Enhancing Tomato Shelf Life Using Selected Plant Extracts and Mushrooms

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This study aimed to investigate the effect of selected plant extracts and mushrooms on the shelf life of tomatoes. The impact of various plant extracts on the shelf life and quality of fresh tomatoes presents promising opportunities for extending their storage duration while maintaining their freshness and nutritional value. Through the exploration of natural compounds found in plants, such as essential oils, polyphenols, and flavonoids, researchers have identified several strategies to inhibit microbial growth and oxidative deterioration in tomatoes. Tomatoes have a short shelf life due to their climacteric nature. The current work was conducted to extend the shelf life of fresh tomatoes with Cassia fistula, aloe vera, and mushroom plant extract coatings. After that about nine sets were prepared. In each set, the relevant extracts were sprayed on the daily one time for five days. The results revealed that the weight loss of tomatoes after the 5th day was minimal by Cassia fistula extract. Moreover, the trend of weight loss in tomatoes was: Cassia fistula extract < Aleo vera extract < mushroom extract. In conclusion, the utilization of plant extracts represents a promising approach to enhancing the shelf life and quality of fresh tomatoes, offering sustainable and natural alternatives to synthetic preservatives. Continued research in this area holds the potential to unlock new strategies for preserving fresh herbs and improving food security.

Keywords: Tomato shelf life, Plant Extracts, Mushroom, Postharvest Preservation, Food Storage

Introduction:

The tomato, or Solanum lycopersicum L., is one of the most extensively consumed vegetables in the world, both in cooked dishes and when eaten raw. With many health advantages, it is an abundant supply of vitamins, minerals, and antioxidants. Unfortunately, tomatoes have a short shelf life because of their quick ripening and microbiological deterioration, which results in large financial losses. There are several methods to preserve food and extend the shelf life of tomatoes, including packaging in modified atmospheres, using chemical preservatives, and employing cold storage techniques. Nevertheless, the environment and human health might suffer as a result of these techniques. Consequently, there's a rising focus on creating substitute tactics to raise tomato quality and increase shelf life [1].

Tomato quality may be enhanced and its shelf life extended by using natural plant extracts, according to several proposals. The usefulness of several plant extracts in improving tomato quality, postponing fruit ripening, and preventing microbial development has been documented in a number of studies. Plant extracts include bioactive substances with antibacterial and antioxidant capabilities, such as flavonoids, phenolic compounds, and essential oils, which may help preserve tomato quality. Additionally, it is believed that using

natural plant extracts is safe, environmentally friendly, and has no adverse effects on human health [2].

Numerous studies have explored the effectiveness of natural plant extracts in improving tomato quality and extending its shelf life, focusing on how these extracts can naturally preserve the fruit for longer periods. They claimed that natural plant extracts might prevent microbial development, lessen weight loss, and postpone tomato ripening. Moreover, the use of plant extracts has been reported to enhance sensory qualities and extend the shelf life of tomatoes. Additionally, plant extracts improved the color, firmness, and total phenolic content of the tomato fruits. [3].

Plant extracts being natural, can be used to enhance the life of tomatoes, which is a practical way to improve their quality. This can be done by incorporating plant extracts into packaging materials, spraying plant extracts onto the surface of the tomato, or dipping the tomato in a solution of plant extracts. This might result in lower post-harvest losses, higher food producers' and farmers' profits, and better tomatoes for customers. Studying the physiological and biochemical mechanisms that support tomato quality preservation and shelf-life extension. This entails analyzing the bioactive chemicals included in the plant extracts, their mode of action, their antibacterial and antioxidant properties, and their impact on the physiological and biochemical systems governing fruit ripening and quality. This information can guide the creation of more potent preservation techniques and result in the discovery of novel bioactive substances with prospective uses in the food sector [4].

In general, there are practical and scientific ways to increase food safety and sustainability by utilizing natural plant extracts to extend the shelf life of tomatoes. Factors including growth circumstances, harvesting timing, and content of tomato samples, can have an impact on the outcome. Tomatoes encounter during market storage and transportation since it can only examine the impact of natural plant extracts under particular storage settings on tomato shelf life [5].

Objectives:

- To evaluate the efficacy of Aloe vera gel, Cassia fistula extract, and mushroom extracts in enhancing the shelf life of tomatoes.

Novelty Statement:

This study introduces a novel, natural preservation approach by utilizing Aloe vera gel, Cassia fistula extract, and mushroom-derived compounds to extend the shelf life and enhance the nutritional quality of tomatoes. Unlike conventional synthetic preservatives, this method emphasizes sustainability and consumer safety, offering a green alternative that aligns with current trends in organic food preservation and waste reduction.

Research Design and Methodology:

Collection of tomatoes

The 21 fresh tomatoes were purchased from a nearby market in Minhaj University, Lahore, with minimal damage (Figure 1). The tomato sampling was conducted in February 2023, with daytime temperatures reaching around 22°C (71°F) on the sampling days.

Figure 1. Selected areas of markets near Minhaj University, Lahore from where the tomatoes were collected**.**

Collection of Plants and Mushrooms:

Aloe vera leaves were gathered from the Madr-e-Millat nursery, which is situated close to Minhaj University in Lahore, to prepare plant extracts (Figure 2). Moreover, the leaves of Cassia fistula were collected from the trees located on Ali Road near Ideal Park, Township, Lahore (Figure 3). The samples were collected from the East, West, North, South, and center of each mentioned area. Moreover, the button mushroom was bought from the departmental store i.e., Askari departmental store, Township, Lahore (Figure 4).

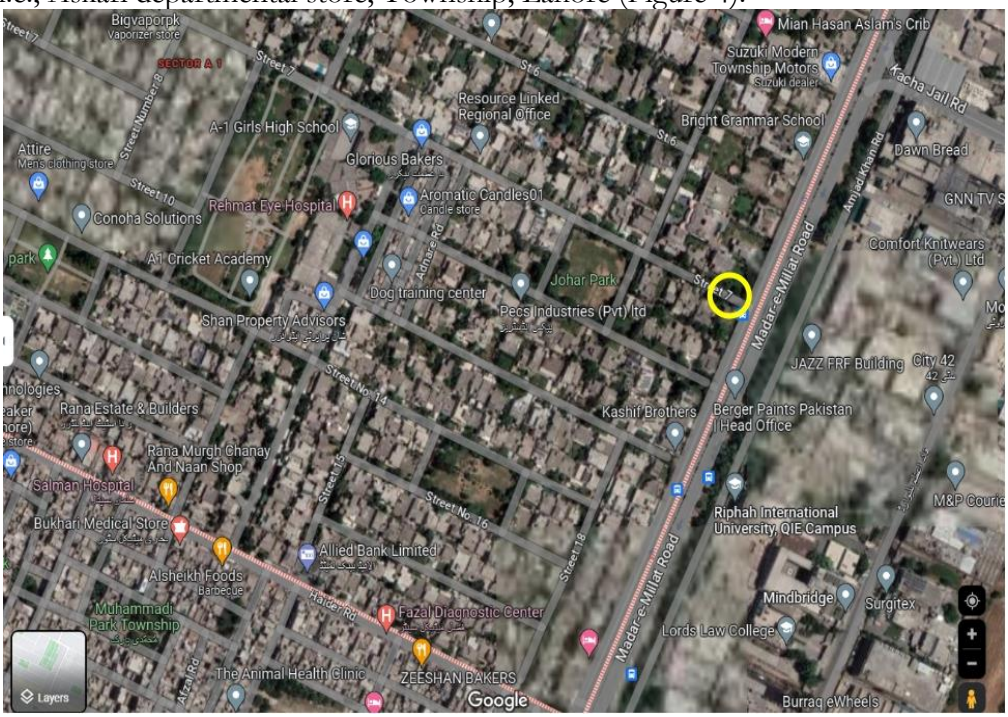

Figure 2. Collection area of aloe vera leaves: Nursery located on Madr-e-Millat road, near the vicinity of Minhaj University, Lahore

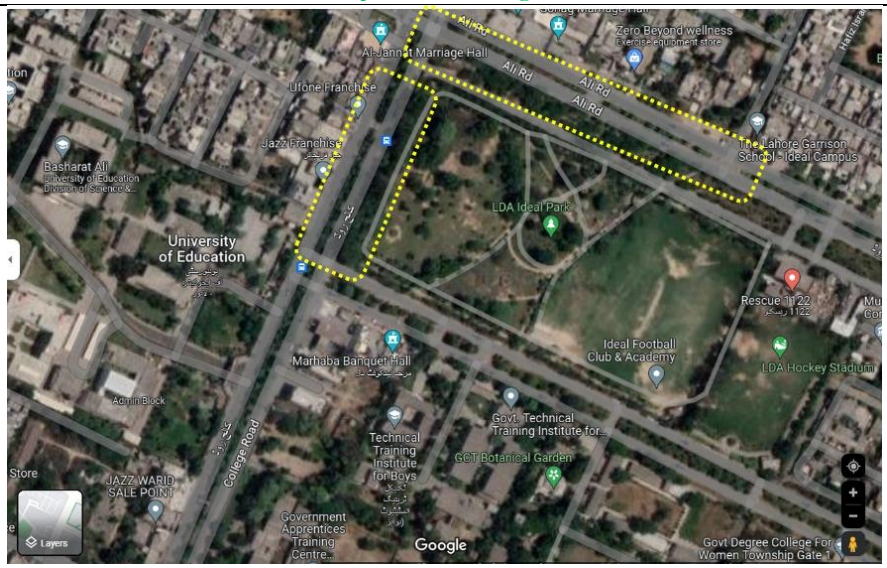

Figure 3. Collection area of Cassia fistula leaves: Trees located on Ali Road near Ideal Park, Township, Lahore

Figure 4. Collection of Cassia fistula, aloe vera, and button mushroom for study

Preparation of Aqueous and Ethanolic Extract:

Cassia Fistula Leaf Extract:

To create an aqueous extract and an ethanolic extract, 100 milliliters of distilled water and 100 milliliters of ethanol were combined with approximately 5 grams of C. fistula leaves. The mixture was then heated for 15 minutes at 60°C. Next, the leaves were removed from the garden and cleaned with ordinary tap water. Subsequently, it was cooled down and filtered by Whatman filter paper followed by storing at 4 ℃ for further use (Figure 5).

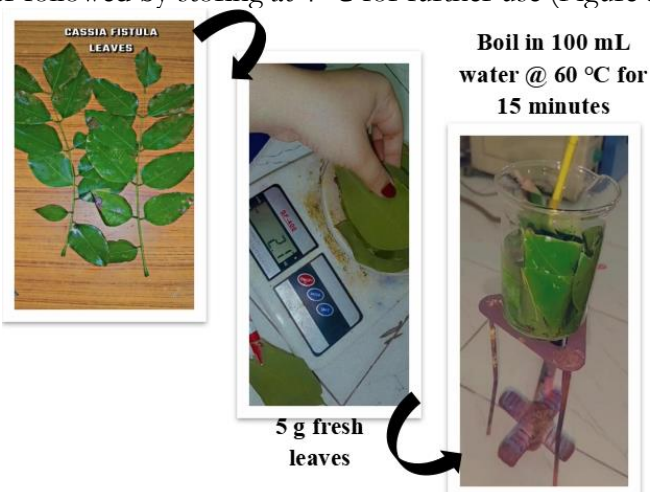

Figure 5. Flow diagram: Preparation of Cassia fistula leaf extract (aqueous, ethanolic.

Aloe Vera Gel Extract:

The outer covering of the aloe vera leaves was peeled off, and the gel was removed using a sharp knife to prepare the aloe vera aqua gel extract. The gel was weighed to get five grams, and then it was dissolved in 100 milliliters of ethanol and 100 milliliters of distilled water to yield an aqueous extract and an ethanolic extract, in that order. The solution was then allowed to cool and filter through Whatman filter paper before being boiled for 15 minutes at 60 °C. It was then kept at 4 °C for later use (Figure 6).

Figure 6. Flow diagram: Preparation of aloe vera gel extract (aqueous and ethanolic extract)

Button mushroom aqueous extract:

For the aqueous extract, 100 milliliters of distilled water and 100 milliliters of ethanol were combined with approximately 5 grams of button mushrooms, and the mixture was heated for 15 minutes at 60 degrees Celsius. Following that, it was cooled, filtered using Whatman filter paper, and kept at 4 °C for later use (Figure 7).

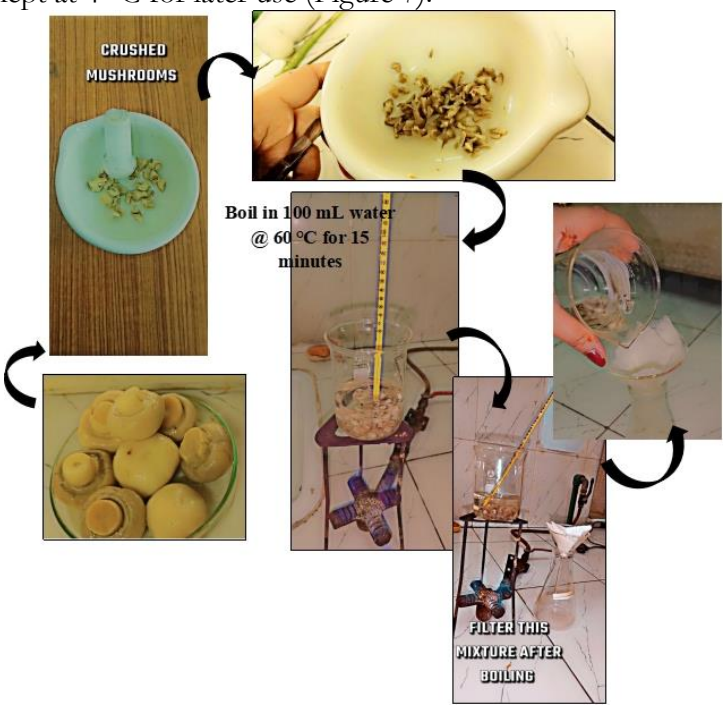

Figure 7. Flow diagram: Preparation of button mushroom extract (ethanolic and aqueous extract)

Experiment design:

Treatment plan:

Table 1 shows the seven groups/treatments into which the tomatoes were split:

Table 1. Treatment plan

Treatment 1 (T1)	Control (receive only water)
Treatment 2 (T2)	Aloe vera aqueous gel extract
Treatment 3 (T3)	Cassia fistula leaf aqueous extract
Treatment 4 (T4)	Button mushroom aqueous extract
Treatment 5 (T5)	Aloe vera ethanolic gel extract
Treatment 6 (T6)	Cassia fistula ethanolic leaf extract
Treatment 7 (T7)	Button mushroom ethanolic extract

Three tomato duplicates were used in each treatment set. For seven days, the tomatoes were sprayed with each of the individual sprays listed in Table 3.2 every day. Seven days later, the tomatoes' physiochemical analysis was examined.

Physiochemical analysis of Cucumber:

Weight loss:

Tomato weight loss over the storage period was estimated as the difference between the starting and final weights, and it was multiplied by three at the seven-day storage interval.

Appearance change:

Appearance changes were analyzed by visual and photographic recording. All photographs were taken at the same angle and same distance.

Color and firmness:

1 = red 2 = breaker 3 = turning 4 = pink 5 = light red 6 = red 7 = ripe red	1 = hard 2 = sprung 3 = Between springing and eating ripe 4 = eating ripe 5 = overripe 6 = rotten
The changes in the color of the tomato were determined using a numerical rating scale of 1–7 [6], where:	The firmness of tomato fruit was determined by hand feel using a numerical rating scale of 1–6, where:

Sensory analysis:

The sample was assessed on a hedonic scale by a panel of five judges based on organoleptic features, such as fruit texture, color/appearance, flavor, and taste, after being tasted at various storage periods [7]. They were rated on a hedonic scale, with 9 denoting extreme likenesses, 8 extreme likenesses, 7 moderate likenesses, 6 mild likenesses, 5 neither extreme like nor dislike, 4 minor dislikes, 3 moderate dislikes, 2 strong dislikes, and 1 extreme dislike.

Percent decay

To find the samples' percentage decay, the following formula was applied: (A-B)/A - 100 is the percent degradation (%).

Where B is the sample's decay and A is the sample's total weight.

Statistical analysis

With treatment and storage duration acting as sources of variation, data was analyzed using the least significant difference (LSD).

Results:

The plant extracts were categorized into two groups i.e., Group 1: plant (Cassia fistula leaf, aloe vera gel) and mushroom extracts were prepared in aqueous solution; Group 2: plant (C. fistula leaf, aloe vera gel) and mushroom extracts were prepared in ethanol solution. The

prepared extracts were sprayed on fresh tomatoes after seven days. After that various parameters like changes in morphology of tomatoes and weight loss were observed. The main purpose of observing parameters such as weight loss and morphological changes is to assess the shelf life of tomatoes and determine whether the application of various extracts effectively delays spoilage. Moreover, the presence of post-harvest fungal and bacterial pathogens was also noticed.

Morphological Alterations in Tomatoes:

The quality of fruit perceived by consumers is greatly influenced by the color and consistency of tomato fruit. Tomatoes treated with aqueous extracts were observed on a daily basis for seven days. The results revealed several findings related to color changes in tomatoes treated with aqueous extracts of C. fistula, aloe vera, and mushrooms, as well as ethanolic extracts of C. fistula, aloe vera, and mushrooms. It was found that those tomatoes that were treated with an aqueous extract of C. fistula (AECF), aqueous extract of mushroom (AEM), and ethanolic extract of C. fistula (EECF) exhibited no change in color of tomatoes. Nevertheless, there was some browning in the tomatoes treated with (AEAV), (EEAV), and ethanolic mushroom extract (EEM) (Figure 8).

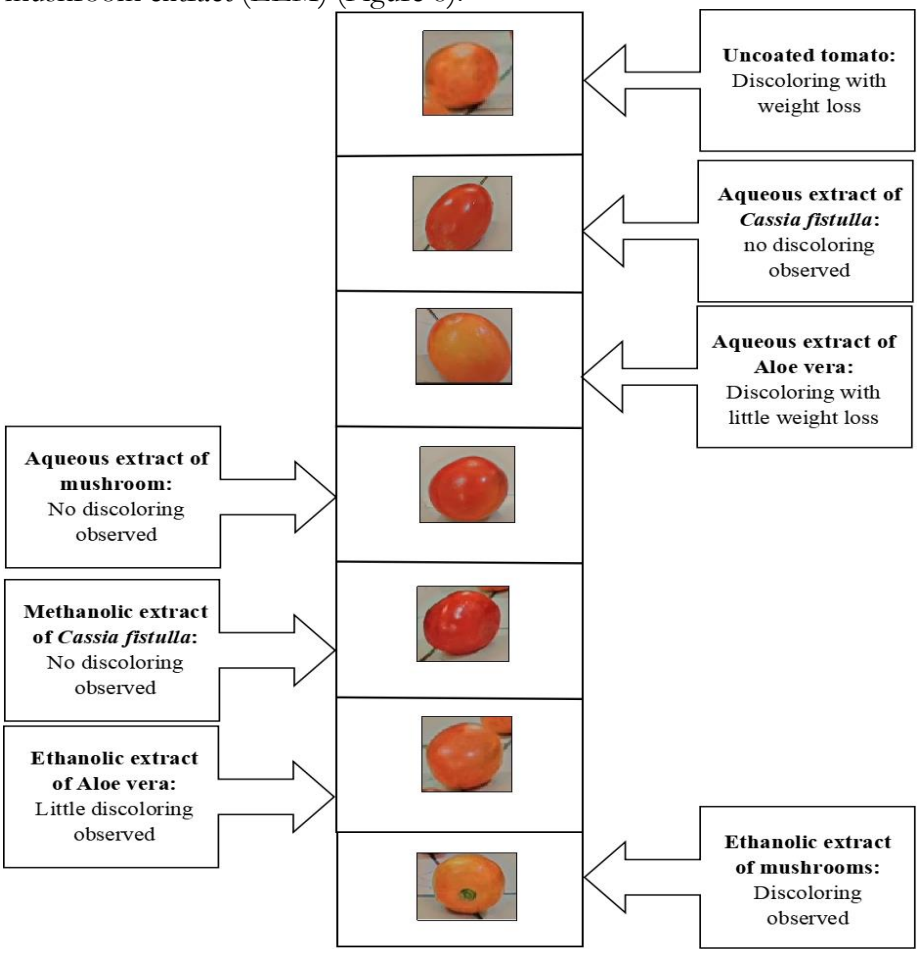

Figure 8. Change in tomato fruit color after seven days.

Color and firmness:

The color and firmness of the tomatoes were noticed after the 7th day experiment (Table 2). It was noticed that the uncoated tomato had turned yellowish green. The tomatoes treated with ethanolic extract of mushroom showed a pinkish to red color. The tomatoes treated with aqueous extract of aloe vera and mushroom; and ethanolic extract of aloe vera exhibited light red color of fruit. Conversely, the mature red color of the fruits was displayed by the ethanolic and aqueous extracts of C. fistulla.

Table 2. Color of tomatoes observations taken numerical rating scale of tomato.

Treatments	1= green/ yellow	2= breaker	3= turning	4= pink	5= light red	6= red	7= ripe red
Uncoated tomato	+	-	-	-	-	-	-
Aqueous extract of Cassia fistula	-	-	-	-	-	-	+
Aqueous extract of Aloe vera	-	-	-	-	+	-	-
Aqueous extract of the mushroom	-	-	-	-	+	-	-
Ethanolic extract of Cassia fistula	-	-	-	-	-	-	+
Ethanolic extract of Aloe vera	-	-	-	-	+	-	-
Ethanolic extract of mushrooms	-	-	-	+	-	-	-

The firmness of tomato fruits was also observed after treatment with various extracts (Table 3). The uncoated tomatoes were observed rotten after 7 days of incubation. While the tomatoes treated with aqueous extract of aloe vera and mushroom exhibited tomatoes between sprung and eating ripe. Moreover, the tomatoes treated with aqueous and ethanolic extract of C. fistula, ethanolic extract of aloe vera, and mushroom showed ripped tomatoes that could be used for further food.

Table 3. Firmness of tomatoes observations taken numerical rating scale of tomato.

Treatments	1 = hard	2 = sprung	3 = Between springing and eating ripe	4 = eating ripe	5 = overripe	6 = rotten
Uncoated tomato	-	-	-	-	+	+
Aqueous extract of Cassia fistula	-	-	-	+	-	-
Aqueous extract of Aloe vera	-	-	+	-	-	-
Aqueous extract of the mushroom	-	-	+	-	-	-
Ethanolic extract of Cassia fistula	-	-	-	+	-	-
Ethanolic extract of Aloe vera	-	-	-	+	-	-
Ethanolic extract of mushrooms	-	-	-	+	-	-

Sensory analysis of tomatoes:

The sensory analysis of tomatoes after the treatment of various aqueous and ethanolic extracts of leaf, gel, and mushroom is portrayed in Table 4. Amazing results of tomato tastes treated with various aqueous and ethanolic exacts were reported by the five-panel judges based on their observations.

Table 4. Sensory analysis of tomatoes by using a hedonic scale at different aqueous and ethanolic extracts.

Scale	Uncoated tomato	Aqueous extract of Cassia fistula	Aqueous extract of Aloe vera	Aqueous extract of the mushroom	Ethanolic extract of Cassia fistula	Ethanolic extract of Aloe vera	Ethanolic extract of mushrooms
9= like extremely	-	-	-	-	-	-	-
8 = like very much	-	+	+	-	-	-	-
7= like moderately	-	-	-	-	+	-	-
6= like slightly	-	-	-	-	-	+	-
5= neither like nor dislike	-	-	-	-	-	-	+
4=dislike slightly	-	-	-	-	-	-	-
3=dislike moderately	-	-	-	-	-	-	-
2=dislike very much	-	-	-	-	-	-	-
1=dislike extremely	+	-	-	-	-	-	-

Percentage Age Decay:

The % age decay of tomatoes after treatment with various aqueous and ethanolic extracts was calculated at different six days (daily) with a regular spray of extracts. The results revealed that maximum weight loss or %age decay of tomatoes was observed by those tomatoes that were sprayed with Ethanolic extract of C. fistula and ethanolic extract of aloe vera. However, the tomatoes treated with an aqueous extract of button mushroom exhibited a minimum reduction in weight loss (Figures 9 to 15). Moreover, the trend of weight loss in tomatoes was observed as: Ethanolic extract of Cassia fistula > Ethanolic extract of Aloe vera > Control > Ethanolic extract of button mushroom > Aqueous extract of Aloe vera > Aqueous extract of Cassia fistula > Aqueous extract of button mushroom.

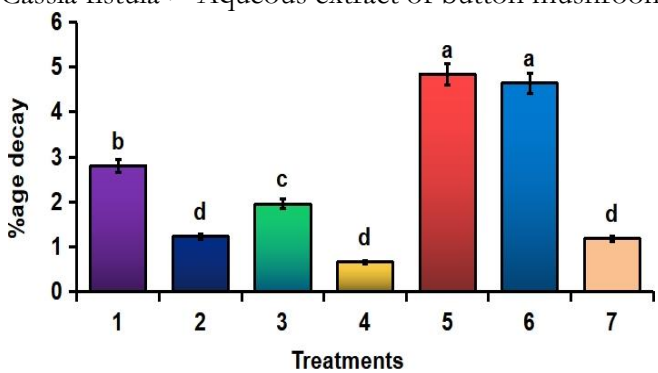

Figure 9. Statistical analysis (standard error and least significant difference) of percentage decay of tomatoes at different doses of aqueous and ethanolic extracts after one day. 1: Control; 2: Aqueous extract of Cassia fistula, 3: Aqueous extract of Aloe vera; 4: Aqueous extract of button mushroom; 5: Ethanolic extract of Cassia fistula, 6: Ethanloic extract of Aloe vera; 7: Ethanolic extract of button mushroom.

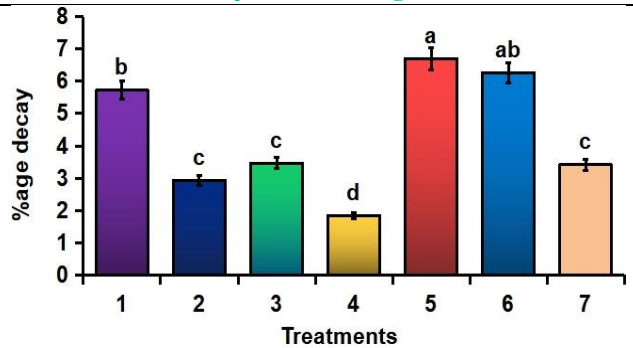

Figure 10. Statistical analysis (standard error and least significant difference) of percentage decay of tomatoes at different doses of aqueous and ethanolic extracts after 2nd day. 1: Control; 2: Aqueous extract of Cassia fistula, 3: Aqueous extract of Aloe vera; 4: Aqueous extract of button mushroom; 5: Ethanolic extract of Cassia fistula, 6: Ethanolic extract of Aloe vera; 7: Ethanolic extract of button mushroom

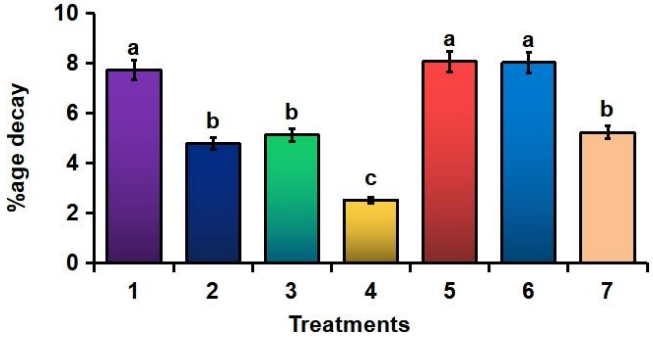

Figure 11. Statistical analysis (standard error and least significant difference) of percentage decay of tomatoes at different doses of aqueous and ethanolic extracts after 3rd day. 1: Control; 2: Aqueous extract of Cassia fistula, 3: Aqueous extract of Aloe vera; 4: Aqueous extract of button mushroom; 5: Ethanolic extract of Cassia fistula, 6: Ethanolic extract of Aloe vera; 7: Ethanolic extract of button mushroom

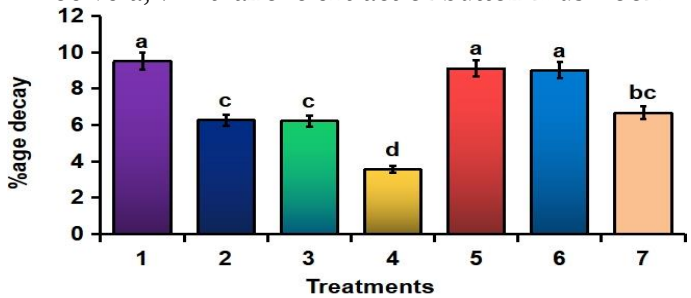

Figure 12. Statistical analysis (standard error and least significant difference) of percentage decay of tomatoes at different doses of aqueous and ethanolic extracts after 4th day. 1: Control; 2: Aqueous extract of Cassia fistula, 3: Aqueous extract of Aloe vera; 4: Aqueous extract of button mushroom; 5: Ethanolic extract of Cassia fistula, 6: Ethanloic extract of Aloe vera; 7: Ethanolic extract of button mushroom.

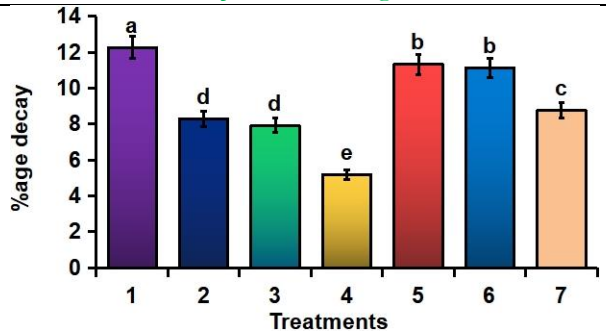

Figure 13. Statistical analysis (standard error and least significant difference) of percentage decay of tomatoes at different doses of aqueous and ethanolic extracts after the 5th day. 1: Control; 2: Aqueous extract of Cassia fistula, 3: Aqueous extract of Aloe vera; 4: Aqueous extract of button mushroom; 5: Ethanolic extract of Cassia fistula, 6: Ethanolic extract of Aloe vera; 7: Ethanolic extract of button mushroom

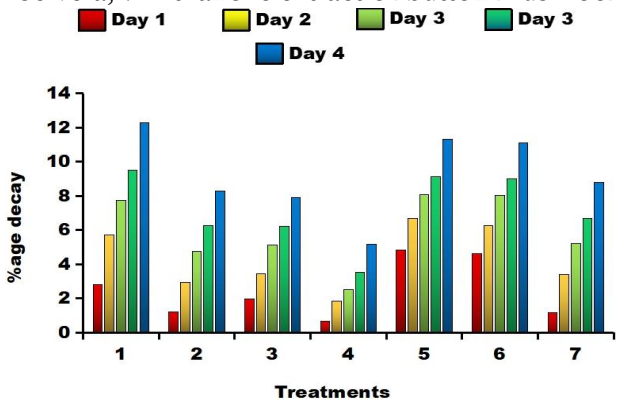

Figure 14. Statistical analysis (standard error and least significant difference) of percentage decay of tomatoes at different doses of aqueous and ethanolic extracts on different days. 1: Control; 2: Aqueous extract of Cassia fistula, 3: Aqueous extract of Aloe vera; 4: Aqueous extract of button mushroom; 5: Ethanolic extract of Cassia fistula, 6: Ethanolic extract of Aloe vera; 7: Ethanolic extract of button mushroom

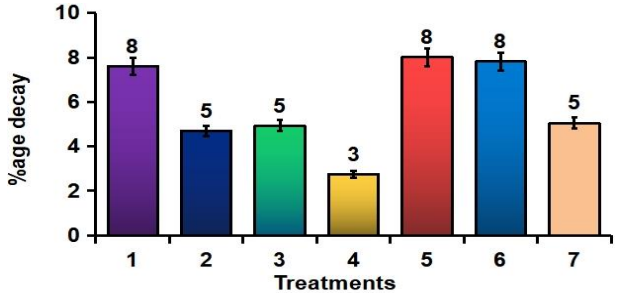

Figure 15. Comparative analysis (standard error) of percentage decay of tomatoes at different doses of aqueous and ethanolic extracts on different days. 1: Control; 2: Aqueous extract of Cassia fistula, 3: Aqueous extract of Aloe vera; 4: Aqueous extract of button mushroom; 5: Ethanolic extract of Cassia fistula, 6: Ethanolic extract of Aloe vera; 7: Ethanolic extract of button mushroom

Discussion:

Button mushrooms, scientifically known as Agaricus bisporus, contain natural compounds such as phenols, flavonoids, and polysaccharides that possess antimicrobial activity. Fruits treated with button mushroom aqueous extract have less bacteria and fungus growing on them, which helps prevent spoiling. Fruit degeneration, resulting in spoiling and shortened shelf life, is caused by these microbes. The antimicrobial compounds present in the extract can effectively suppress the growth of microorganisms by interfering with their

metabolic processes, disrupting their cell membranes, or inhibiting their enzyme activity. Consequently, the development and spread of spoiling bacteria on the fruit's surface are inhibited, prolonging the fruit's storage life [8].

Additionally, the extract may also exhibit antioxidant properties, which can help prevent oxidative damage and delay the deterioration of fruits. Fruit deterioration due to oxidative reactions results in color changes, taste alterations, and nutritional loss. By reducing oxidative stress, the extract helps preserve the fruits' freshness and quality for longer. It's important to keep in mind that while adding mushroom extract may extend the shelf life of fruits, it may not be able to prevent deterioration permanently. Many additional factors, including temperature, humidity, and proper handling and storage practices, have a substantial impact on the freshness and quality of fruit [9].

The plant Cassia fistula, also referred to as the Indian laburnum or golden shower tree, has long been utilized for a variety of therapeutic purposes. While there is limited specific research on the use of Cassia fistula extract for extending the shelf life of fruits, it is believed that certain properties of the plant may contribute to its potential effectiveness. Here are a few reasons that have been suggested [10].

Antimicrobial properties of C. fistula have been reported. The fruit surface microbial load can be decreased and its shelf life increased by the presence of bioactive substances including anthraquinones, tannins, and flavonoids in the plant extract, which may have antimicrobial actions against microorganisms that cause spoiling [11].

Flavonoids and phenolic compounds are among the phytochemicals with antioxidant qualities found in C. fistula extract. Fruit degeneration may be attributed to oxidative stress and free radical scavenging, both of which are inhibited by antioxidants. Fruit spoiling may be delayed and shelf life extended by Cassia fistula extract by lowering oxidative damage [12].

Fruits experience enzymatic browning due to specific enzymes such as peroxidase (POD) and polyphenol oxidase (PPO). In addition to changing a fruit's appearance, enzymatic browning causes taste alterations and nutritional loss. According to some research, the extract from Cassia fistula may block these enzymes, preventing enzymatic browning and prolonging the shelf life of fruits [13].

It's worth noting that while C. fistula extract shows promise, further scientific studies are needed to validate its effectiveness in extending the shelf life of fruits. Additionally, the specific fruit types and concentrations of the extract used could also influence the results. There have been a number of proposed explanations for the usage of Aloe vera extract to extend the shelf life of fruits. To properly comprehend the effects of Aloe vera extract on fruit shelf life, further research is necessary, as there hasn't been much scientific study done in this field yet. These are some of the theories that have been put out [10].

Bioactive substances found in aloe vera include polysaccharides, phenolic compounds, and saponins; these substances are thought to have antibacterial qualities. By inhibiting the growth of bacteria and fungi that cause rotting on the fruit's surface, these compounds may increase the fruit's shelf life [14].

Numerous antioxidants, such as flavonoids, beta-carotene, and vitamins C and E, are present in aloe vera extract. Fruit degeneration can be attributed to oxidative stress and free radicals, both of which are countered by antioxidants. Aloe vera extract may help postpone fruit deterioration and increase fruit shelf life by lowering oxidative damage [10].

High in water content, aloe vera gel is well renowned for its capacity to hold onto moisture. It could form a barrier to protect the fruit's surface when applied as an aqueous extract, preventing water loss and preserving the right amount of moisture. This can lessen the chance of fruits shriveling, withering, and dehydration—all of which can hasten their early deterioration [15].

Aloe vera extract has been reported to have beneficial effects on postharvest physiological processes in fruits. It may help regulate ethylene production, a hormone involved in fruit ripening and senescence. Aloe vera extract may be able to slow down fruit ripening and increase fruit shelf life by adjusting ethylene levels. It's crucial to keep in mind that different fruit types, extract concentrations, and application techniques can all have an impact on how well aloe vera extract prolongs fruit shelf life. To best utilize aloe vera extract for fruit preservation and confirm these possible advantages, more scientific study is required [16].

Regarding their impact on fruit shelf life, ethanolic (alcoholic) and aqueous (water-based) plant extracts differ based on the particular plant and extraction technique employed. However, there are a few general reasons why ethanolic plant extracts may have potentially worse effects compared to aqueous plant extracts when it comes to increasing the shelf life of fruits. Ethanol, being a strong solvent, can extract a wide range of compounds from plants, including both desirable bioactive compounds and potentially toxic substances. If not properly controlled, the high ethanol concentration in extracts can have adverse effects on the fruits, such as tissue damage, altered cellular metabolism, and increased susceptibility to microbial contamination [17].

Ethanol has a dehydrating effect and can cause tissue dehydration in fruits. Prolonged exposure to high concentrations of ethanol can lead to excessive water loss, resulting in fruit shriveling, loss of texture, and overall deterioration. Volatile component loss: The solvent qualities of ethanol may cause some volatile chemicals, which enhance fruit taste and scent, to change. The fruits' sensory properties may be compromised during the extraction process if these volatile chemicals are lost or broken down. Diminished antioxidant activity: Certain antioxidants found in plant extracts may have stability and activity issues when exposed to ethanol. In order to keep fruits safe from oxidative damage and degradation, these antioxidants are essential. Fruit shelf life may be limited by the efficacy of antioxidants if large doses of ethanol are used or if ethanol exposure is extended [18].

Conclusion:

The decision to use ethanolic or aqueous plant extracts for fruit preservation is influenced by a number of variables, such as the particular plant, the required bioactive chemicals, the effectiveness of the extraction process, and the intended use. Proper extraction techniques and controlled concentrations are necessary to mitigate any potential negative effects of ethanolic extracts. Additionally, individual plant species and their specific bioactive compounds can also influence the effectiveness and safety of ethanolic extracts for fruit preservation.

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