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Isolation and the Use of Fungal-derived Chitosan as a Substrate-Free Edible Coating to Extend the Postharvest Shelf Life of Guava

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ABSTRACT

Background: Guava (*Psidium guajava*) is a nutrient-rich tropical fruit with a very short postharvest shelf life due to its thin skin, high respiration rate and susceptibility to microbial spoilage. Chitosan is an edible film and a preservative, which can be developed from the fungal source and it benefiting the shelf life of perishable foods and vegetables.

Methods: The fungal species were isolated and identified by standard methods. Acid and alkali treatments were used to extract the chitosan from the chosen fungal isolates. FTIR and XRD were used to characterize the isolated chitosan. The surface of the guava fruit was coated with the fungal-based chitosan (1% and 2%). Various physiological properties such as weight loss, ripening and shelf life were evaluated at regular intervals. The DPPH assay and the Agar well diffusion method were used to assess antibacterial and antioxidant properties.

Result: Fungal isolates were selected, namely *Fusarium oxysporum* and *Aspergillus fumigatus*, based on morphological stability for the biomass yield for chitosan extraction. The yields of the chitosan for *A. fumigatus* (0.685 g/100 ml) and *F. oxysorum* (0.850 g/100 ml), respectively. Fruits that have been treated with 2% fungal-based chitosan exhibited a lower weight loss (3.2%), slow ripening and longer shelf life (9 days) and retained higher antioxidant activity (68.2%), than 1% and control group. 2% chitosan of *A. fumigatus* showed high antibacterial activity. The current study focusing on developing a fungal derived chitosan, which can be used as a suitable sustainable, non-toxic and safe alternative preservative to prolong the shelf life of guava.

Key words: Antibacterial activity, Chitosan, DPPH assay, Shelf life, Weight loss.

INTRODUCTION

Guava (*Psidium guajava*) is a very nutritious fruit encountered in the tropics. It contains a large amounts of dietary fiber, protein, soluble carbohydrates, riboflavin, essential amino acids, vitamin C and antioxidants (Khan *et al*., 2025). It is easily prone to spoilage after harvest because of the cuts, growth of microbes, dehydration and enzyme degradation. The industry faces a lot of trouble mainly due to the thin delicate nature of skin in guavas, but even more so due to high demand in the market and the many benefits associated with them. Maintaining the long shelf life of guava remains a difficult aspect to the producers and retailers, particularly in regions where there is a low level of the development of the cold storage facilities (Nor *et al*., 2020). The conventional use of chemical preservatives as a way of extending shelf life through the incorporation of formaldehyde, BHA and BHT is also diminishing as people become more cognizant of the eventual risks to their health and safety (Hanani *et al*., 2023). One of the potential solutions to reducing post-harvest losses, preserving fruit quality and ensuring food safety is natural edible coating such as chitosan (Francisco *et al*., 2020). Edible coatings are an economically viable solution to protraction of food as well as sustainable health of customers (Kaur *et al*., 2024; Hazarika *et al*., 2023).

Chitosan is a linearly structured polysaccharide composed of covalently bound D-glucosamine and N-acetyl-D-glucosamine and possesses remarkable characteristics to be biodegraded, biocompatible, non-toxic and able to form a film (Muxika *et al*., 2017; Rajaraman *et al*., 2020). This has made it suitable to be used in many areas such as preservation of foods, agriculture, pharmaceuticals and bio-medical applications (Kouhi *et al*., 2020). It is a highly valuable source in the food industry due to being a natural non-synthetic polymer capable of serving as an edible film, benefiting the shelf life of perishable foods and vegetables by sealing a semi-permeable structure to moisture, oxygen

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and pathogen penetration (Wang *et al*., 2024; Jeyakumari *et al*., 2023).

The potential of fungal biomass as a substitute source has gained more attention for the production of chitin and chitosan by fungal mycelium. Fungal mycelia also have significantly lower than normal amounts of inorganic constituents than in traditional crustacean-based chitin, which removes the necessity of any demineralization processes to support fungal mycelia-derived products. Moreover, the occurrence of allergens in crustacean residues is a risk to vulnerable customers, which restricts its usage in foods and biomedical products (Huq *et al*., 2022). Classically, chitosan is produced with a two-phase procedure of treating the fungal cell walls with both acids and alkali (Manal *et al*., 2019). The other pathway through which chitosan is made by the fungi is through enzymatic deacetylation of chitin (Kumar *et al*., 2023).

Some filamentous fungi, especially the genus of *Aspergillus*, *Fusarium*, *Mucor* and *Rhizopus*, have chitin and chitosan in cell walls (Pochanavanich and Suntornsuk, 2002). Chitosan derived fungi can be generated in the regulated fermentation environment with readily available and easily accessible substrates available throughout the year and with little impact on environment. In addition, the produced chitosan is allergen free as well as vegetarian with cheaper as well as less polluting extraction process. Because of these benefits, fungal chitosan is a promising option to be utilized in the pharmaceutical, food and biomedical sectors (El-Sabbagh *et al*., 2023).

Dipping was one of the oldest methods of commercial coating and is commonly seen today as constant improvements are made to this in perpetuity way. This process is used to soak the fruits in a coat solution to ensure that they get the full surface coating. This technique is effective with solutions of a variety of viscosities in coating requirements (Fathi *et al*., 2021).

The objective of the research is to investigate, explore and compare the usefulness of the fungal produced chitosan as naturally occurring biodegradable and edible coating on the guava fruit shelf life. Through analysis of the fungal basis resources in terms of aspects such as physicochemical parameters of chitosan, antimicrobial activity, a possibility of fungal derived chitosan as a precious source of antimicrobial activating compounds as a replacement of the standard sources used as food preservatives is assessed. In addition, the innovative aspect of the study is the choice of the fungal strains as very few studies have been done on extraction of chitosan over the two strains.

MATERIALS AND METHODS

Isolation and identification ientification of fungi

Soil samples were collected and serially diluted to isolate fungal strains using a standard protocol. Identification was done using Lactophenol cotton blue (LPCB) stain. The characterization, antibacterial activity was done in Saveetha University, Thandalam, Chennai and the other works were performed at Valliammal College for women, Anna Nagar, Chennai. A research period of December 2019-January 2022 was established.

Inoculation of fungal spores

Aqueous preparation of fungal inoculum was prepared aseptically by directly pouring sterile distilled water on fully growing of the fungal mycelia that had been grown on Sabouraud Dextrose Agar (SDA) plates. Spores were scraped gently with a sterile inoculating wire and the suspension of spores was filtered into sterile flask. A hemocytometer was used to measure the concentration of the spores and they were diluted to 10^7 spores/ml. There after, respective flasks were inoculated with 1 mL of fungal spore suspension. The cultures were placed under batch conditions and grown at 28°C over 5 days period and a complete growth of the fungal mycelium was observed (Bhargava and Tandon, 2015).

Mass cultivation

The culture of the selected strains of fungi was prepared in a synthetic microbial liquid growth medium, which included 20% potato extract, 2% dextrose, 1% peptone, 0.1% NaCl, 0.01% $CaCl_2$ and 0.05% of $MgSO_4$ 7. H_2O. To achieve good growth of the mycelium, the cultures were incubated at 28°C centrifuge at 120 rpm for 10 to 15 days. Produced fungal biomass was collected through filtration and then washed excessively using distilled water in the process of eliminating medium constituents; followed by air-drying at the room temperature.

$$\text{Chitosan production (\%)} = \frac{\text{Chitosan dry weight (g)}}{\text{Biomass dry weight (g)}} \times 100$$

Chitosan extraction and purification

Fungal mycelia were collected at the final stage of the cultivation phase using Whatman No. 1 filter paper. The harvested biomass was washed twice with distilled water and dried at 65°C until a constant weight was achieved. Chitosan extraction from the fungal biomass involved a series of chemical treatments, starting with deproteinization and deacetylation using an alkaline solution, followed by solubilization in dilute acetic acid (Nwe *et al*., 2010). Initially, the biomass was treated with 1 M sodium hydroxide (NaOH) at a ratio of 1:40 (w/v) and heated at 90°C for 3 hours. This process yielded a solid residue known as alkali-insoluble material (AIM). The AIM was separated by centrifugation at 6000 rpm for 15 minutes, thoroughly washed with distilled water and centrifuged repeatedly until a neutral pH was reached.

For chitosan extraction, the neutralized AIM was treated with 10% (v/v) acetic acid (1:40 w/v) at room temperature for 6 hours on a rotary shaker operating at 200 rpm. The resulting acid-insoluble residue was removed by vacuum filtration. Chitosan remained in the filtrate and the pH was adjusted to 9.0 using 4 M NaOH, resulting in chitosan precipitation.The precipitate was recovered by centrifugation, washed with distilled water and dried at 60°C until a

constant weight was obtained (Abdel-Gawad *et al*., 2017). Throughout the studies, the chitosan extraction using *Fusarium oxysporum* indicates the Sampe 1 or S1 whereas Sample 2 or S2 denoted for *Aspergillus fumigatus.*

Characterization of chitosan

Fourier transform infrared spectroscopy (FTIR)

Using Shimadzu IR Affinity-1S Spectrometer, FTIR analysis was done for chitosan, to define group of absorptions based on functional groups. Dried chitosan was were taken in thin cut samples, crushed in a potassium bromide (KBr) and then formed into a disk and scanned in wavenumbers 4000-400 cm^{-1}.

XRD

The Powder X-ray Diffraction (PXRD) analysis using D8 Advance Bruker (Germany) diffractometer and Cu Kα (l=1.54059) as the source of radiation.

Chitosan coating on guava

Treatment and storage condition

The coating solutions was prepared with 2.5 g and 5 g of chitosan powder dissolved in 900 ml of distilled water with addition of 2% of citric acid was added to facilitate the chitosan powder to dissolve and also as a plasticizer. Each one of the solutions was adjusted to pH 5.5 using 0.1 M NaOH. The treatment comprised of 0.25%, 0.5% and control (an acid solution that defied the presence of chitosan). The prepared emulsion of coating solution was dipped in the form of a coating over the guava fruits and the other was untreated and kept as control. All fruits were labeled using the sample number and other information. A comparative experiment on the treated and untreated guavas was carried out to test it.

Observation of shelf life

After the post harvests treatment, guava fruits were stored in controlled environments and their shelf life was being studied at every time interval. Different quality variables were measured periodically including the color, weight loss and symptoms of spoilage of the treated.

Various parameters of the guava before and after treatment

Weight loss

To calculate the weight loss, the weight of the guava samples on Day 0 and the weight measured on Days 3, 6, 9 and 12 after coating were exerted. The weight of the fruit was measured using a laboratory weighing balance. The percentage of weight loss was calculated by the following equation:

$$\text{Reduced weight (\%)} = \frac{(W1 - W2)}{W1} \times 100$$

Where,
W1 = Initial weight of the guava.
W2 = Weight at each time point following coating.

Antioxidant activity

According to the protocol of Wani *et al*. (2018), the DPPH radical scavenging assay and a mixture of 3.5 mL DPPH solution determined oxidative strength and 0.5 mL guava fruit extract was added. The percentage of antioxidant activity was measured at an absorbance of 615 nm using UV-Visible Spectrophotometer. The inhibition percentage of antioxidant activity was expressed as follows:

$$\text{Antioxidant activity (\%)} = \frac{(AC - AS)}{AC} \times 100$$

Where,
AC=Absorbance control
AS=Absorbance sample

Determination of antibacterial activity

The prepared fungal-based chitosan solution was used to check the antibacterial activity against *Staphylococcus aureus*, *Klebsiella pneumoniae and Escherichia coli* using Agar well diffusion method.

RESULTS AND DISCUSSION

Isolation of fungi

On SDA plate, a diverse growth of fungi was observed. The plate showed a range from light green to dark green, brown and white colored colonies with a cottony, powdery hyphae were shown in Fig 1 and 2.

Identification of fungal species

The colonies were analyzed morphologically using Lactophenol Cotton Blue (LPCB) staining and observed under high power of objective microscope (40x). Identification of the fungal species was tabulated (Table 1). Among four morphologically distinct identified fungal strains, two strains of fungi were shown in Fig 3 and 4 *Fusarium oxysporum* and *Aspergillus fumigatus* that were picked and used for the further experiment.

Biomass production

A thick fungal mat was observed on the surface of the liquid medium after 10-15 days of incubation. The resultant mycelium biomass was collected, air-dried and decanted in order to extract chitosan in the next stage shown in Fig 5.

Extraction of chitosan

The fungal liquid biomass was used to obtain chitosan through a renowned set of chemical reactions that successively isolated the chitosan as well as purifying it. The extraction process was evidenced by the uniformity of the finished product, which was shown in Fig 6a-6e. The final yield of chitosan from *Fusarium oxisoporum* (S1) was 0.685 g/100 ml whereas 0.850 g/100 ml from *Aspergillus fumigatus* (S2). The fungal cell walls were treated with acids and alkalis in a two-step process. Proteins and soluble polysaccharides were removed successfully after being treated with NaOH and deposition

of an alkali-insoluble material (AIM) as solid sediment was the evident. During the treatment, a combination of chitin and glucan dissociates and deacetylation step produced the chitosan.

FTIR

The existence of distinctive functional groups in the chitosan isolated from *Fusarium oxysporum* was verified by FTIR was presented in Fig 7a. Extensive hydrogen bonding is indicated by a large absorption band seen in the 3368-3683 cm^{-1} range, which is correlated with the O-H stretching vibrations of hydroxyl groups and the N-H stretching of amino groups. Asymmetric and symmetric C-H stretching vibrations of -CH, groups are responsible for the peaks at 2922.16 cm^{-1} and 2852.72 cm^{-1}. Overtones or lingering contaminants could be the cause of a little band at 2374.37 cm^{-1} and a slight peak at 2725.42 cm^{-1} (Sharma *et al*., 2024). Partial deacetylation is indicated by a band at 1375.25 cm^{-1} that corresponds to the C-N stretching vibrations of amino groups. The peak at 1155.36 cm^{-1} is linked to the chitosan backbone's asymmetric stretching of the C-O-C bridge (Berger *et al*., 2018). These spectrum characteristics verify that chitosan with structural properties comparable to those of typical fungal-derived chitosan was successfully extracted.

The FTIR spectra of the chitosan extracted by *Aspergillus fumigatus* have characteristic functional groups that prove its molecular composition was shown in Fig 7b. The presence of there is quantum of hydroxyl and amine due to the presence of large sum of absorption seen at 3446.79 cm^{-1}, which is O-H and N-H stretching vibrations. The vibrations of the $-CH_2$ groups responsible are the C-H asymmetric and the C-H symmetric stretching and the corresponding peaks are 2922.16 cm^{-1} and 2852.72 cm^{-1}. The formation of inter- and intramolecular hydrogen bonds enhances the structural stability of pure chitosan (Praveen *et al*., 2017). The highest peak at 1554.63 cm^{-1} can be attributed to N-H bending, yet strong and evident peak at 1656.85 cm^{-1} can be connected with amide (C=O stretching of residual N-acetyl groups. The contribution of CH_2 bending is assigned at 1458.18 cm^{-1}. The C-N stretching is found to be located at a peak 1377.17 cm^{-1} (Street *et al*., 2018).

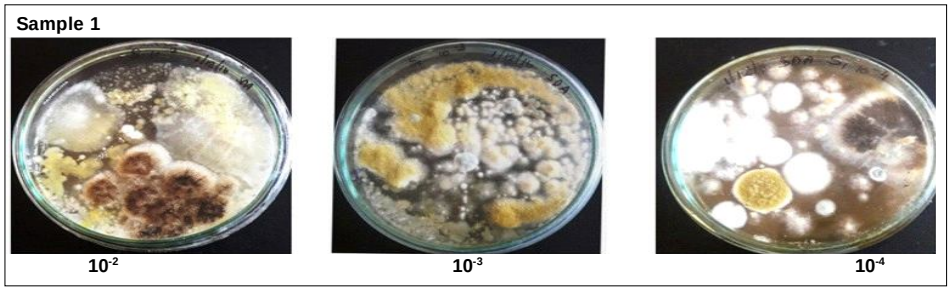


Fig 1: Fungal colonies on SDA.

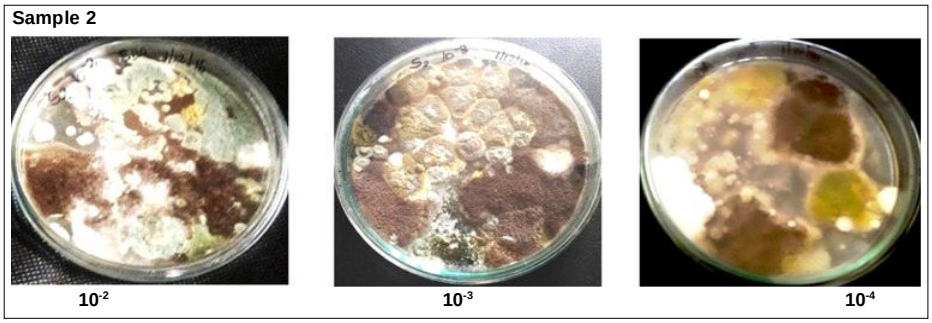


Fig 2: Fungal colonies on SDA.

Table 1: Identification of isolated fungal species.

Macroscopic appearance	Microscopic appearance	Inference
Mature colonies covered with black spores.	Black to brownish black conidia with hyaline conidiophores, possess both primary secondary sterigmata.	*Aspergillus niger*
Velvetty yellowish green in colour	Branched septate hyphae with elliptical vesicle, sterigmata covers 3/4th of the vesicle surface.	*Aspergillus flavus*
Cottony, white to cream orange in colour	Macroconidia are multicelled, fusiform or sickle shaped, Microconidia are oval globose/ellipsoidal	*Fusarium oxysporum*
Velvetty blue-green colony with white apron around the edges	Branched septate hyphae, Flask shaped vesicle, Sterigmata found only on the upper half of the vesicle.	*Aspergillus fumigatus*

These spectrum properties are evidence that the chitosan extraction is effective since it is based on the fungal source.

XRD

Chitosan produced by fungal strains *Fusarium oxysporum* and *Aspergillus fumigatus* exhibited certain characteristic peak angles of the diffraction obtained on the XRD plots displayed in Fig 8a, b around 2θ = 9°-10° and 19-20° demonstrating the semi-crystalline nature of chitosan. Chitosan extracted from *F. oxysporum* exhibited sharper and more defined peaks at 9.15° and 19.60° denoting a better degree of crystallinity. It implies that the molecular chains of this sample might be more regular and dense, which can increase its mechanical properties, thermal stability, barrier properties. Differently, chitosan obtained in *A. fumigatus* showed wider and weaker peaks at 9.25° and 19.55°, indicating a more amorphous structure, with low crystallinity. These distinctions can be affected by a number of factors, which include the inherent metabolic and enzymatic characteristics of fungus used as the production organism, differences in cell wall composition, change in extraction procedures like deproteinization, deacetylase activity and drying practices.

Preparation of chitosan coating solution

In order to measure their stability and solubility, different combinations of chitosan coating solutions were successfully prepared and displayed in Fig 9. The chitosan (S1) turned turbid and clearly there is sedimentation implying that it was not totally dispersed. Better clarity and homogeneity were noted with 1% chitosan and 2% citric acid (S1 with CA) solution showing better solubilization of chitosan in acidic solution. As an acidic environment control, the sample appeared to be translucent on the 2% citric acid alone sample leading to the observation that it lacks particle matter.

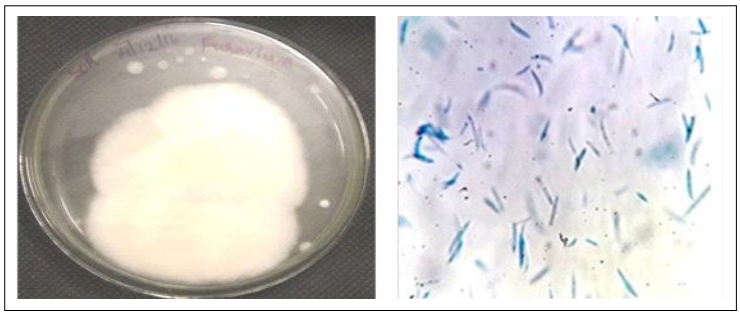


Fig 3: *Fusarium oxysporum* from sample 1.

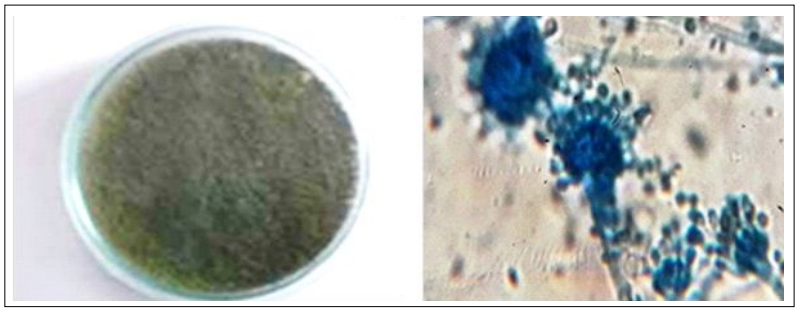


Fig 4: *Aspergillus fumigatus* from sample 2.

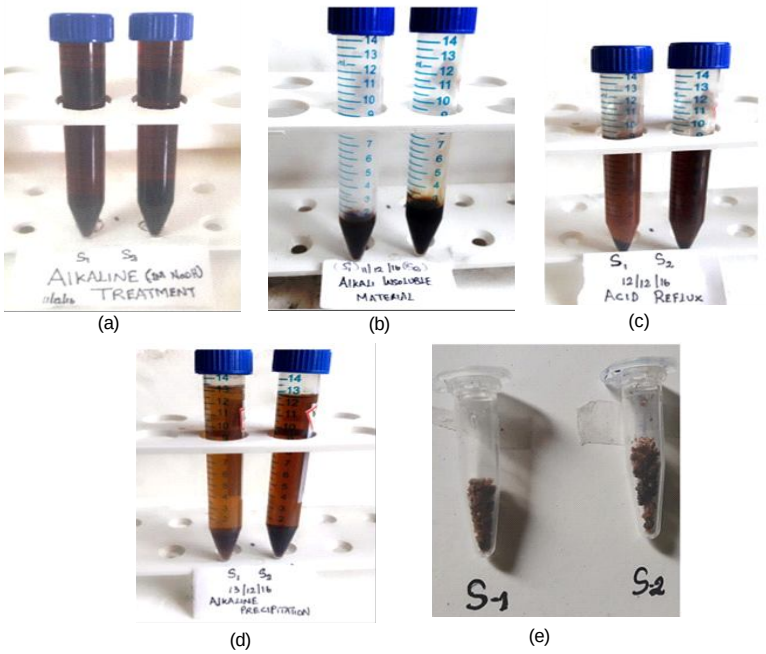


Fig 5: Mass cultivation of fungal spores.

Postharvest quality of guava with chitosan coating

A noticeable increase in the colour change of guava fruits was observed from the third day of storage. However, by the ninth day, fruits coated with 2% chitosan (Sample 1: *Fusarium oxysporum*) showed significantly less colour development compared to the untreated control group, indicating a delay in the ripening process. Among all treatments, the formulation combining 1% chitosan with 2% citric acid (Sample 1) was the most effective in preserving the visual quality of the guava during storage. The postharvest application of chitosan notably extended the shelf life of the fruits was shown in Fig 10.

In addition to delaying ripening, chitosan-treated fruits showed better retention of firmness, reduced weight loss and lower microbial decay throughout the storage period. The semipermeable nature of chitosan film likely created a modified internal atmosphere, slowing down respiration and senescence (Soares *et al*., 2011). Overall, chitosan coating effectively preserved the postharvest quality of guava, making it a promising treatment for extending marketable shelf life (Dutta *et al*., 2012).



(a) (b) (c) (d) (e)

(a) Liquid biomass treated with NaOH; (b) Sedimentation of alkali insoluble material; (c) Separation of Chitin and Chitosan by acid refux; (d) Alkaline precipitation of Chitosan; (e) Chitosan Powder.

Fig 6: Extraction of chitosan.

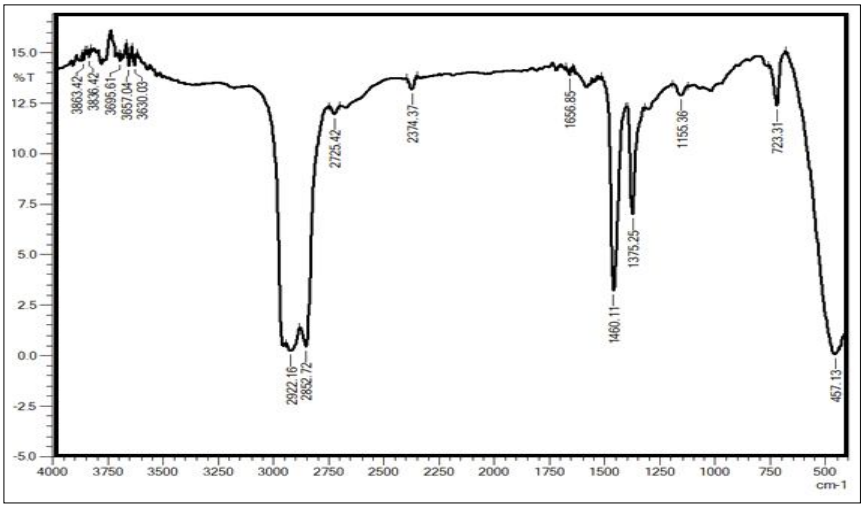


Fig 7a: FTIR analysis of chitosan extracted from *Fusarium oxysporum.*

Weight loss

Using the initial weight, the % weight loss of coated and uncoated fruits over a 12-day storage period was calculated. At the end of day 12, coated fruits showed a progressive decrease in weight, ranging from 3.2%, whereas uncoated fruits, on the other hand, demonstrated a noticeably greater reduction in weight, ranging from 0.98% at day 12. The guava weight loss results are presented in Fig 11 showing that there was a significant ($p<0.05$) increase in the percent weight loss. Fresh fruit loses weight through respiration and transpiration. The key reasons leading to a decrease in weight include respiration and loss of

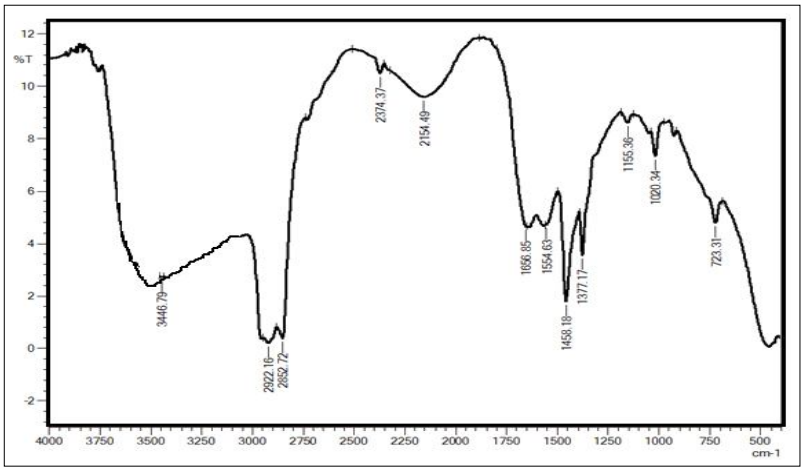
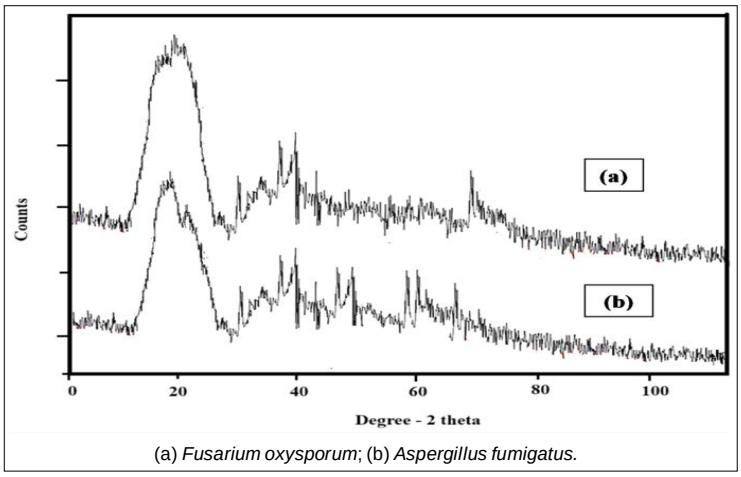


Fig 7b: FTIR analysis of chitosan extracted from *Aspergillus fumigatus*.



(a) *Fusarium oxysporum*; (b) *Aspergillus fumigatus.*

Fig 8: X-ray diffraction of chitosan extracted from fungal strain.

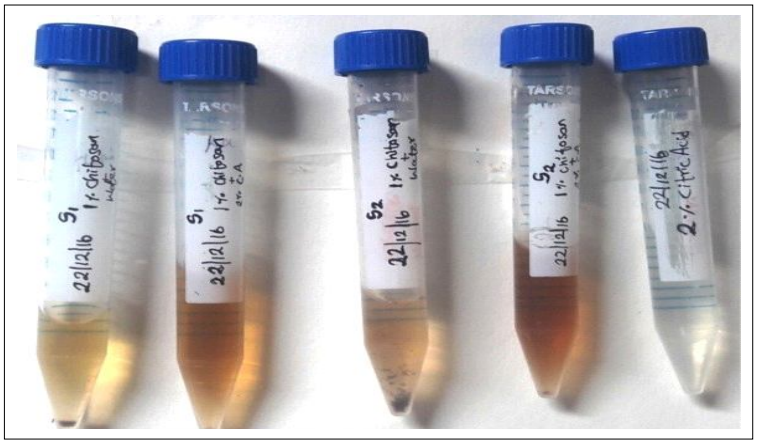


Fig 9: Preparation of chitosan coating solutions.

moisture between the fruits internal and environmental external conditions of air (Hernández-Muñoz, 2006; Zhang *et al*., 2018). Chitosan coatings delayed the process of dehydration by avoiding the loss of water and also avoided mechanical damages and overcome the cuts that occur by default on the fruits skin (Hong *et al*., 2012).

Antibacterial activity

The antibacterial activity of chitosan formulations was evaluated against *Klebsiella pneumoniae*, *Escherichia coli* and *Staphylococcus aureus*, with inhibition zones compared to a standard antibiotic (Table 2) and Fig 12. When comparing, 2% chitosan showed a highest zone of inhibition than 1% chitosan sample. Among three different bacterial strains, *Escherchia coli* growth was inhibited higher than *Klebsiella* and *Staphylococcus.* Usually, the mechanism of the antimicrobial is based on electrostatic interactions with the cytosolic contents, cell wall and outer membrane of the bacteria (Duan *et al*., 2019). Antibacterial activity of chitosan is widely demonstrated to be due to its binding to the

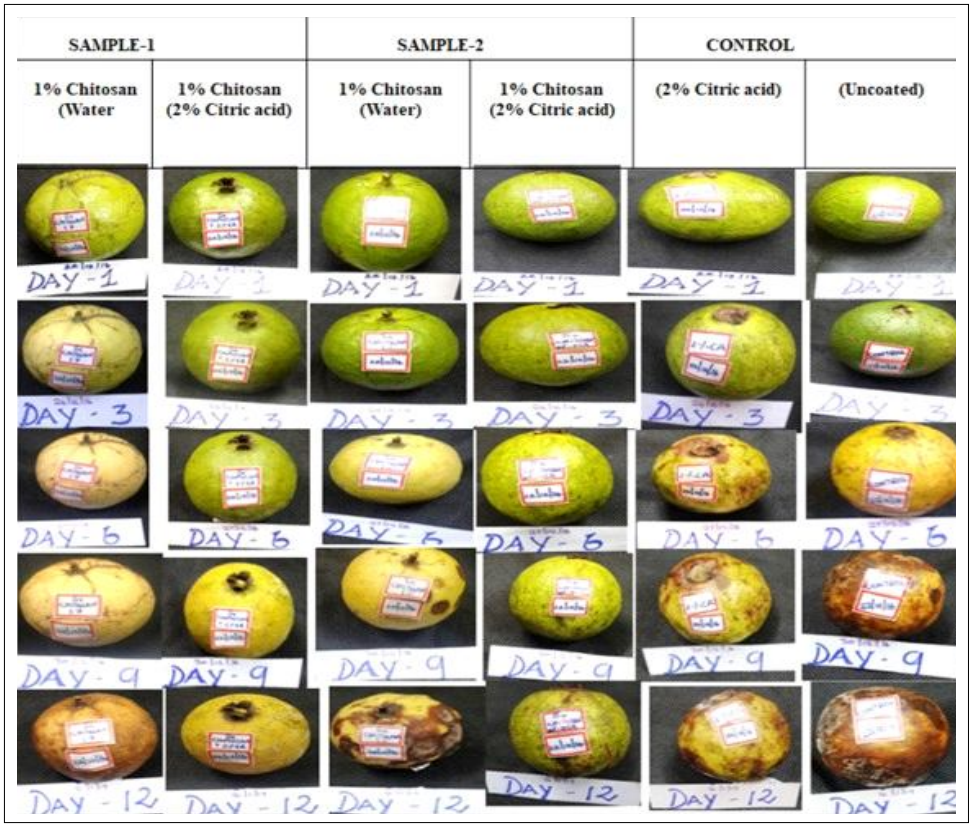


Fig 10: Effect of chitosan on postharvest quality of Guava.

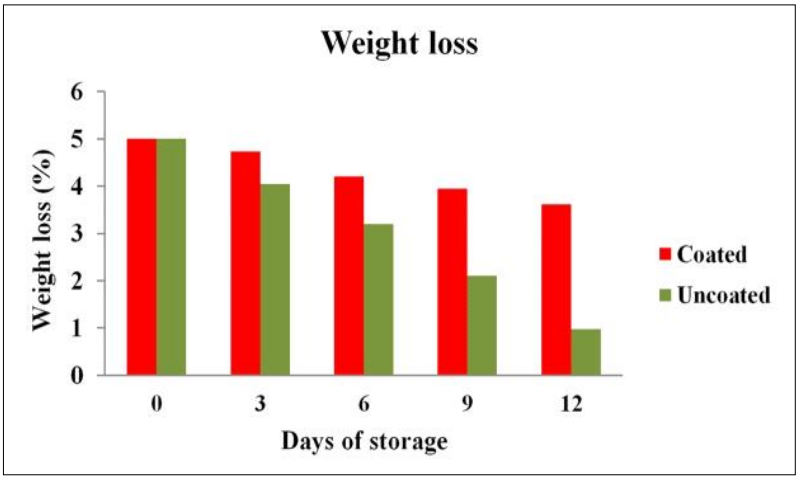
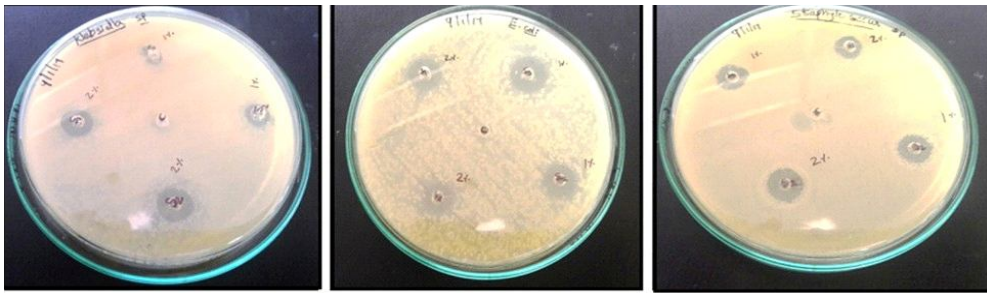


Fig 11: Changes in weight after post harvesting of guava.



(a) (b) (c)

(a) *Klebsiella pneumoniae* (b) *Escherichia coli* (c) *Staphylococcus aureus*

Fig 12: Antibacterial Activity of chitosan solution against.

Table 2: Antibacterial efficacy of chitosan solutions.

Organism	Samples					
	Concentration of chitosan					
	S1-1%	S1-2%	S2-1%	S2-2%	Std	Control
Klebsiella pneumoniae	2 mm	5 mm	4 mm	10 mm	19 mm	-
Escherichia coli	6 mm	7 mm	10 mm	11 mm	18 mm	-
Satphylococcus aureus	6 mm	4 mm	6 mm	8 mm	23 mm	-

S1- Chitosan extracted from *Fusarium oxysporum*; S2- Chitosan extracted from *Aspergillus fumigatus*; Control- Citric acid; Std- Ciprofloxacin.

Table 3: Percentage of DPPH inhibition.

No of days stored	DPPH inhibition %	
	Coated fruit	Uncoated fruit
0	87	87
3	85.9	80.2
6	80.4	61.8
9	72.4	42.9
12	68.2	20.8

negatively charged cell wall of bacteria thus rupturing the cell wall and altering the porousness of the membrane.

Antioxidant activity

The antioxidant activity in the control (Uncoated) samples declined significantly from an initial 87% to 20%, whereas in the coated samples, it decreased only to 87 to 68.2%. The antioxidant activity in terms of DPPH showed highest with higher concentration of chitosan Table (3). The observed reduction in antioxidant capacity in the control group is most likely determined by a generation of free radicals because of the degradation of phenolic compounds due to senescence and elevated level of respiration (Ghasemnezhad *et al*., 2010; Rehman *et al*., 2020). The edible coatings affect the internal environment of fruits by slowing down metabolic reactions by a large margin leading to a significant decrease in the production of flavonoids and phenolic compounds (Gonzalez-Aguilar *et al*., 2010; El-Sayed *et al*., 2019). Conversely, the guava that coated with chitosan maintained higher antioxidant activity than the uncoated guavas. This increase is possible due to the ability of the coating to change the internal atmosphere of the fruit to reduce the oxidative stress level and slow down the degradation of the antioxidant compounds. Wang and Gao (2013) obtained a similar result demonstrating that strawberries undergoing coating of chitosan maintained a more acceptable total phenolic content and antioxidant activity when stored.

CONCLUSION

This study shows the potential of fungal-based chitosan, *Fusarium oxysporum* and *Aspergillus fumigatus*, to provide effective, environmental friendly and non toxic edible wrapping to extend the post-harvest life of guava (*Psidium guajava*). The functional groups of the extracted fungal chitosan were successfully characterized using FTIR. The fungal-derived chitosan showed a strongest antibacterial against both Gram positive and Gram negative bacteria. The effectiveness of antioxidant capacity of guava fruits coated with fungal extracted chitosan was clearly depicted in the DPPH antioxidant test where the antioxidant capacity of guava fruits coated with chitosan was able to withstand the antioxidant capacity throughout the storage period than the un-coated control fruits. The coating successfully retained phenolic compounds and other bioactive antioxidants and led to the extension of fruit quality and shelf life. These results show that fungal chitosan can be considered a promising candidate of natural edible coating to keep postharvest fruits in high nutritional and functional quality. Unlike the rapid decline recorded in controls, the shelf life of the fungal chitosan coated guava significantly delayed the ripening

process, reduced weight loss and preserved antioxidant activity. The chitosan treated guava fruit samples maintained the quality for upto nine days in ambient conditions. The chitosan exhibited strong antibacterial activity against pathogenic strains commonly found in food such as *Staphylococcus aureus, Klebsiella pneumoniae* and *Escherichia coli* at the 2% concentration.

These results support the application of fungal chitosan as alternative to the utilization of conventional synthetic preservative compounds since the results satisfy consumer preference to clean-label and non-allergens food preservatives. Fungal chitosan should be considered as a best option to be employed in postharvest handling processes because it can have a combination of both antibacterial and physical barrier actions, particularly in regions where there is no advanced cold-chain structure. Further business analysis and scale-up studies are needed to inquire into its broader use in the preservation of other perishable fruits and vegetables.

Conflict of interest

All authors declare that they have no conflict of interest.

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