A Seminar Paper on

Application of *Aloe vera* to produce safe, sustainable fruits and vegetables

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Application of *Aloe vera* to produce safe, sustainable fruits and vegetables[1]

by

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Abstract

Aloe vera (ALV), with its unique nutritional profile, is being used for food, health, and nutraceutical industries globally. It is organic in nature, and has created much interest in exploring its potential to extend the shelf life of fresh produce. ALV gel could delay fruit ripening by lowering ethylene biosynthesis, respiration rate, and internal metabolic activities. In addition, it reduces the microbial spoilage due to its antimicrobial properties. The use of *Aloe vera*-based coatings/films has been investigated to maintain the quality and freshness of fruits and vegetables during storage and transportation. Thus this coating creates an opportunity to reduce the use of synthetic preservatives, and ensuring safe food. *Aloe vera* has also been reported to enhance the growth and yield of crops and increase their resistance to biotic and abiotic stress. The current seminar paper highlighted the potential of *Aloe vera* to produce and ensure safe fruits and vegetables. The challenges of using ALV in producing safe perishables and future research directions are also discussed.

Key words: Postharvest, preharvest, shelf life

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Agriculture holds a direct influence on the world economy both nationally and internationally (Mason *et al*., 2019). However, crops exposed to natural environmental conditions often threatened by a variety of pathogenic microorganisms (such as bacteria, viruses, nematodes, and fungi) and cause significant crop yield loss (Velásquez *et al*., 2018). Traditionally, these phytopathogens have been controlled using synthetic fungicides (Jiménez *et al*., 2019). These compounds also have disadvantages, such as toxic waste in plants and fruits after treatment that cause harmful effect in human body and environment. This scenario arises the research interest in using safe produce such as natural or organic products to develop sustainable and profitable agro industry (Jiménez *et al*., 2018, Jiménez *et al*., 2019, Yigit *et al*., 2020). The most important natural antimicrobial products currently used includes microorganisms, extracts, essential oils, or active compounds from plants (Jiménez *et al*., 2019). Among them plant extracts are extremely important for their different physiological properties and active metabolic compounds those either prevent or protect from insects or pathogens invasion (Bennett & Wallsgrove 1994). Interestingly, these metabolites are not harmful to health and environment in most cases (Sayago *et al*., 2012). Therefore, they were considered as an excellent alternative for the control of phytopathogenic fungi (Bolívar *et al*., 2020).

In recent years some plant extracts have been successfully tested against different pre- and postharvest microorganisms that produce significant economic losses worldwide and can cause diseases in humans. The study of different plant extract based food coatings has also acquired much importance in the food industry in recent years. The application of these food coatings often prolongs the perishable shelf life, and helps to maintain their quality. Therefore, these coatings could act as a potential alternative to the chemical preservation methods. These plant extracts and food coatings have no adverse effect on the environment and non-toxic (for human consumption) at the applied doses (Hasan *et al*., 2021, Sempere *et al*., 2022)

Several findings have been carried out to examine the known and unexploited plant species with antimicrobial properties (Mwangi *et al*., 2021). A number of botanical pesticidal compounds have been discovered from various cultivated and wild plant parts. For example, a number of plants from *Liliaceae, Rutaceae, Compositae, Meliaceae, Leguminosae, Araceae,* *Platycodoniaceae, Solanaceae, Chenopodiaceae, Zingiberaceae, Labiatae, Loniceraceae, Umbelliferae, Polygonaceae,* and *Euphorbiaceae* possess secondary plant metabolites, including alkaloids, terpenoids, and flavonoids that have pesticidal activities. Ngegba *et al*., (2022), listed some commercially plant-based pesticides, extracted from Aloevera (*Aloe vera*), pyrethrum (*Tanacetum cinerariifolium*), tobacco (*Nicotiana tabacum* L.), neem (*Azadirachta indica* A. Jus*s*), sabadilla (*Schoenocaulon officinale* Gray), and ryania (*Ryania speciosa*) (Ngegba *et al*., 2022).

This seminar paper discussed different research findings those worked with *Aloe vera* for food preservation as edible coatings and gels. It is known that, edible coatings generally provide a thin layer on the fruit surface, and acts as a barrier to atmospheric gases and moisture. *Aloe* gels help to reduce the respiration and transpiration of fresh produce and delay postharvest deterioration of foods, promoting food preservation. (Kahramanoğlu *et al*., 2019) The use of *Aloe vera* can reduce postharvest losses, enhance food safety and quality, extend shelf life, and promote environmental sustainability (Sonker *et al*., 2016).

Objectives:

i. To evaluate the potentiality of *Aloe vera* for using as a preharvest treatment to increase crop quality and reduce preharvest treatment

ii. To evaluate its potential in reducing the postharvest losses, improving the quality, and extending the shelf life of fruits and vegetables.

iii. To identify the challenges in using *Aloe vera* for producing and preserving fruits and vegetables.

CHAPTER 2

MATERIALS AND METHODOLOGY

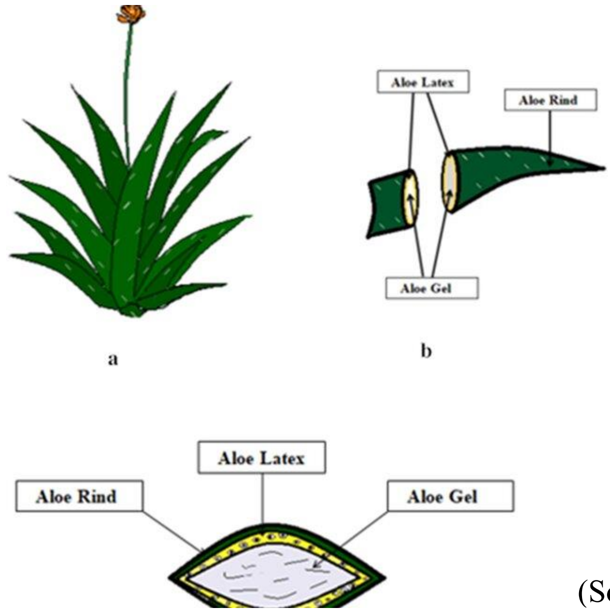
This seminar paper is exclusively a review paper so, all of the information has been collected from the secondary sources. This seminar paper has been prepared by reciting different books, journals, booklets, proceeding, newsletters, consultancy report which are available in the libraries of BSMRAU and internet. Maximum necessary supports were taken from internet searching. This seminar paper was prepared with the consultation of my respective major professor and honorable seminar course instructors. After collecting necessary information, it has been compiled and arranged chronologically for better understanding and clarification.

CHAPTER 3

REVIEW OF FINDINGS

3.1. *Aloe vera*

Aloe vera is one of the oldest plant species among *Aloe* genus and well-known for its marvelous medicinal characteristics. The word "*Aloe*" derived from the Arabic word "Alloeh" or the Hebrew "Halal" meaning shinny substance (Gage, 1996). It was originated in Arabia, Oman, Sudan, and Somalia and now widely distributed throughout the tropics and sub-tropics of the world (Schmelzer, 2008). *Aloe* L. genus contains 446 species in *Xanthorrhoeaceae* family reported around the globe and most of them are found in South Africa. Among all, *Aloe vera, Aloe arborescens, Aloe barbadensis*, and *Aloe ferox* are widely studied and well-established species (Salehi *et al*., 2018). It is a perennial plant and known as "plant of immortality." It has resemblance with cactus due to thickness, thorn-edged leaves, ranging in color from gray to bright green but in fact it is a member of *Liliaceae* family (Figure 1a). *Aloe vera* leaves are arranged in a rosette pattern at the stem and are triangular-shaped with soft spikes. The leaves are made up of mainly water (95%), and present more than 200 bioactive compounds, (Sempere-Ferre *et al*., 2022). These thick leaves have a high capacity to store water for long periods which helps the plant to survive in drought and very warm dry climate. This plant has also ability to survive in very harsh circumstances where most of other vegetation disappears. This plant produces two or three yellow tubular flowers (Figure 1a) intermittently throughout the year and has resemblance in shape with Eastern Lily (Gage, 1996). The leaves of Aloe vera can be viewed in three sections (Figure 1b and c) such as a) The Rind: It is the outermost layer of the leaf and imparts about 20–30% of total leaf weight; b) Latex: It contains latex, also known as aloe juice/sap; c) The inner layer (Gel): The gel of Aloe vera is stored in thin parenchymatous cells that make the innermost layer of the leaf (Jangra *et al*., 2022).



(Source Jangra *et al*., 2022)

Figure 1. Overview of *Aloe vera* plant a) an *Aloe vera* plant with flower, b) Longitudinal section of *Aloe vera* leaf showing aloe rind, latex, and gel, c) Cross-section of *Aloe vera* leaf showing aloe rind, latex, and gel.

Traditionally, *Aloe vera* has been extensively used in different medicines in the Indian subcontinent because it incredibly works as a therapeutic and curative agent for the cure of several diseases. Recent reports have revealed that *Aloe vera* markedly reduced the risk of increasing cholesterol levels, cardiovascular diseases, and alleviated cancers particularly in human liver (Kumar *et al*., 2013; Salehi *et al*., 2018). Moreover, *Aloe vera* provides protection against inflammation of gums and relieves the pain of teeth and helps in the wound healing (Maan *et al*., 2018). Besides its medical uses, the *Aloe vera* leaf extracts including *Aloe vera* juice and *Aleo vera* gel also used as bio-preservative for fresh horticultural produce. It is a well-known thickener, antimicrobial coating, and gelling agent, which has close association with aloin content (Zapata *et al*., 2013), having various applications in pharmaceutical and food industry to maintain the food quality and shelf life (Sanchez-Machado *et al*., 2017).

3.1.1. Active components of *Aloe vera* with their properties

Aloe vera is known to contain around 75 potentially active constituents: vitamins, enzymes, minerals, sugars, lignin, saponins, salicylic acids and amino acids (Table 1).

Table 1. The active components present in *Aloe vera*

Active component	Active components present in *Aloe vera*
Vitamins	Vitamin A (beta-carotene), C and E, - antioxidants. It also contains vitamin B1, B2, B6 & B12, folic acid, and choline. Antioxidants protect the body by neutralizing free radicals.
Enzymes	Aliiase, alkaline phosphatase, amylase, oxidase, bradykinase, carboxypeptidase, catalase, cellulase, lipase, cylooxygenase, and peroxidase.
Minerals	Calcium, chromium, copper, selenium, magnesium, manganese, potassium, sodium and zinc.
Sugars	Monosaccharides (glucose and fructose) and polysaccharides (glucomannans/polymannose).
Organic acids	Sorbate, salicylic acid, uric acid
Anthraquinones	Aloin, barbaloin, isobarbaloin, anthranol, *Aloe*tic acid, *Aloe*-emodin, ester of cinnamic acid, resistannol, chrysophannic acid and emodin
Fatty acids and Steroids	Fatty acids like Arachidonic acid, γ-linolenic acid. .
Non-essential amino acids	Histidine, arginine, aspartic acid, glutamic acid, proline, glycine, tyrosine, alanine and hydroxyl proline.
Essential amino acids	Methionine, phenylalanine, isoleucine, leucine, valine, threonine and lysine.
Hormones	Auxins and gibberellins .
Others	Lignin, and saponins

(Source: Lanka, 2018)

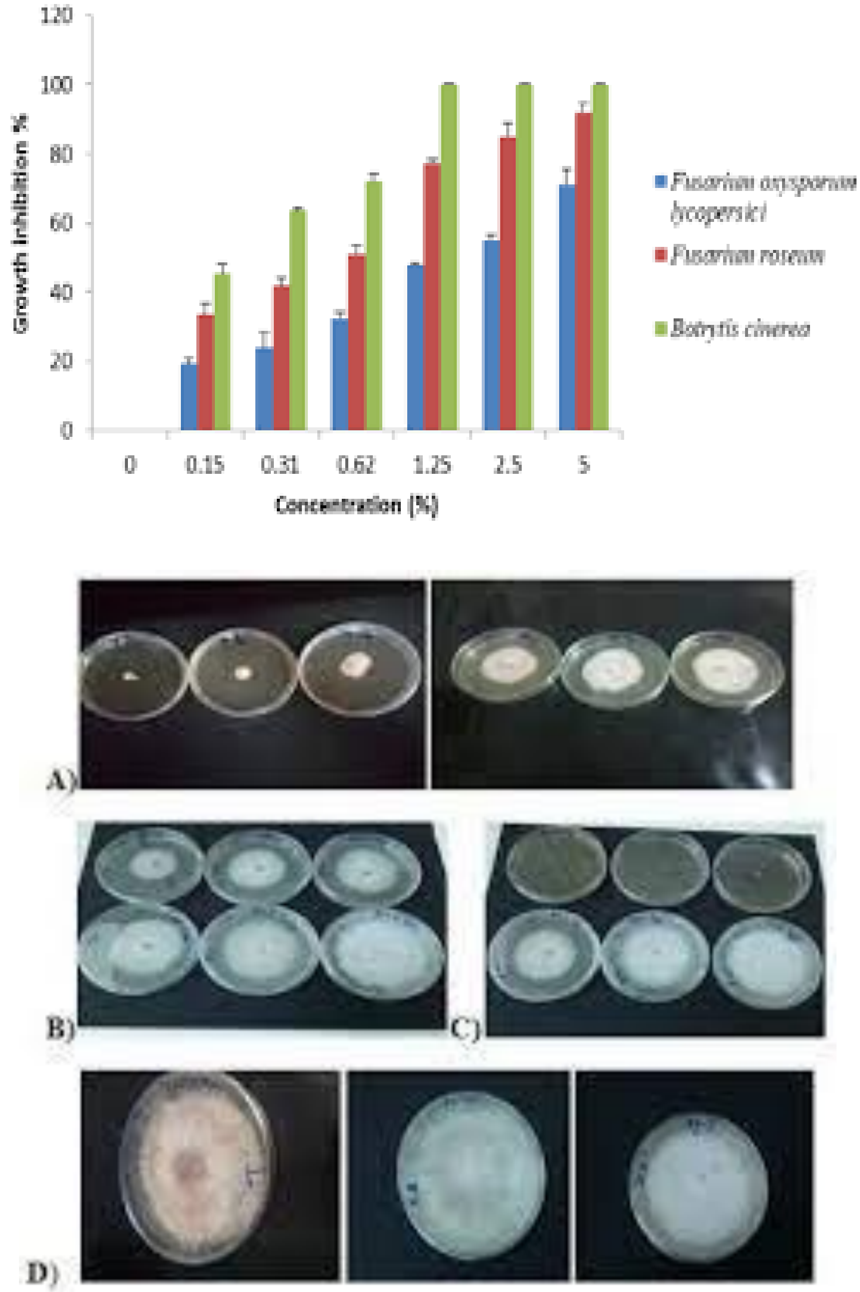
3.1.2. Antimicrobial activity

Aloe vera plant extracts have antimicrobial characteristics that kill microorganisms (including bacteria (antibacterial activity), fungi (antifungal activity), and viruses (antiviral activity)) or stop their growth (Kahramanoğlu *et al*., 2019). The inhibitory activities of *A. barbadensis* or *Aloe vera* leaves against some bacteria viz., *Aeromonas hydrophius, Aggregatibacter actinomycetemcomitans, Bacillus sphaericus, Bacteroides fragilis, Enterococcus faecalis, Escherichia coli, Klebsiella pneumoniae, Listeria monocytogenes, Micrococcus luteus, Morganella morganii, Mycobacterium smegmatis, Porphyromonas gingivalis, Proteus mirabilis, Proteus vulgaris, Pseudomonas aeruginosa, Shigella boydii, Staphylococcus aureus,* *Streptococcus mutans, Streptococcus pyogenes* and *Vibrio parahaemolyticus* have been evaluated (Alemdar and Agaoglu, 2009; Arunkumar and Muthuselvam, 2009; Pandey and Mishra, 2010; Saritha *et al*., 2010; Fani and Kohanteb, 2012; Nejatzadeh-Barandozi, 2013) in the recent past (Dharajiya *et al*., 2017).

The antifungal activity of *Aloe* sp. also reported against some fungi viz., *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Botrytis gladiolorum, Candida albicans, Colletotrichum coccodes, Crytococcus neoformans, Drechslera hawaiensis, Fusarium oxysporum, Heterosporium pruneti, Microsporium canis, Penicillium gladioli, Penicillium maneffei, Penicillum digitatum, Rhizoctonia, Phythium sp., solani, Trichophyton, mentagraphytes* and *Trichophyton schoenleini* (Agarry and Olaleye, 2005; DeRodrıguez *et al*., 2005; Rosca-Casian *et al*., 2007; Alemdar and Agaoglu, 2009; Khaing, 2011; Sitara *et al*., 2011).

3.2. Preharvest application of *Aloe vera*: effect on seed germination, seedling growth nad pathogen growth reduction

The antimicrobial activity of *Aloe vera* leaf extract or gel is comparatively less studied area. Bendjedid *et al*., (2022) subjected the aqueous extract of *Aloe vera* leaves was also evaluated for its allelopathic potential on seed germination and seedling growth of *Triticum durum* and *Amaranthus hybridus*. By LC-MS analysis, 11 bioactive phytochemical compounds were identified by the research in ethanol extract: such as 5-((S-2'-oxo-4'-hydroxypentyl-2(ßglucopyranosyl-oxy-methyl) chromone, iso*Aloe*risin D, *Aloe*nin, *Aloe*ninB, *Aloe*nin-2`-p-coumaroyl ester, *Aloe*-emodindiglucoside, 10-hydroxyaloin B, 10-hydroxyaloin A, aloin B, aloin A, aloveroside B. The antifungal activity showed that the ethanol extract has an inhibitory activity against all the mycelial strains. The allelopathic effect of different concentrations slowed the kinetics of germination of *Triticum durum* and *Amaranthus hybridus* and significantly decreased the rate of final germination of *Amaranthus hybridus* (100% at C10% and C25%), and a weak effect of inhibition of the germination was noticed for *Triticum durum* (40% at C25%). The aqueous extract has an inhibitory effect on the length of the roots (98% at C25%) and the height of the stems (100% at C25%) of *Triticum durum*.



(Source: Bendjedid *et al*., 2022)

Figure 2. Growth inhibition of different preharvest pathogen by *Aloe vera* gel

a) Growth inhibition percentage of ethanol extract concentrations of *Aloe vera* leaves.

b) *Fusarium roseum* (A), *Fusarium oxysporum lycopersici* (B) and *Botrytis cinerea* (C) colonies grown on PDA medium supplemented with ethanol extract of *Aloe vera* leaves, tested at six concentrations (5%, 2.5%, 1.25%, 0.62%, 0.31% and 0.15%,) recorded after 144 hours of incubation.

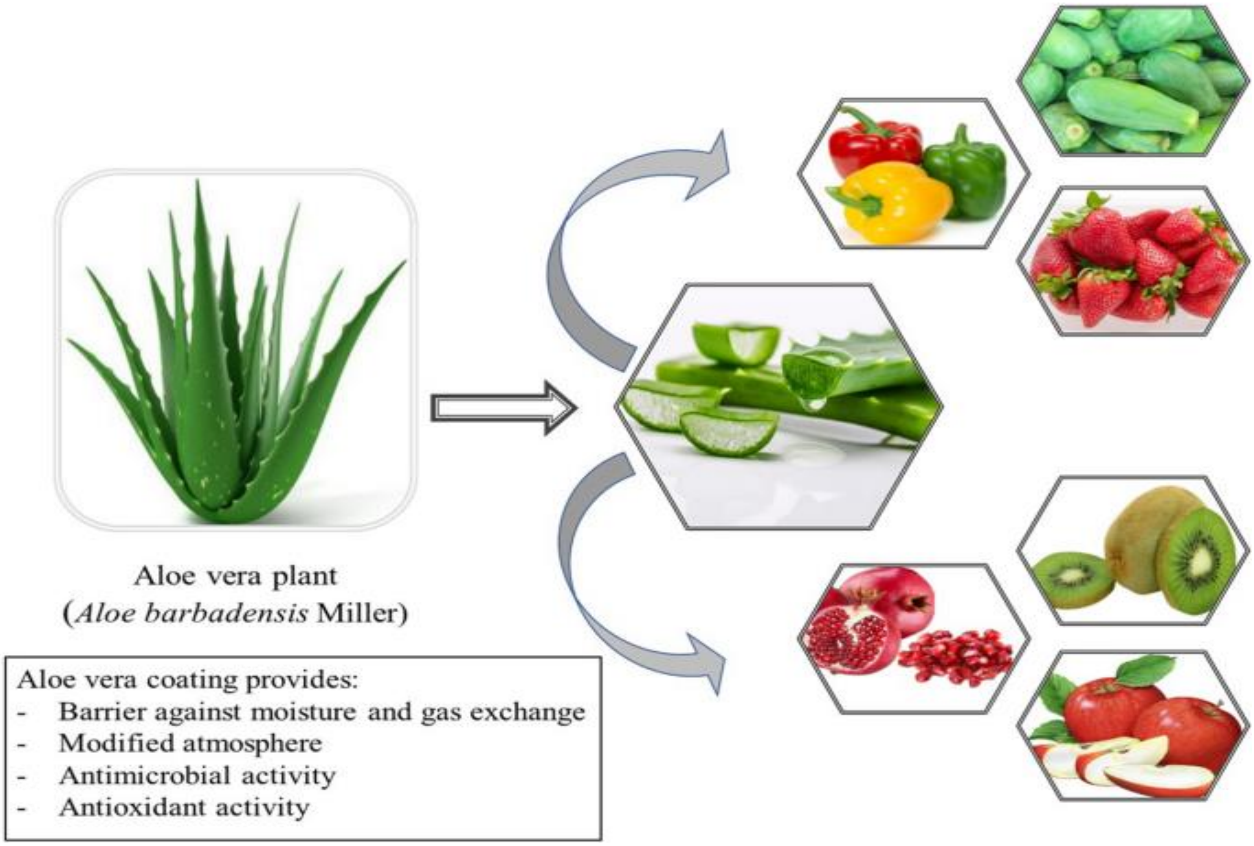
All concentrations of the aqueous extract have an inhibitory effect on the root length of *Amaranthus hybridus*. In addition, the investigation also evaluated the ethanol extract of *Aloe vera* leaves to test the antifungal activity against three plants pathogenic fungi*, Fusarium roseum, Fusarium oxysporum lycopersici* and *Botrytis cinerea* by using the agar plate diffusion plate method (Figure 2 a and b). These results showed that *Aloe vera* would be suggested as a new potential source of natural herbicides and fungicides (Bendjedid *et al*., 2022)

Again According to Dania and Gbadamosi, (2019), the preharvest anthracnose incidence in cowpea was significantly reduced to between 10.5 and 13.3% in treatment with combination of *Aloe vera* leaf extract and *Trichoderma asperellum*. Previously, Sitrata *et al*. (2011) also reported the *in vitro* antimicrobial activity of *Aloe vera* gel/leaf extracts against a number of fungi that cause preharvest infection such as *Alternaria*, *Botryrtis cinerea*, and *Fusarium oxysporum*.

3.3. Postharvest application of *Aloe vera*: effect on postharvest fruit and vegetable disease control and quality loss

Fruits and vegetables are highly susceptible to spoilage after harvest. Being living entities, fruits, and vegetables continue to respire, i.e., use oxygen, and produce carbon dioxide. Due to continuous respiration, the nutritional, physical, and chemical qualities deteriorate (Rawat, 2015). Moreover, postharvest water loss also affects the quality of fruits and vegetables and is a significant contributor to degradation. Excessive water loss often results in wilting, shriveling, overripening, chilling injury, and loss of texture of perishables finally reduce the market value of the product (Ziv & Fallik 2021).

It was mentioned earlier that the extract/gel is rich in soluble sugars, polysaccharides and lipids. The hydrophobic properties of these components acts as a gas and water barrier, making it an ideal edible coating material (Hassan *et al*., 2018). Thus, this gel coatings also reduce the respiration rate, thereby preventing anaerobic conditions and conserving fruit quality. As a coating material, *Aloe vera* gel maintains the texture, color, and shelf life of fruits and vegetables (Rehman *et al*., 2020). It is edible, invisible, odorless, and does not affect the quality of the fruit and vegetables, moreover, it is safe for human health and ecofriendly (Al-Tayyar *et al*., 2020). Furthermore, it reduces respiration rate, moisture loss, softening of tissues, oxidative browning, and proliferation of microorganisms in fruits, such as strawberry, cherry laurel fruit, and grapes using *Aloe vera* gel dip coating reduced weight loss, changes in the physicochemical parameters, and decay, extending the shelf life of figs and litchi fruits (Hassan *et al.,* 2022).



(Source: Sarker & Grift, 2021)

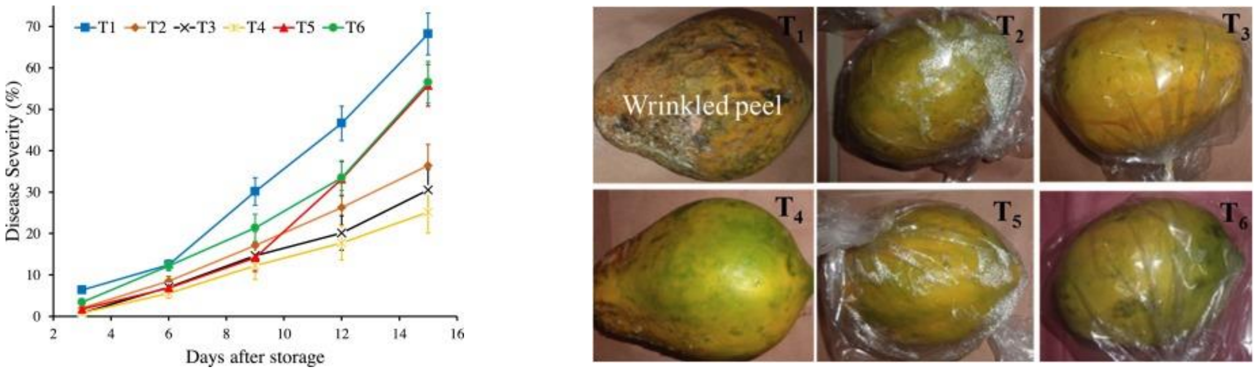
Figure 3. Potential benefits of *Aloe vera* gel coating on fresh and minimally processed fruits and vegetables.

3.3.1 *Aloe vera* treatment for postharvest disease control

Traditionally, the edible coatings are being used to improve the external quality and to enhance the marketability of fruits and vegetables which also conserve the nutritional profile with best eating quality. Several reports are available for ALV as a natural source having astonishing antimicrobial and antifungal properties which significantly reduce the mycological diseases (Nidiry *et al*., 2011). However, in past decades, very little information was available about *Aloe vera* extract/ gel coating in- depth effect on postharvest disease control for fruits and vegetables.

Although, postharvest ALV coating have been reported as better elicitor of disease incidence in sweet cherry (Martínez- Romero *et al*., 2006), strawberry (Sogvar *et al*., 2016), pistachio (Vanaei *et al*., 2014), nectarine (Navarro *et al*., 2011), grapes (Castillo *et al*., 2010), and avocado (Bill *et al*., 2014) fruits, respectively. In recent studies, ALV coating was tested against identified causal organism during storage. (Khaliq, *et al*., 2019) reported that anthracnose caused by *Colletotrichum musae* significantly reduced in coated banana fruits. Similarly, ALV coating reduced the mycelial growth of pathogenic fungi (*Lasiodiplodia theobromae, Aspergillus niger, and Colletotrichum gloeosporioides*) causing postharvest disease in "Sekaki" papaya fruit (Mendy *et al*., 2019). In another study, mandarins coated with ALV (50%) had significantly lowered fruit decay of green mold rot caused by *Penicillium digitatum* due to induced defense mechanism as compared to uncoated control fruits (Jiwanit *et al*., 2018).

According to Parven *et al*. (2020), the disease severity was increased slowly (17.7 %) due to antifungal properties of *Aloe vera* gel (Figure 4). This research investigated the combined effect of *Aloe vera* gel coating and polythene bag packaging on postharvest diseases of papaya. According to the investigation, once the fruit senescence was started, the disease infestation was increased (25.2% at 15 days after storage or DAS) within a very short time. All the other treated fruits (T2, T3, T5 and T6) reached their maximum climacteric stage at 9 DAS, therefore, no significant variation was observed until this observation period. After 9 days of storage, the fruits provided a favourable condition for disease infestation, i.e., fungal growth and spore germination. Moreover, disease severity in T5 and T6 was higher than T2 and T3 as Aloe vera gel coating facilitated more heat generation and favoured more disease infestation. Because of this reason, disease severity was higher in T2 than T3, and no differences were observed between T5 and T6. Fruits in control reached a maximum climacteric stage at 6 DAS, therefore, disease severity was higher than all other treatments. This result indicated the advantages of Aloe vera gel coating as well as drawbacks if the gel-coated fruits are further packed in a polythene bag (Parven *et al*. 2020).

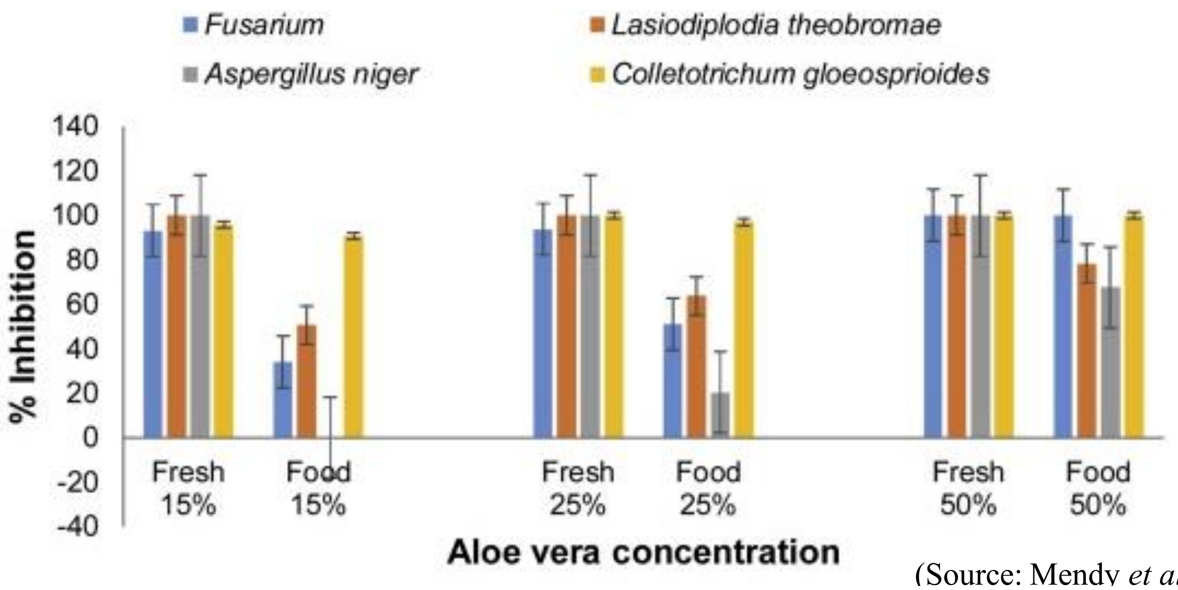


a b

(Source: (Parven *et al*., 2020)

Figure 4. Effect of *Aloe vera* gel coating and polythene bag packing on postharvest disease of Papaya fruit. a) Effect of different treatments on disease severity of papaya (% of fruit skin disease), at different days after storage. b) peel colour of papaya fruits influenced by different treatments at 6 days after storage (DAS). Treatments: no packaging, without (T1) and with (T4) Aloe vera gel; packaging with unperforated transparent polythene, without (T2) and with (T5) Aloe vera gel; packaging with perforated transparent polythene, without (T3) and with (T6) Aloe vera gel. The vertical bars represent the significant differences of means for four replicates ($p \leq 0.05$).

In another experiment, the two types of *Aloe vera* gel used such as filtered fresh *Aloe vera* and food grade *Aloe vera*. Filtered fresh *Aloe vera* was initially filtered with muslin cloth, then filter paper and finally nylon filter 0.45 μm. Food grade *Aloe vera* was also able to suppress mycelial growth in the second experiment but not as effective as fresh *Aloe vera*. The highest percentage of *in vitro* inhibition was shown by filtered fresh *Aloe vera* gel for all fungi up to the sixth day after incubation. At the end of the incubation period for filtered fresh *Aloe vera* gel, 100% inhibition was shown by all fungi at 50% concentration, *Lasiodiplodia theobromae, Aspergillus niger, Colletotrichum gloesoporioides* at 25% concentration and *Lasiodiplodia theobromae* and *Aspergillus niger* a 15% concentration. For food grade *Aloe vera*, the maximum percentage inhibition was shown by *Fusarium* sp. and *Colletotrichum gloesoporioides* at 50% concentration on the seventh after incubation (Fig. 5).



(Source: Mendy *et al.*, 2019)

Figure 5. Effect of filtered fresh *Aloe vera* and food grade *Aloe vera* on different postharvest pathogen.

The reason why unfiltered fresh *Aloe vera* was not able to suppress fungal growth in the first test could be due to the presence of nutritional compounds present in the gel extract that stimulated fungal growth and masked the inhibitory effects (Levin *et al*.,., 1988). Filtered fresh *Aloe vera* in this test was able to inhibit fungal growth better than the unfiltered fresh *Aloe vera* gel. Similar findings were reported by Rodríguez *et al*, (2005), who studied the antifungal activity of *Aloe vera* pulp and liquid fraction on the mycelial growth and development of *Rhizoctonia solani, Fusarium oxysporum* and *Colletotrichum coccodes* isolated from potato crop and reported that the liquid fraction showed a broader range of antifungal activity than the pulp. The liquid fraction inhibited the mycelial growth of the three pathogens, whereas the pulp inhibited only *F. oxysporum*. The antifungal potential of *Aloe vera* gel in the mentioned study was confirmed by inhibiting diametric colony growth of *Fusarium sp., Lasiodiplodia theobromae*, *Aspergillus niger* and *Colletotrichum gloesoporioides* with an increase in concentration. Moreover, the fresh gel coating positively affect the storage life of papaya fruits after 15 days of storage at room temperature (28 ± 2 °C).

However, a number of recent research findings regarding the antifungal efficacy of *Aloe vera* against different postharvest perishable diseases *in planta* (Table 2).

Table 2. Effect of Aloe vera application on postharvest disease incidence of fruits

Crops	Diseases	Causal agents	Concentrations	Impact description	References
Avocado	Anthracnose	*Colletotrichum gloeosporioides*	2%	Effectively controlled fruit decay during storage in combination with thyme oil	Bill *et al*. (2014)
Banana	Anthracnose	*Colletotrichum musae*		Significantly enhanced phenolic contents which induced disease resistance during storage	Khaliq, Abbas, *et al*. (2019)
Grapes		*Penicillium digitatum* and *Botrytis cinerea*	25%	Inhibited the mycelial growth of decay causing fungal species and significantly lower mesophilic aerobics, mold, and yeasts counts	Castillo *et al*. (2010)
Grapes	Gray mold	*Botrytis cinerea*	25%	Reduced disease incidence, fruit decay, and rachis browning with extended marketable life	Tarabih and Metwally (2020)
Mandarin	Green mold rot	*Penicillium digitatum,*	50% (1:1)	Reduced fruit decay due to induced defense mechanism	Jiwanit *et al*. (2018)
Nectarine		*Rhizopus stolonifer*, *Botrytis cinerea*, and *Penicillium digitatum*		Reduced infection damage and decay during storage	Navarro *et al*. (2011)
Pistachio	Disease incidence		50%	Declined fruit disease index during 30 days of low temperature storage (4°C)	Vanaei *et al*. (2014)
Papaya		*Lasiodiplodia theobromae*, *Aspergillus niger*, and *Colletotrichum gloeosporioides*	50%	Reduced mycelial growth of pathogenic fungi in vitro and in vivo conditions	Mendy *et al*. (2019)
Strawberry			5%	Reduced microbial growth; reduction in mesophilic aerobic bacteria, yeast and mold during storage	Sogvar *et al*. (2016)

3.3.2 *Aloe vera* treatment for postharvest quality

Aloe vera has been studied as a natural treatment for enhancing the postharvest quality of fruits and vegetables. The plant contains various bioactive compounds, including polysaccharides, amino acids, vitamins, and enzymes, that have antioxidant and antimicrobial properties. (Kumar *et al*., 2022)

Treating fruits and vegetables with *Aloe vera* gel can help to prolong their shelf life by reducing spoilage and maintaining their quality. *Aloe vera* gel can be applied as a coating or spray on the surface of fruits and vegetables to create a protective barrier that prevents moisture loss and inhibits the growth of bacteria and fungi. (Hasan *et al*., 2021) In addition, *Aloe vera* treatment has been shown to improve the nutritional value of fruits and vegetables. Kumar & Saini (2021) have demonstrated that treating tomatoes with *Aloe vera* gel can increase their levels of vitamin C and antioxidants. Similarly, treating grapes with *Aloe vera* gel has been shown to increase their total phenolic content and antioxidant activity (Misir *et al*., 2014).

Ergun and Satici (2012) found that at concentration of 10% AVL gel could store Granny Smith and Red Chief cultivars of Apple for 6 months at 2°C which delayed fruit senescence; maintained biochemical quality. AVL gel at 33% concentration could store cherry for 60 days at 0.5°C with 90 ± 5% RH which reduced respiration rate, fruit weight loss, decay; increased ascorbic acid contents, total antioxidants, anthocyanins and flavonoids (Ozturk et al. 2019).

Table 3 Examples of some fruits coated with *Aloe vera* gel as a single coating material

Fruits	Tested concentrations	Test condition	Key variables studied	Results	References
Grapes	0, 10, 20, and 30%	Stored in poly packaging and open plates at 0 °C and 30 °C	pH, WL, C, DS, ST	20% *Aloe vera* coating was the most effective in extending the shelf life; it resulted in the best visual and physicochemical results	(Nia *et al*., 2021)
Table grapes	Diluted 1:3 with distilled water	35 days at 1 °C and 95% RH; shelf life monitored at 20 °C, 90% RH for 4 days	TAA, PC, AA, TAC	Functional compounds, such as total phenolics and ascorbic acid, were maintained by the *Aloe vera* coating	(Nia *et al*., 2022)
Peach fruit	*Aloe vera* gel with distilled water (1:3)	30 days at 1 °C and 95% RH	F, C, WL, ST, TSS, TA	Coated fruit had reduced weight loss, color change, total soluble solids, and titratable acidity than control	(Hazrati *et al*., 2017)
Litchi fruit	50%	20 ± 1 °C and 90% RH for 8 days	pH, TAC, TA, TSS, BI, WL, PC, EA, AA, EL	Coated fruit had reduced weight loss, browning index, peroxidase, and polyphenol oxidase activities, electrolyte leakage, hydrogen peroxide, and malondialdehyde content	(Ali *et al*., 2019)
Apple	0, 1, 5 and 10%	2 °C for 6 months	WL, F, TA, SSC, pH	*Aloe vera* gel retarded the quality losses of Granny Smith apple	(Mahajan *et al*., 2018)

(Source: Sarker & Grift, 2021)

F firmness, WL weight loss, TPA textural profile analysis, TA titratable acidity, TSS total soluble solids, RR respiration rate, AA ascorbic acid, C color, MG microbial growth/load, DS decay symptoms/spoilage, ST sensory test, Et ethylene, MI maturity index, PDI percent disease index, PC phenolic compounds, TAC total anthocyanin content, BD/BI browning degree/index, SA scavenging activity, OVQ overall visual quality, TAB total aerobic bacteria, EA enzyme activities, REL relative electrolyte leakage, AVD aroma volatile development, TAA total antioxidant activity

3.4. Challenges associated with *Aloe vera* treatment application and functionality:

Different *Aloe* plants from different geographical locations could have variations in their chemical composition. Therefore, the use of those plants in experiments could result in conflicting observations. Moreover, variation in isolation techniques from laboratory to laboratory for a specific component of *Aloe vera* extract could lead to that difference. (Vaou *et al*., 2021) Further, inefficient harvesting, processing, and marketing procedures could lead to undesirable *Aloe* products. The original structure of the polysaccharide and other bioactive compounds could undergo irreversible changes due to the processing steps. A dehydration temperature of 60°C modified the physicochemical properties of the *Aloe* components, especially the storage polysaccharide, acemannan (Sarker & Grift 2021). The structural modifications that occurred due to the high applied temperature could affect the related functional properties of the polysaccharide (Alvarado *et al*., 2019). Moreover, a high processing temperature not only affects the bioactive and functional properties but also affects the consistency and viscosity of the *Aloe* gel. Likewise, it has been reported that the *Aloe* gel polysaccharides are unstable while kept under environmental stress as heat, acidity, and enzymatic reactions (Sarker & Grift 2021). Moreover, following the improper extraction technique of gel from the *Aloe vera* leaf could lead to bitter products. Besides, a threshold at 20% (w/w) was proposed for sensory acceptance (Radziejewska *et al*., 2014). Also, selecting an optimum coating concentration and formulation for a specific fresh commodity is imperative and often challenging. The high solid concentration of coating could lead to an enhanced physiological loss in the mass of commodities (Janjarasskul *et al*., 2016). Besides, inadequate processing techniques could result in very little or virtually no mucopolysaccharides in the *Aloe* products, which is one of the active ingredients in *Aloe vera* gel (Pandey & Singh 2016). Heat is often applied to let the gel free from bacterial contamination, but high heating for a prolonged time might further deteriorate the bioactive components of the gel with decreased efficiency (Du *et al*., 2022). Moreover, there is no standard methodology for heat treatment, coating preparation, and application, such as dipping time, which may further challenge its industrial implementation. Also, the low film-forming property of the *Aloe vera* gel prevents its widespread application as edible films and coatings (Ribeiro *et al*., 2021). To minimize the deterioration of the *Aloe* components and to retain the polymeric substances like polysaccharides, it is important to follow a standardized and steady processing method (Hamman 2008). For the complete inhibition of microbial growth until 90 days at 4 °C storage, the application of high hydrostatic pressure (HHP) could be an alternative to thermal pasteurization of the *Aloe vera* gel (Vega *et al*., 2011). Also, precautions should be made so that the freshly harvested leaves immediately go to the processing facilities otherwise should be properly refrigerated to reduce the decomposition of the gel. Overall, understanding the solution's physicochemical and mechanical properties and the resultant film is important in designing an ideal food packaging system.(Sarker & Grift, 2021)

CHAPTER IV

CONCLUSION

The use of *Aloe vera* in producing safe and sustainable fruits and vegetables offers numerous potential benefits. *Aloe vera* extracts can improve crop growth and yield while also increasing resistance to biotic and abiotic stress. Preharvest anthracnose incidence in cowpeas was significantly decreased to between 10.5 and 13.3% when treated with a combination of *Trichoderma asperellum* and *Aloe vera* leaf extract. The antimicrobial activity of *Aloe vera* gel and leaf extracts *in vitro* is effective against a variety of fungi that cause preharvest infection, including *Alternaria, Botrytis cinerea*, and *Fusarium oxysporum*.

Antimicrobial, anti-inflammatory, and antioxidant properties of *Aloe vera* can assist in the reduction of disease incidence, as well as the safety and shelf-life of fruits and vegetables in postharvest pathology *Fusarium sp., Lasiodiplodia theobromae, Aspergillus niger,* and *Colletotrichum gloesoporioides* showed the greatest percentage inhibition of food grade Aloe vera at 50% concentration. At 33% concentration, AVL gel could store cherry for 60 days at 0.5°C with 95% RH, and at 10% concentration, apple could be stored for 6 months at 2°C.

However, there are some challenges to overcome, such as determining optimal Aloe vera concentrations that maximize benefits while minimizing potential negative effects. The structural modifications that occurred due to the high applied temperature could affect the related functional properties of the polysaccharide. Aloe vera gel's low film-forming ability prevents it from being widely used as edible films and coatings. Furthermore, there is no standard methodology for heat treatment, coating preparation, and application, such as dipping time, which may make industrial implementation difficult. Overall, the use of Aloe vera in the production of fruits and vegetables has the potential to improve food safety and sustainability, benefiting both human health and the environment.

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