectively. Nicotinic acid has the highest level of water-soluble vitamins in gel of *A. vera*. Also generally gel *A. vera* has the higher levels of water-soluble vitamins (Table 3.1). The quantities of ascorbic acid, riboflavin, nicotinic acid, nicotinamide, pyridoxine, pyridoxal, and vitamin B12 in the *A. vera* plant gel and green leaf sections were significantly different ($p<0.05$). However, statistical analysis revealed no significant differences in the B1, B5, and B9 contents of the gel and green leaf components of the *A. vera* ($p > 0.05$).

Table 3.1 Amount of water-soluble vitamins concentrations μg/g.

	Green leaf part	**Gel**
Ascorbic acid	[a] 1.16±0.03	[b] 3.17±0.14
Thiamine	[a] 1.86±0.07	[a] 1.61±0.06
Riboflavin	[a] 4.71±0.11	[b] 1.90±0.09
Nicotinic acid	[a] 9.34±0.38	[b] 90.55±2.63
Nicotinamide	[a] 12.1±0.47	[b] 39.80±0.99
Pantothenic acid	[a] 4.96±0.13	[a] 5.42±0.36
Pyridoxal	[a] 3.67±0.16	[b] 2.13±0.10
Pyridoxine	[a] 3.53±0.15	[b] 14.93±0.30
Folic acid	[a] 10.8±0.56	[a] 12.72±0.49
Cyanocobalamin	[a] 22.56±1.03	[b] 0.23±0.01

Statistical significance level was expressed as $p<0.05$. Different letters in the rows indicate a statistical difference, while the same letters indicate that there is no statistical different.

3.2. Fat-soluble vitamins (A & E), β-carotene, lycopene and 4-HNE

Based on the findings of this study, vitamins A and E were detected in various part of the plant. The concentration of Vitamin A obtained in the green leaf part and gel of *A. vera* were 0.17±0.03 µg/g and 0.26±0.05µg/g. There was no significant difference in the concentration of vitamin A between the plant gel and green leaf portions ($p<0.05$). While Vitamin E concentration was 3.6±0.57 µg/g in the green leaf part and was 1.1±0.09 µg/g in the gel of the *A. vera*. The vitamin E contents of the gel and green leaf portions of the plants were not significantly different from one another ($p > 0.05$). Furthermore, it is clear that gel had a higher vitamin A concentration than green leaves. On the other hand, the green leaf part generally had higher vitamin E levels than the gel of *A. vera.* (Table 3.2).

Table 3.2 shows that the 0.63±0.14 µg/g of β-carotene level observed in the green leaf part of *A. vera* while in gel was 0.07±0.01 µg/g. The β-carotene contents of the gel and green leaf portions of the *A. vera* were not significantly different from one another ($p > 0.05$).

The concentration of lycopene was 7.6±1.50 µg/g in the green leaf part of *A. vera*; on the other hand, gel contained 3.01±0.69 µg/g of lycopene. Statistically, there is no significant difference in the lycopene level of the gel and green leaf part components of the *A. vera* plant ($p > 0.05$).

The green leaf part of the plant contains high levels of β-carotene and lycopene. The green leaf part of *A. vera* has a (5.6± 1.07 µg/g) concentration of 4-Hydroxynonena; on the other hand, the gel shows a (3.68±0.74 µg/g) level for 4-HNE. Thus, the gel showed a higher 4-hydroxynonena level. Statistically, there is no significant difference in the 4-hne value of the gel and green leaf part components of the *A. vera* plant ($p > 0.05$).

Table 3.2 Amount of vitamin A, E, β-carotene, lycopene and 4-HNE concentrations µg/g.

	Green leaf part	Gel
Vitamin A	[a] 0.17±0.03	[a] 0.26±0.05
Vitamin E	[a] 3.6±0.57	[b] 1.1±0.09
β-Carotene	[a] 0.63±0.14	[b] 0.07±0.01
Lycopene	[a] 7.6±1.50	[b] 3.01±0.69
4-HNE	[a] 5.6±1.07	[a] 3.68±0.74

Statistical significance level was expressed as $p<0.05$. Different letters in the rows indicate a statistical difference, while the same letters indicate that there is no statistical different.

3.3. Total phenolic, total flavonoid, DPPH & ABTS content

The total amount of phenolic compounds is provided as µg of Gallic acid equivalent/g of extract and is represented in (Table 3.3). The green leaf part of *A. vera* showed a higher level of total phenolic content (0.17±0.01 µg/g) than the gel that has (0.04±0.00 µg/g) of total phenolic content. The green leaf part has a higher concentration of total phenolic content, than the gel of *A. vera*. The quantities of total phenolic content in the *A. vera*'s green leaf part and gel were found to be significantly different ($p<0.05$).

The total amount of flavonoid compounds is provided as µg of Quercetin equivalent/g and is represented in (Table 3.3). TFC in the green leaf part of *A. vera* was obtained as (0.96±0.21 µg/g). On the other hand, the gel was estimated at (0.26±0.07 µg/g) The total flavonoid content of the gel and green leaf portions of the plant is not significantly different from one another ($p > 0.05$).

So similar to total phenolic content, the green leaf part has a higher concentration of total flavonoid content than gel of *A. vera*.

The common purpose of this experiment is to find out how well different sample extracts scavenge radicals. The premise of the experiment focused on the capacity of the extract to lower DPPH radicals.

The DPPH radical scavenging activities of *A. vera* extracts derived from various sections, was determined in this study. The ability of four distinct concentrations of *A. vera* samples from 50 to 200 µL for DPPH radical scavenging was evaluated. According to the findings, the effects of the *A. vera* extracts start at a concentration of 50 µL and increase with concentration, as shown by the findings.

As shown in (Table 3.3), the methanolic extract of green leaf part of *A. vera* was 133.9±7.08 µg/mL, on the other hand the methanolic extract of gel showed 407.95±9.42 µg/mL, of DPPH radical scavenging activity. So, the green leaf part of *A. vera* has a higher ability to scavenge DPPH radicals. A statistically significant difference was discovered in the DPPH radical scavenging activity between the green leaf section and the gel of *A. vera* ($p<0.05$).

The experiment's premise focuses on the extract's capacity to lower ABTS radicals. The ABTS radical-scavenging activity of *A. vera* extracts derived from various sections, was determined in this study. The ABTS radical scavenging ability of four different concentrations of *A. vera* samples 50-200 µL to ABTS radical scavenge was evaluated. As shown in (Table 3.3), methanolic extract of green leaf part of *A. vera* showed 25.1±2.28 µmole trolox/g, on the other hand the methanolic extract of gel showed 0.95±0.67 µmole trolox /g, of ABTS radical scavenging activity respectively. Therefore, the green leaf part of *A. vera* have a higher ability to scavenge ABTS radicals. Although there was no significant difference in the ABTS radical scavenging activity across various parts of the *A. vera* ($p > 0.05$).

Table 3.3 Amount of total phenolic µg/g, total flavonoid µg/g, DPPH µg/mL and ABTS µmole trolox/g

	Green leaf part	Gel
Total phenolic	[a] 0.17±0.01	[b] 0.04±0.00
Total Flavonoid	[a] 0.96±0.15	[b] 0.26±0.05
DPPH	[a] 133.9±7.08	[b] 407.95±9.42
TEAC	[a] 25.1±2.28	[b] 0.95±0.67

Statistical significance level was expressed as $p<0.05$. Different letters in the rows indicate a statistical difference, while the same letters indicate that there is no statistical different.

3.4. Antimicrobial activity

The disc diffusion technique was used to ascertain the antibacterial and antifungal properties of the extracts of various portions of the *A. vera* plant that were utilized in the study. The results of this determination are shown in (Table 3.4) below. The diverse sections of the plant, namely the green leaf portion and the gel, were shown to be effective in preventing the growth of yeast and bacteria. The extract of the green leaf component of the *A. vera* plant had the greatest impact on *Bacillus megaterium* (11.6±0.32 mm), while it had the least impact on *Escherichia coli* (8.3±0.30 mm). It was shown that the extract of the gel component had the most impact on *Staphylococcus aureus* (20±0.29 mm), while it had the least impact on *Pseudomonas aeruginosa, and Proteus vulgaris* (15.5±0.29 mm). The antimicrobial abilities of *A. vera* plant's gel, green leaf part and standard were found to be significantly different ($p<0.05$).

Table 3.4 Antimicrobial activity of *A. vera* (mm)

	Green leaf part	Gel	Standard
Bacillus megaterium	[a] 11.6±0.32	[b] 19.0±0.35	[c] 24.3±0.33
Pseudomonas aeruginosa	[a] 8.9±0.13	[b] 15.5±0.29	[c] 18.5±0.29
Escherichia coli	[a] 8.3±0.30	[b] 16.2±0.17	[c] 25.3±0.33
Klebsiella pneumoniae	[a] 9.3±0.17	[b] 17.4±0.20	[c] 18.9±0.47
Proteus vulgaris	[a] 9.0±0.29	[b] 15.5±0.29	[c] 18.2±0.20
Staphylococcus aureus	[a] 10.0±0.35	[b] 20.0±0.29	[b] 20.2±0.20
Candida albicans	[a] 9.2±0.20	[b] 17.5±0.29	[c] 21.8±0.39

Statistical significance level was expressed as $p<0.05$. Different letters in the rows indicate a statistical difference, while the same letters indicate that there is no statistical different.

4. DISCUSSION

In this research, the nutritional value, antioxidant capacity, and antibacterial action of *A. vera* were determined.

Medicinal plants are said to possess healing powers because they contain several phytoconstituents, including vitamins, flavonoids, phenols, and more [105]. Of the around 420 species of *Aloe* found in nature, *A. vera* is the most medicinally significant. *A. vera* has been utilized for its therapeutic and curative power, and many researchers have attempted to study its active components. Reports indicate that compounds derived from *A. vera* have antioxidant properties [106].

A wide range of phytochemicals, health benefits, and potential toxicity may be found in the many species of *Aloe*. Therefore, it is important for scientists, businesses, and rural communities to study the native *Aloe* species for its medical properties and to identify its active ingredients and the ways in which they work biologically. There is a wealth of information available about the use of 95% ethanol extracts of different species of *Aloe* to study their biological activity in the prevention and treatment of various health issues [91].

A typical medicinal and cosmetic plant, *Aloe vera* L. Burm f., was the subject of this investigation into its antimicrobial properties, total flavonoid, total phenolic content, water- and fat-soluble vitamin content, DPPH and ABTS radical scavenging effects, β-carotene, lycopene, and 4-HNE contents.

A. vera's vitamin content, which may be categorized into water-soluble and fat-soluble vitamins, was another metric established within the realm of phytochemicals. Research on *A. vera's* vitamin content is limited. In this study, the levels of fat-soluble vitamins A and E were measured in different sections of *A. vera*.

The human body can't make the vitamins themselves, so they have to get them from food. Vitamins are organic compounds with several biochemical activities; they're required in tiny amounts for metabolism to work properly [107]. The first group contains fat-soluble vitamins such as A, D, E, and K, as well as various carotenoids, while the second group consists of water-soluble vitamins such as C and eight B-vitamins, including thiamine (B1), riboflavin (B2), niacin (B3), pyridoxine (B6), pantothenic acid (B5), biotin (B7), folate (B9), and cyanocobalamin (B12) [108].

It has been determined that some parts of *A. vera* contain water-soluble vitamins. According our investigation, there was 1.16±0.03 µg/g of vitamin C, 1.86±0.07 µg/g of thiamine, 4.71±0.11 µg/g of riboflavin, 9.34±0.38 µg/g of nicotinic acid, 3.67±0.16 µg/g of pyridoxal, 12.1±0.47 µg/g of nicotinamide, 3.53±0.15 µg/g of pyridoxine, 4.96±0.13 µg/g of Pantothenic acid, 10.8±0.56 µg/g of folic acid, and 22.56±1.03 µg/g of vitamin B12 in the green leaf section of *A. vera*.

On the other hand, in the gel of *A. vera*, 3.17±0.14 µg/g of vitamin C, 1.61±0.06 µg/g of thiamine, 1.9±0.09 µg/g of riboflavin, 90.55±2.63 µg/g of nicotinic acid, 2.13±0.10 µg/g of pyridoxal, 39.8±0.99 µg/g of nicotinamide, 14.93±0.30µg/g of pyridoxine, 5.42±0.36 µg/g of Pantothenic acid, 12.72±0.49 µg/g of folic acid, and 0.23±0.01 µg/g of vitamin B12 have been detected. Due to the presence of 99% water in the *A. vera* plant's structure, the current research has found measurable amounts of water-soluble vitamins in various sections of the plant. In comparison to the green leaf portion, the water-soluble vitamin content of *A. vera* gel is often higher. The gel has the highest concentration of nicotinic acid. Vitamin B12 is most abundant in *A. vera*'s green leaf part.

The quantities of ascorbic acid, riboflavin, nicotinic acid, nicotinamide, pyridoxine, pyridoxal, and vitamin B12 in the *A. vera* plant gel and green leaf sections were significantly different ($p<0.05$). However, statistical analysis revealed no significant differences in the B1, B5, and B9 contents of the gel and green leaf components of *A. vera* ($p > 0.05$).

The body's health benefits from the optimal levels of water-soluble vitamins. Vitamins that are soluble in water cannot be synthesized by humans. Therefore, they must be absorbed via their intestines from outside sources. Although foods consumed by humans are the primary means by which these micronutrients enter the body, the role of the typical large intestine microbiome in maintaining adequate levels of several of these nutrients [such as thiamin, folate, riboflavin (RF), pyridoxine, and pantothenic acid], particularly with regard to the cellular nourishment and wellbeing of local colonocytes [109].

Research conducted by Andrea et al. (2020) examined the bioactive chemicals found in seven different species of *Aloe*, and vitamin C was among them. The estimated vitamin C content in the entire *Aloe* leaf extract is as follows: 1.17±0.03 mg/100 g for *A. aculeata*, 2.34±0.16 mg/100 g for *A. africana*, 2.34±0.09 mg/100 g for *A. arborescens,*1.16±0.07 mg/100 g for *A. barbadensis*, 2.34 ±1.13 mg/100 g for *A. ferox*, 2.01±0.09 mg/100 g for *A. marlothii*, and 5.85±0.25 mg/100 g for *A. spectabilis* [110].

Because of its chemical features, ascorbate is an effective free-radical scavenger, and the human body is unable to produce it. Hence, it must be obtained exogenously, such as, from food or supplements. Some of the action of vitamin C influence vascular reactivity, reducing dangerous oxidants in the stomach, and facilitating intestinal iron absorption [111].

Singh et al. (2012) looked at the effects of storage on vitamins A and C in *A. vera* juice and found that both vitamins depleted over time. They concluded that pasteurization is better for preserving vitamin A and chemical preservatives are better for preserving vitamin C [112].

Thiamine (B1) is essential for several cellular functions, including antioxidant activity. A lack of thiamine causes beriberi, which is most often associated with neurological and cardiovascular symptoms [113].

Vitamin B2, or riboflavin, is a nutrient supplement and a medication for inflammatory diseases including angulus infectious, cheilitis, glossitis, sepsis, cataracts, and migraines. An essential function of riboflavin is to maintain the antioxidant status within cellular systems [114].

As an active ingredient in the pyrimidine nucleotide coenzymes NAD and NADP, niacin helps keep pellagra and "black tongue" diseases at bay in both people and dogs [115]. Because of their interconversion, both nicotinic acid and nicotinamide, which are together known as vitamin B3, are equally effective as a vitamin [116].

A. vera pulp has a considerable quantity of several water-soluble vitamins, according to El-Sayed & El-Sayed. (2020). These vitamins include (B1) 9.73±0.21 mg/g, (B2) 141.2± 0.34 mg/g, and (B3) 4.63±0.26 mg/g [117].

Pantothenic acid participates in the metabolism of fatty acids as a component of acyl-carrier proteins and coenzyme A. The formation of the central nervous system, release of steroids, maintenance of healthy skin and hair, and production of antibodies are all areas that are heavily involved [118].

Vitamin B6 is a metabolite that every living thing needs. Recent research has shown its antioxidant capabilities, and it can function as a coenzyme for a wide variety of metabolic activities [119].

Folic acid (B9) is crucial for DNA synthesis and repair. One of the most prevalent deficits observed globally is folic acid deficiency. Its insufficiency affects a variety of demographics, including expectant mothers, the elderly, and children [120]. Vitamin B12 is a coenzyme that promotes appropriate fat and carbohydrate metabolism, is critical for healthy nerve and blood cell function, and is required for DNA methyl group translocation during formation [121].

Few studies have examined the water-soluble vitamin content of *A. vera* in the reviewed literature. Specifically, studies examining vitamins B5, B6, B9, and B12 have been very rare or unavailable.

The investigation was carried out by El Mesallamy et al. in 2019 on the aerial sections of *Forsskaolea viridis*. These water-soluble vitamins were found in plants: vitamin B6 (39.417 µg/100 g), vitamin B9 (12.638 µg/100 g), and vitamin B12 (386.06 µg/100 g) [122].

Seeds of chickpea (*Cicer arietinum L.)* were compared for their water-soluble vitamin content in 2008 by Aslam et al., who looked at both *in vitro* and *ex vitro* germinated seeds. The levels of pantothenic acid were found to be significantly different in the two samples, with the former showing higher concentrations in *in vitro*-grown seedlings [123].

The findings of our investigation showed that the concentration of vitamin A in the green leaf part of *A. vera* was estimated to be (0.17±0.03 µg/g), while in the gel it was determined to be (0.26±0.05 µg/g). There was no significant difference in the concentration of vitamin A between the plant gel and green leaf portions ($p<0.05$).

Vitamin A is an essential antioxidant, has a function in the skin mucosa, regulates reproduction, and is required for the visual process [124]. There is significant evidence from both experimental and epidemiological studies that vitamin A levels are inversely related to cancer induction [125].

A research conducted in Indonesia on the *Aloe chinensis baker* plant found that fresh gel of 7 - 8 months old *A. vera* (raw material) contains (4.59 IU) of vitamin A content [126].

Vitamin A is crucial for several cellular and extracellular matrix-related activities, as well as those involving cell proliferation, differentiation, and interactions. Lack of it, especially at an early stage, hinders the development of linear growth, bone and cartilage, and the differentiation and function of epithelial cells [127].

Vitamin E is another vitamin found in distinct parts of the *A. vera* plant. The findings showed that the green leaf part of the plant had a concentration of 3.6±0.57µg/g of vitamin E, whereas the gel part only had 1.1±0.09 µg/g. The vitamin E contents of the gel and green leaf portions of the plants were not significantly different from one another ($p > 0.05$).

Vitamin E's antioxidant and cholesterol-lowering properties make it an important dietary component [128]. Miranda, M., et al (2008) investigated the impact of ambient temperature on the vitamin E content of *A. vera* gel at different temperatures. Due to its thermal stability, vitamin E was successfully extracted in every instance. At 50 °C, the highest concentration of vitamin E was 0.683±0.017 mg/100 g d.m. Then it decreased slowly according to the following drying temperatures: 60 °C (0.563±0.094 mg/100 g d.m.), 90 °C (0.331±0.013 mg/100 g d.m.), 80 °C (0.262±0.030 mg/100 g d.m.), fresh (0.217±0.003 mg/100 g d.m.), and 70 °C (0.172±0.006 mg/100 g d.m.) [129].

Research conducted in 2011 found that 100 g of *A. vera* gel has a vitamin E level of 0.192 IU/100 g. Researchers have identified vitamin E as a component that contributes to the antioxidant capabilities of plants, leading to a decrease in glucose levels in diabetic rats [130].

Vitamin E stops the progression of lipid peroxidation processes and eliminates free radical intermediates. Therefore, it is considered a crucial antioxidant [131]. Since burns and other internal wounds heal from the inside, increasing the quantity of vitamin E that penetrates the skin helps the healing process by working in the deeper layers of the injured region. Studies have shown that antioxidants, including vitamin E, are particularly important for wound healing and anti-inflammatory activity [132].

This research also looked at the levels of β-carotene plant, which were determined to be 0.63±0.14 μg/g in the green leaf part of *A. vera* and 0.07±0.01 μg/g in the gel. The β-carotene contents of the gel and green leaf portions of the *A. vera* were not significantly different from one another ($p > 0.05$).

β-carotene, which is also called provitamin A due to its conversion into retinol (vitamin A), is regarded as one of the most effective singlet oxygen scavengers [133].

Carotene is a natural pigment, immune system enhancer, and antioxidant. It is a tool forwarding against cancer, particularly those of the skin, liver, and other organs. Serious disorders like night blindness, etc., may result from a deficiency of this vitamin [134].

In 2009, Ozsoy et al. conducted a study to examine the medicinal benefits of *A. vera's* green leaves, excluding their inner gel. The researchers found that the aqueous extract of *A. vera* leaves had a β-carotene content of (15.5±12.39 μg/g FW) [135].

The presence of β-carotene in the secondary metabolites of three distinct *Aloe* species was examined in a study conducted in Korea in 2021. The amount of β-carotene in the powder of *A. A. arborescens* was found to be 55.57± 1.36 μg/g, compared to 34.49±0.22 μg/g in *A. saponaria* and 33.44± 1.69 μg/g in *A. vera* [136].

With its powerful antioxidant properties, β-carotene may shield cells from harmful free radicals and stave against a host of long-term illnesses, including cancer, cardiovascular disease, and the effects of ageing [137].

The amounts of lycopene and 4-HNE in *A. vera* plants were also the subject of this study. No published or rare information on the concentrations of these compounds in *A. vera* was found. One might argue that this study is the pioneering one in identifying lycopene and 4-HNE in *A. vera*. The findings showed that the green leaf part of the plant had a concentration of 7.6±1.50 μg/g of lycopene, while the gel part only had 3.01±0.69 μg/g. Statistically, there is no significant difference in the lycopene level of the gel and green leaf part components of the *A. vera* plant ($p > 0.05$).

Lycopene is one of the most common types of carotenoids. Its biological and physicochemical characteristics, particularly its impact as an antioxidant, have recently attracted a great deal of interest [138].

Martnez-Sánchez et al. (2020) studied the bioactive component of *A. vera* flowers at various stages of maturity. There are three stages of development: the first stage is immature; the second stage is mature; and the third stage is mature. The lycopene concentration was found to be the lowest in the third stage, while in Stage I, immature, it was found to be the highest [139].

The preventive effects of lycopene against a number of diseases and conditions have recently attracted a lot of attention. These include cardiovascular disease, hepatic fibrogenesis, sun induced

erythema, HPV persistence, and several cancers, including prostate, gastrointestinal, and epithelial. Recent studies have shown that lycopene is involved in fetal development and lung function [140].

Among the byproducts of advanced lipid peroxidation is the hazardous reactive aldehyde 4-hydroxynonenal (4-HNE). Free radicals are primary initiators of 4-HNE accumulation and adduct formation. 4-HNE is involved in several cytotoxic processes, including protein malfunction, apoptosis, and inflammatory damage, and has harmful consequences. Therefore lipid peroxidation and oxidative stress may be detected by 4-HNE [141].

The findings of our investigation showed that the concentration of 4-HNE in the green leaf part of *A. vera* was estimated to be (5.6±1.07 µg/g), while in the gel it was determined to be (3.68±0.74 µg/g). Statistically, there is no significant difference in the 4-hne value of the gel and green leaf part components of the *A. vera* plant ($p > 0.05$).

Proteins and peptides are the most significant class of macromolecules targeted by HNE from a quantitative standpoint. Proteins are predicted to be modified by 1–8% of 4-HNE produced in cells [142].

Phenolics are the most important constituents of plants because of their ability to neutralize free radicals [143].

The investigations we performed to ascertain the phytochemical composition of *A. vera* indicated the quantity of total flavonoids and phenolic content. It was discovered that the total phenolic content in the plant's green leaf part was 0.17±0.01 µg Gallic acid /g, while in the gel it was 0.04±0.00 µg Gallic acid /g. The quantities of total phenolic content in the *A. vera*'s green leaf part and gel were found to be significantly different ($p<0.05$).

Results from phytochemical analyses of complete *A. vera* leaves that collected in Myanmar showed that the plant's fresh leaves contained phenolic compounds [144].

The lowest estimated amount of total phenolic content was 97.95 ± 21.5 µg GAE/mg, while the maximum value was 332.4 ± 32.6 µg GAE/mg, according to another study done in Pakistan, examined various fractions of *A. vera* leaf [145].

Similarly, in a study conducted in South Korea, Debneth et al. (2018), discovered that an ethanolic extract of *Aloe barbadensis* flowers contained (17.52±1.34 mg gallic acid/100g dry mass) of total phenolic compounds [146].

The role of plant phenols in promoting health and warding off chronic illnesses has received more attention and funding in recent years. The antioxidant, antitumor, and antibacterial properties of plant phenols have been recognized as crucial in many studies [147].

Among the many factors contributing to the accurate assessment of antioxidant capability, phenolic compounds stand out [148]. While the specific types of phenolic compounds might affect

an extract's antioxidant capacity, in general, an extract's overall phenolic concentration is compatible with its antioxidant activity [56].

The green leaf portion of the *A. vera* plant had the highest quantity of total flavonoids content (0.96±0.21 µg Kuersettin/g), while the gel of plant had the lowest TFC (0.26±0.07 µg Kuersettin/g). The total flavonoid content of the gel and green leaf portions of the plant is not significantly different from one another ($p > 0.05$).

A study conducted in 2003 by Hu et al. examined *A. vera* plant samples taken at various stages of maturity. The researchers discovered that *A. vera* plant that were three years old had a greater amount of flavonoid content that estimated as (4.70 ± 0.48 g/kg), and four years old *A. vera* had (4.28±0.18 g/kg) flavonoid concentration, in the other hand two years old plant had (3.63±0.38 g/kg) of flavonoid content [86].

Researchers in India looked at how climate change can affect the variety of phytochemicals found in *A. vera*. The study's methanolic extract predicted the maximum flavonoids value from *A. vera* samples collected from 12 distinct areas under varied circumstances [149].

In their investigation of several leaf fractions of *A. vera*, Tariq et al. (2019) also measured the plant's total flavonoid content. The highest total flavonoid content in the *A. vera's* methanolic extract samples was assessed to be(87.54± 15.5 µg QE/mg), while the lowest was (18.46± 7.68 µg QE/mg) [145].

Researchers have demonstrated that flavonoids may provide protection against cancer and cardiovascular problem via plausible mechanisms in both *in vitro* and *in vivo* studies. According to available evidence, some flavonoids may have therapeutic potential for the treatment of various diseases. Research on plants with traditional medical uses for treating various diseases has provided some evidence by identifying flavonoids as a common bioactive component of these plants [150].

It has been shown that flavonoids exhibit several biological actions, including anti-inflammatory, antibacterial, antiviral, and antiallergic properties [151].

Plants contain vast amounts of flavonoids, which are bioactive polyphenols with low molecular weights. These compounds are vital for cells that engage in photosynthetic respiration, the process by which plants make oxygen [152].

The nutritional values discovered in this study are at odds with what is already known from the literature. This could be due to genus variations, plant collection locations, seasons, climate change effects in these areas, or maturation stage of plant. It could also be because of the solvent or laboratory procedures used.

In the present study, the DPPH and ABTS radical-scavenging abilities of *A. vera* were determined. The ability of four distinct concentrations of *A. vera* samples from 50 to 200 µL to scavenge free radicals was established. Based on these findings, it was concluded that the *A. vera*

extracts had effects at a concentration of 50 µL and that this effect varied with concentration. The methanolic extract of green leaf part of *A. vera* was 133.9±7.08 µg/mL, on the other hand the gel showed 407.95±9.42 µg/mL of DPPH radical scavenging activity. While, methanolic extract of green leaf part of *A. vera* showed 25.1±2.28 µmole trolox/g, on the other hand the gel showed 0.95±0.67 µmole trolox/g, of ABTS radical scavenging activity respectively. So, the green leaf part of *A. vera* has a higher ability to scavenge DPPH and ABTS radicals.

A statistically significant difference was discovered in the DPPH radical scavenging activity between the green leaf section and the gel of *A. vera* ($p<0.05$). There was no significant difference in ABTS radical scavenging activity across the various parts of *A. vera* ($p > 0.05$).

DPPH assay, which is based on a hydrogen atom transfer reaction, is required to analyze the presence of antioxidants [153].

According to Saeed et al. (2022) the antioxidant activity of *A. vera* powder extract was analyzed, and the findings showed that at doses of 20–100 µg/mL, water extracts showed a % inhibition (DPPH) of 10.23–35.80, while methanol extracts showed 12.84–44.96 [154].

Researchers in 2022 looked at the ability of cookies made with *A. vera* gel to scavenge DPPH-free radicals. At a concentration of 10 mg/mL, *A. vera* cookies reduced the activity of DPPH free radical by 28.75% [155].

Researchers Nazim Uddin et al. (2020) tested the antioxidant properties of *A. vera* gel using a variety of solvents. The *A. vera* gel powder exhibited an 81.24±0.93% reduction in DPPH radicals at a concentration of 1000 µg/mL when tested with acidified methanol. At a concentration of 1000 µg/mL, the suppression of the DPPH radical was less pronounced in pure methanol and aqueous ethanol [156].

The capacity of *A. vera* gel to scavenge ABTS radicals was investigated in research by Nazim Uddin et al. (2020) utilizing various solvents. At a concentration of 1000 µg/mL, the *A. vera* gel powder exhibited 96.39 ± 2.90% ABTS radical inhibition when combined with acidified methanol. A concentration of 1000 µg/mL inhibited the ABTS radical less effectively with pure methanol and aqueous ethanol [156]. This research was conducted by Jairath. et al. (2015) The capacity of the aqueous methanolic *A. vera* gel to scavenge ABTS radicals was determined to be 96.14% [157].

The findings of this study were consistent with those of previous studies. Studies on *A. vera* have shown that the radical scavenging capacity of a plant is proportional to the concentration of the studied compound.

Microbial resistance to commonly used antimicrobial medications is a growing global health crisis that threatens the health of millions of people annually [158]. The antimicrobial properties of *A. vera* are due to the presence of many compounds in the leaves [159].

The antibacterial action of *Aloe* spp. has been previously shown *in vitro*, with results showing that Aloe extracts may inhibit the growth of both Gram positive and Gram negative bacteria, such as *S. aureus, E. coli*, and *K. pneumonia* [160].

When the antibacterial and antifungal properties of the extracts of various portions of *A. vera* were investigated, it was found that the extracts were effective against all microorganisms and influenced their growth at varying rates. This indicated that the extracts were effective against all microorganisms. *Bacillus megaterium* (11.6±0.38 mm), *Staphylococcus aureus* (10±0.35 mm), *Pseudomonas aeruginosa* (8.9±0.13 mm), *Klebsiella pneumoniae* (9.3±0.17 mm), *Candida albicans* (9.2±0.20 mm), and *Escherichia coli* (8.3±0.30 mm) were the microorganisms that were proven to be affected by the extract of the green leaf part of *A. vera*. The following microorganisms were shown to be affected by the extract of the gel part: *Staphylococcus aureus* (20±0.29 mm), *Bacillus megaterium* (19±0.35 mm), *Candida albicans* (17.5±0.29 mm), *Klebsiella pneumoniae* (17.4±0.20 mm), *Pseudomonas aeruginosa*(15.5±0.29mm), *Escherichia coli* (16.2±0.17 mm), and *Proteus vulgaris* (15.5±0.29mm). The antimicrobial abilities of *A. vera* plant gel and green leaf sections were found to be significantly different ($p<0.05$).

Researchers Musa Abakar et al. (2017) looked at the antibacterial properties of *A. vera* leaves. The methanolic extract of the leaves exhibited an inhibitory effect against all of the tested bacteria and fungi, including *S. aureus* (25 mm), *Acinetobacter niger* (24 mm), *Candida albicans* (22 mm), *Bacillus subtilis* (20 mm), *Escherichia coli*, and *Pseudomonas aeruginosa* each at 19 mm. [161].

The antimicrobial activity of *A. vera* gel was studied using the disc diffusion technique in a study by Kaithwas et al. (2008) *A. vera* gel has been shown to limit the development of some germs, according to the findings of this study. *Escherichia coli* (6 mm), *Staphylococcus aureus* (9.56 mm), *Pseudomonas aeruginosa* (6 mm), and *Proteus vulgaris* (6 mm) are the specimens that were used [162].

The antibacterial characteristics of *A. vera* gel were studied by Udgire M.S. et al. utilizing the well agar diffusion technique in conjunction with methanol, ethanol, and diethyl ether, three distinct solvents. According to the results of this study, the methanol extract had a zone of inhibition of (11) mm against *Staphylococcus aureus* and (10) mm against *Staphylococcus epidermidis*, followed by (9) mm zones of inhibition against *E. coli*, *P. vulgaris*, and *P. aeruginosa*, appropriately. *P. mirabilis* and *K. pneumoniae* had a minimum zone of inhibition of (8) mm in diameter. Whereas the other solvents had less antibacterial effects against the test microorganisms compared to methanol [163].

Shireen et al. (2015) conducted research using the disc diffusion technique to study the antifungal efficacy of *A. vera* extract against *Candida albicans*. The investigation revealed that *A. vera* extract suppressed the development of *Candida albicans*, measuring 14 mm in length [164].

This study's investigations to determine the antimicrobial capacity of various parts of *A. vera* yielded different results from the literature. This discrepancy may be due to experiments being conducted in different regions, under different climatic conditions, at different stages of plant growth, with different solvents, or with unknown specific parts of the plant.

5. CONCLUSIONS

Aloe vera has gained more popularity in recent years for its medicinal, cosmetic, and food uses. This plant has become of interest because of its wide range of applications, and the number of scientific studies on it is continually growing. *A. vera* was found to be a rich source of nutrients and has the potential to fulfil a person's daily requirements for vitamin B12, according to the findings of this study, which analyzed the nutritional contents of various parts of the plant. The fact that it is a powerful antioxidant was also discovered. We concluded that the green leaf part of *Aloe vera* has powerful antibacterial potential and that it stops the growth of germs by taking into consideration its antimicrobial ability, which can be used to treat the growing resistance of microbes to synthetic antibiotics. At the same time, people are becoming aware of the negative effects of synthetic antioxidants, which cause severe health issues. As a result, researchers have begun looking for natural alternatives to antimicrobials and antioxidants in order to reduce the negative effects of synthetic drugs. So, *A. vera* can be used as an alternative antioxidant because of its radical-scavenging ability. Over the past several years, there has been an increase in the number of researchers interested in plants. As a result, it is believed that this study will contribute to research on alternative antioxidants and antimicrobials.

RECOMMANDATIONS

The advancement of technology has shown the potential of *A. vera* leaves to be used in many applications due to their wound healing, anti-inflammatory, and antibacterial properties. Specifically, combining the gel into antibacterial and personal care products using nanotechnology and other modern techniques broadens the range of applications in which we can use the plant's medicinal properties. To maximize the medicinal properties of plants to the fullest extent, it is necessary to conduct interdisciplinary research in the industrial sector to create efficient, secure, and organic products. The *A. vera* plant has a long history of usage, spanning many cultures and contexts, but notably in the beauty and medicinal industries. Now that its health advantages have been demonstrated, it has caught the interest of academics. The pharmaceutical and cosmetic industries also use it. A number of phytochemical and antibacterial actions of *A. vera* were identified in this study. Since it contains water soluble vitamins that can keep hair and skin hydrated, it can be used in cosmetic products. Because it has been found to contain nutritional substances, more study is necessary before it can be used as a dietary supplement.

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APPENDICES

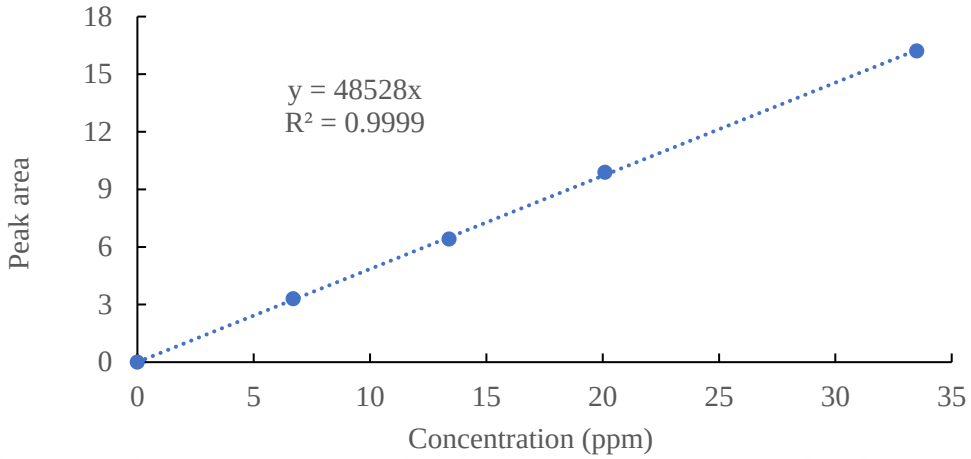

Figure A 1 Working graph for the correct equation of vitamin C

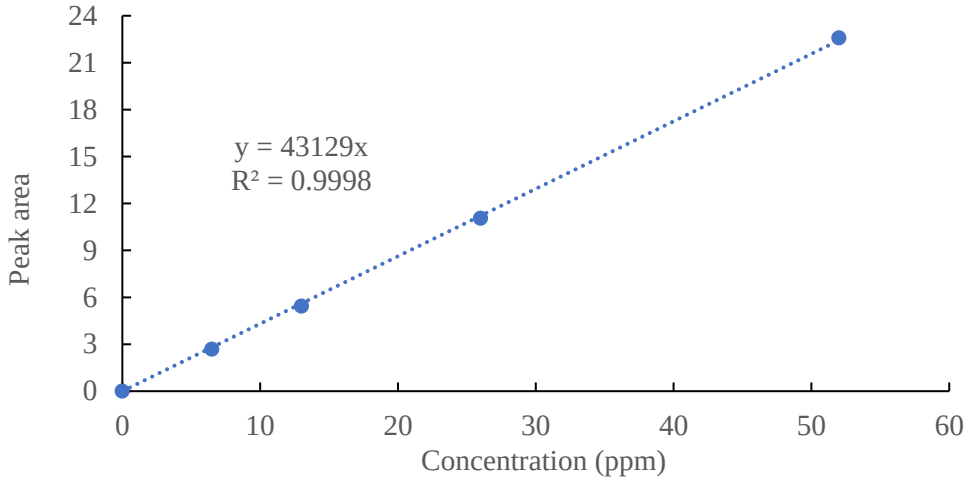

Figure A 2 Working graph for the correct equation of vitamin B1

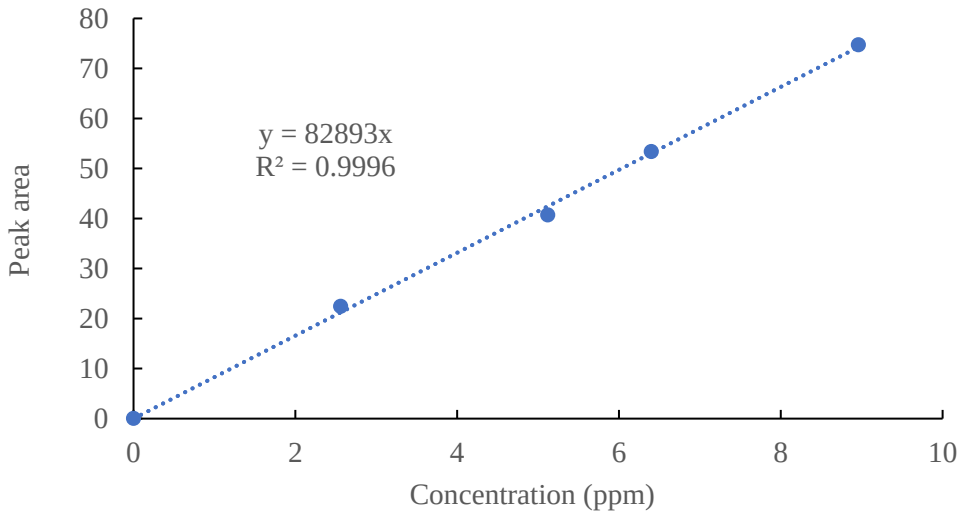

Figure A 3 Working graph for the correct equation of vitamin B2

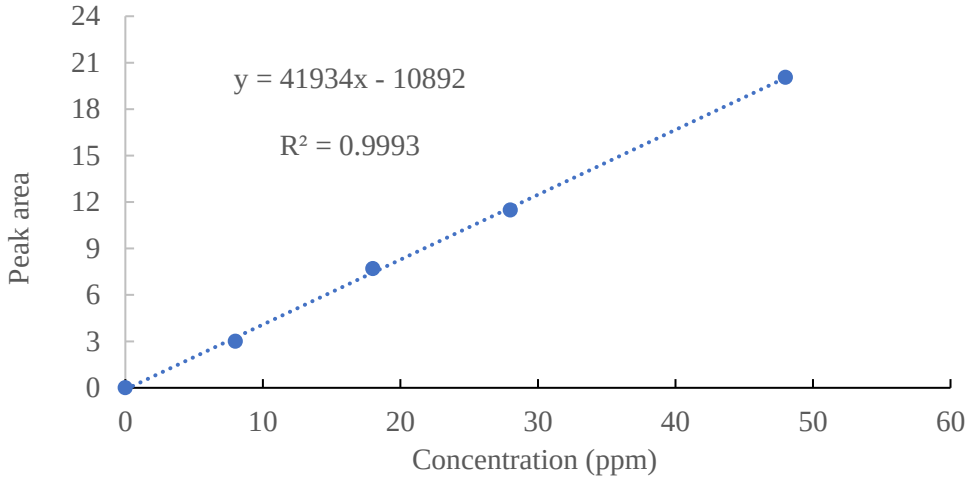

Figure A 4 Working graph for the correct equation of nicotinic acid

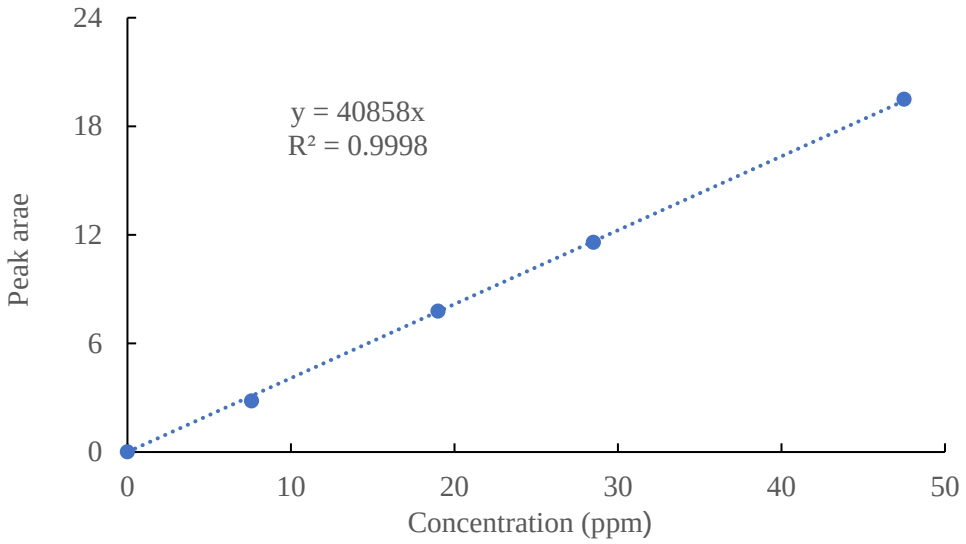

Figure A 5 Working graph for the correct equation of nicotinamide

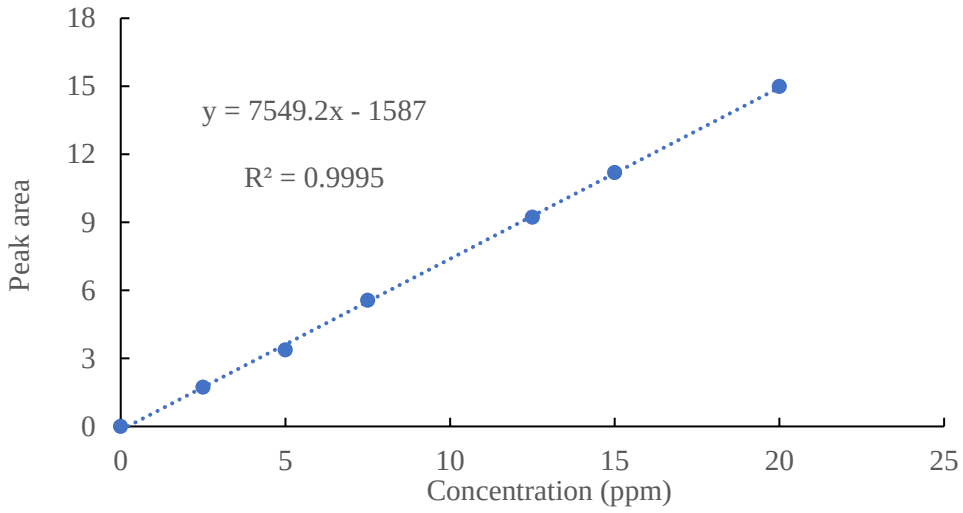

Figure A 6 Working graph for the correct equation of vitamin B5

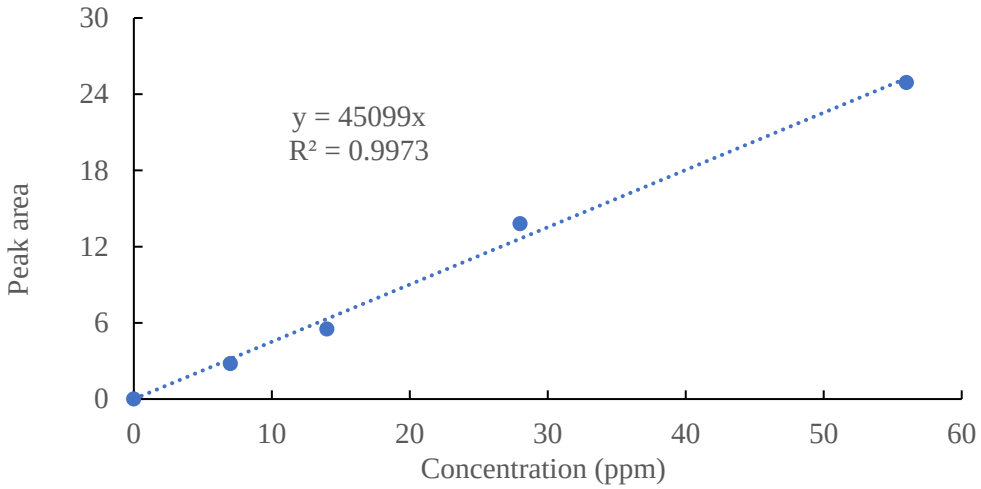

Figure A 7 Working graph for the correct equation of vitamin B6

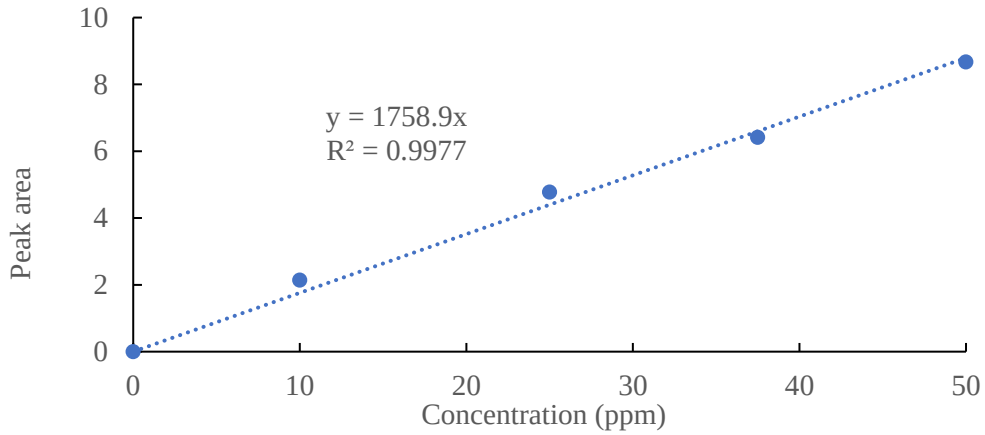

Figure A 8 Working graph for the correct equation of vitamin B9

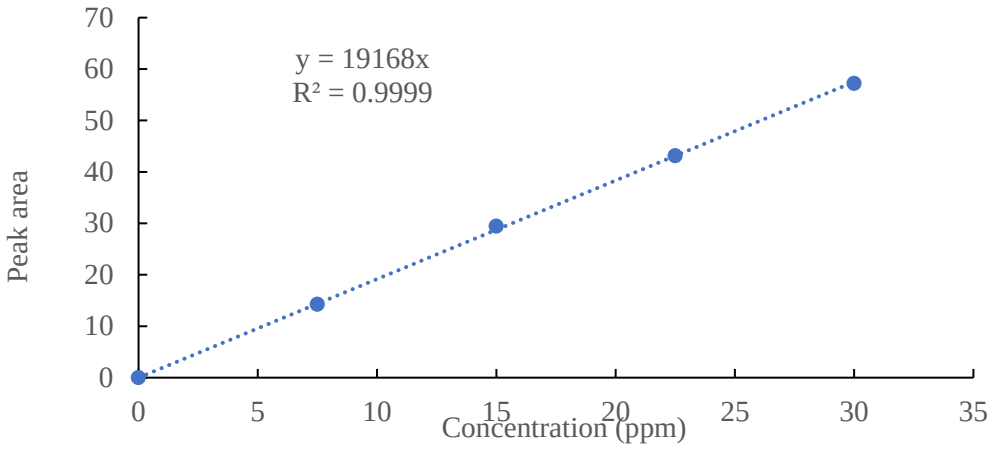

Figure A 9 Working graph for the correct equation of vitamin B12

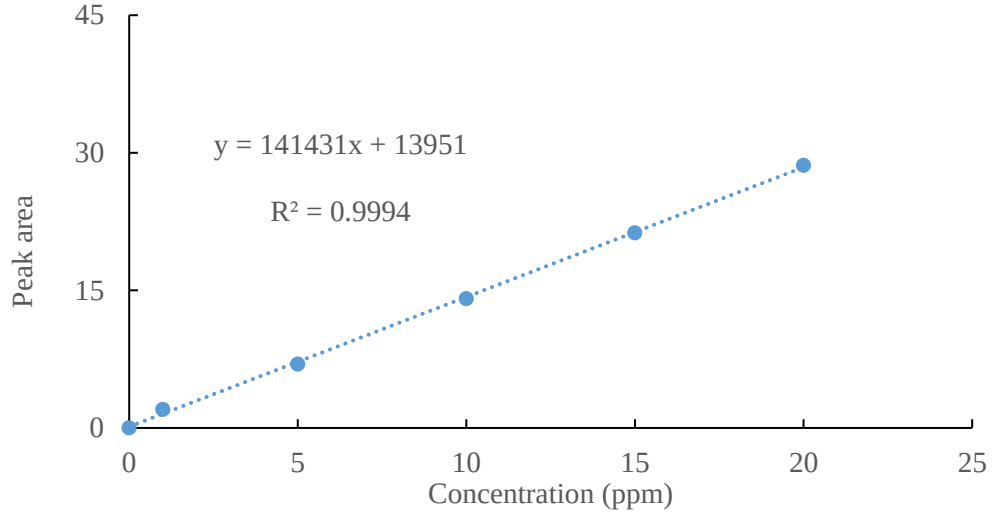

Figure A 10 Working graph for the correct equation of vitamin A

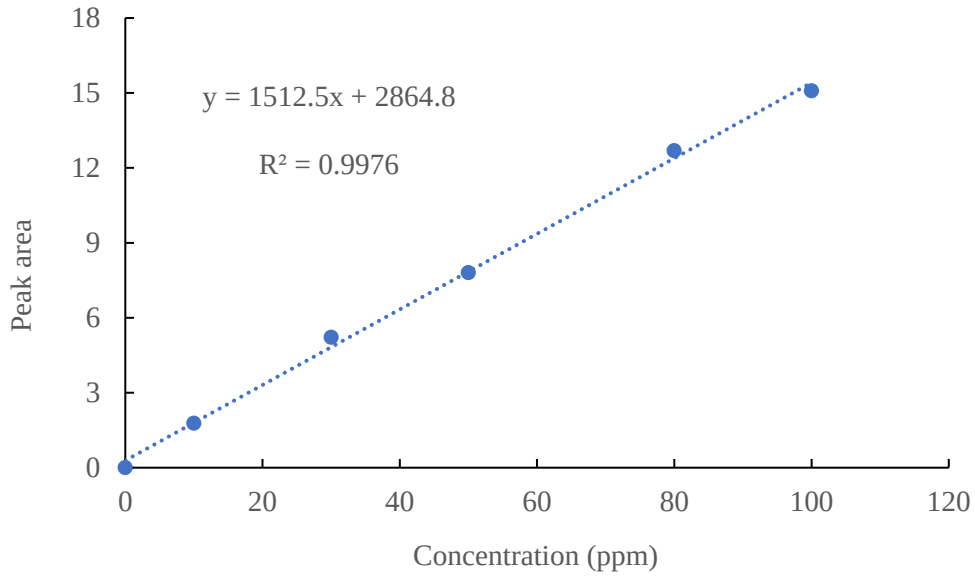

Figure A 11 Working graph for the correct equation of vitamin E

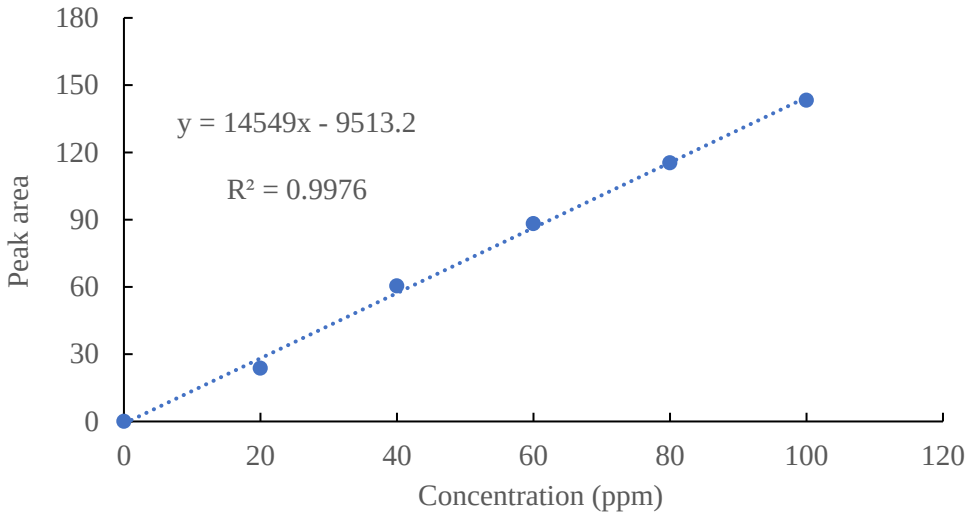

Figure A 12 Working graph for the correct equation of β-carotene

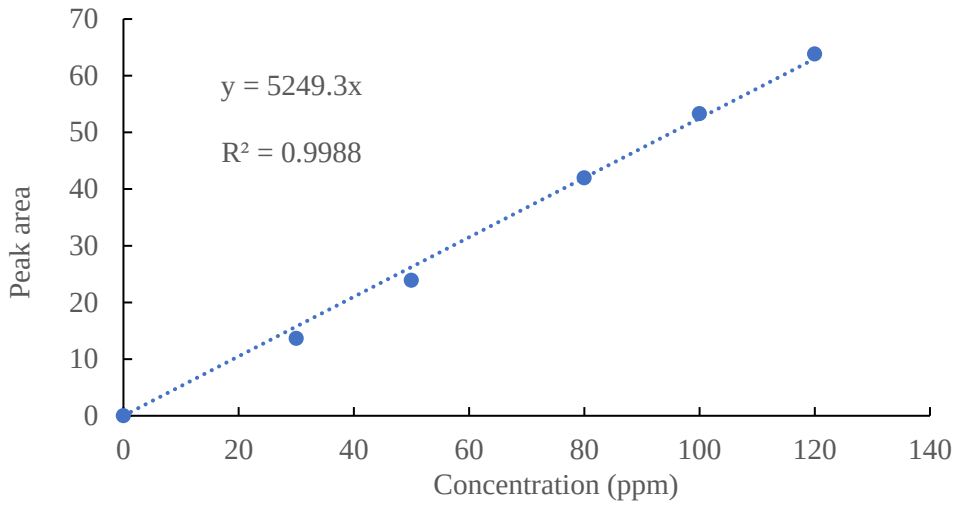

Figure A 13 Working graph for the correct equation of lycopene

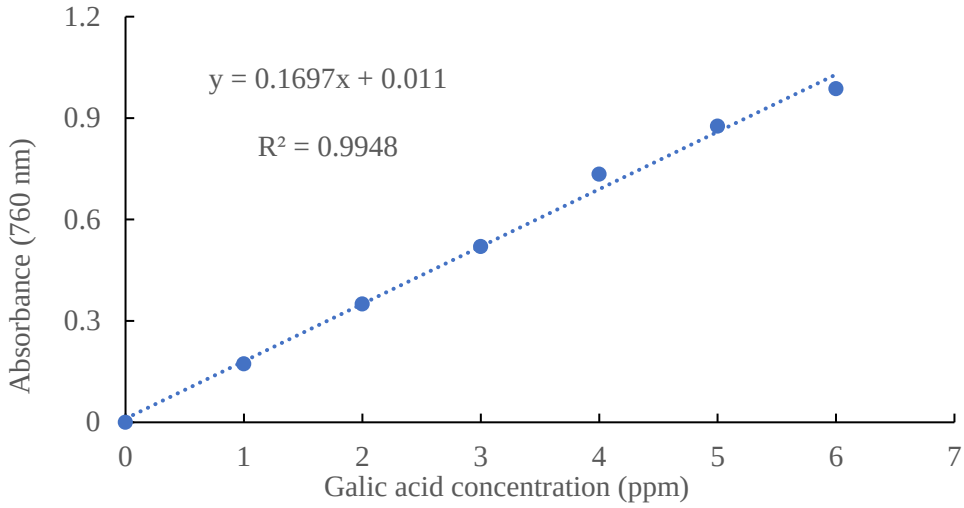

Figure A 14 Working graph for the correct equation of total phenolic acid

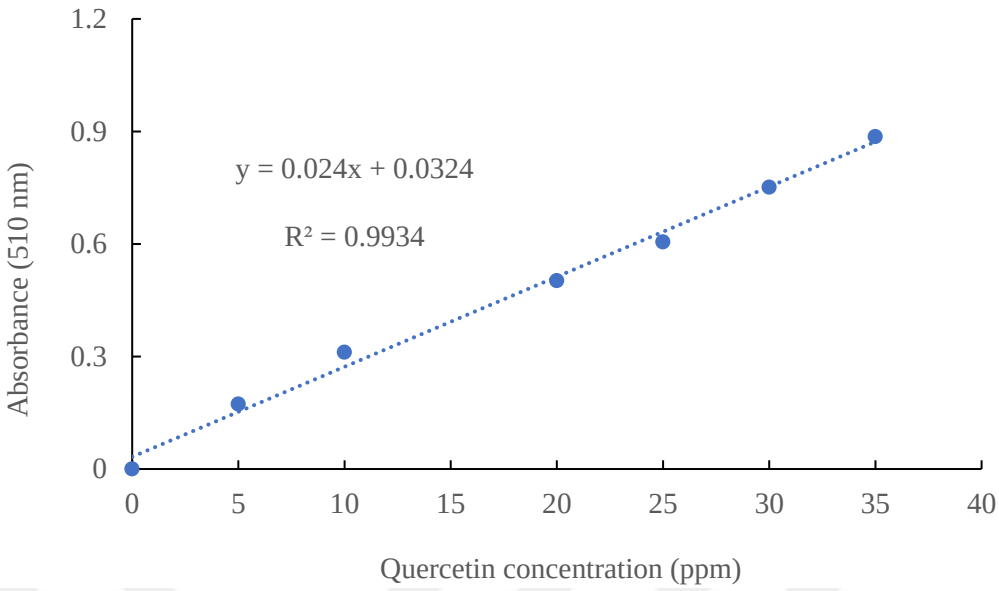

Figure A 15 Working graph for the correct equation of total flavonoids

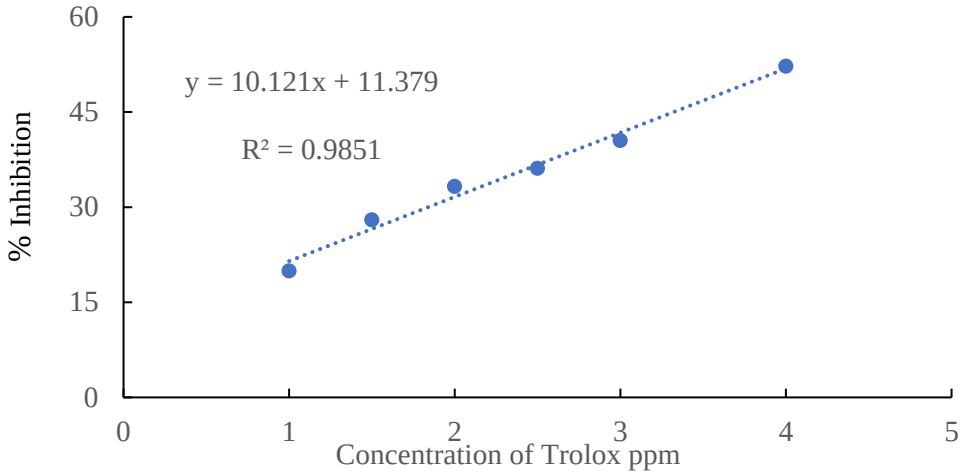

Figure A 16 Working graph for the correct equation of trolox

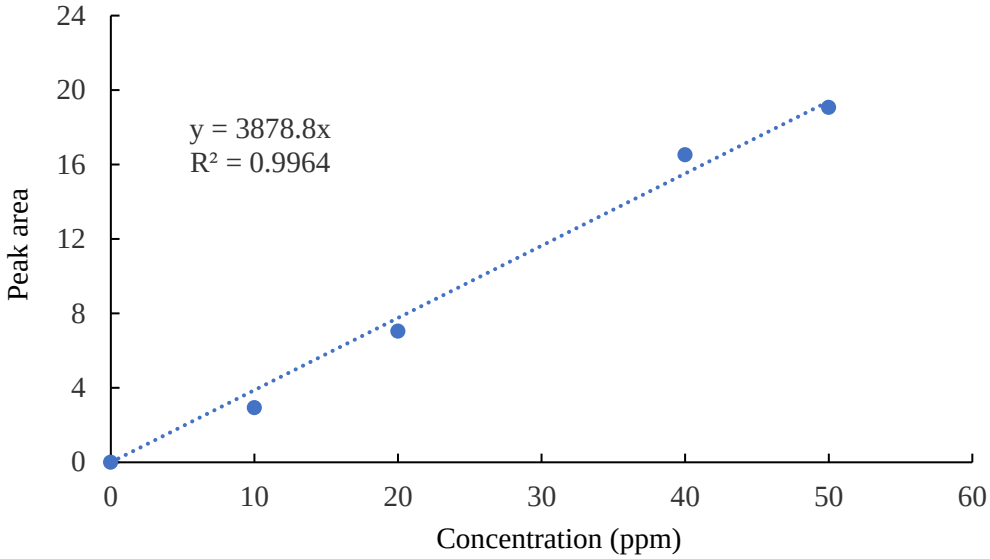

Figure A 17 Working graph for the correct equation of 4-HNE

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ACADEMIC ACTIVITIES

[1] S.K. and F.K. Heleen Tahseen Yaseen Yaseen, Comparative of water soluble vitamins in gel and green leaf parts of *Aloe vera* (L.), Balkan 10th Int. Conf. Appl. Sci. (n.d.) 15–20.