Development of Crude Extract-Based Edible Coatings for Shelf Life Extension and Control of Crown Rot Disease Caused by *Fusarium spp.* in Namwa Banana (*Musa sapientum*)

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Abstract

This study aimed to evaluate the effectiveness of an edible coating made from gum arabic, chitosan, and herbal extracts in controlling *Fusarium spp.*, the main cause of crown rot disease in Namwa bananas, and to investigate its effects on postharvest fruit quality. The fungal pathogen was isolated from infected bananas and identified based on its morphological characteristics. Clove and sweet flag extracts were prepared using 99% ethanol and tested for antifungal activity on potato dextrose agar (PDA) at concentrations of 1%, 5%, and 10%. The results showed that 10% clove extract provided the highest inhibition of fungal growth compared with the other concentrations and the sweet flag extract. Therefore, it was selected as the active ingredient for the coating formulation. Chitosan concentrations of 1%, 2%, and 3% were also evaluated, and 2% chitosan showed the best balance between antifungal effectiveness and coating performance. The developed edible coating was then applied to Namwa bananas and compared with an untreated control. The coated bananas showed reduced fungal growth on the crown, lower weight loss, delayed peel color change,and a slower increase in total soluble solids (%TSS). These findings indicate that the edible coating containing gum arabic, 2% chitosan, and 10% clove extract is an effective and environmentally friendly method for controlling *Fusarium spp.* and extending the postharvest shelf life of Namwa bananas.

keywords : Namwa Banana, *Fusarium spp.*, Crown rot disease, Edible coating

Introduction

Namwa banana (*Musa sapientum*) is an important economic crop in Thailand due to its high nutritional value and wide consumer demand. However, postharvest losses caused by crown rot disease, mainly caused by *Fusarium spp.*, significantly reduce fruit quality and shelf life during storage and transportation. Although chemical fungicides are commonly used to control this disease, their continuous use may lead to chemical residues, health risks, and environmental concerns.

To address these limitations, environmentally friendly alternatives have gained increasing attention. Edible coatings made from natural materials such as gum arabic and chitosan can reduce water loss, delay fruit ripening, and improve postharvest quality. In addition, herbal extracts such as clove (*Syzygium aromaticum*) and sweet flag (*Acorus calamus*) contain bioactive compounds with antifungal properties that help inhibit the growth of plant pathogenic fungi.

Therefore, this study aimed to evaluate the effectiveness of a natural edible coating containing herbal extracts in inhibiting the growth of Fusarium spp. and to assess its effects on the postharvest quality and shelf life of Namwa bananas. The findings of this study may provide an environmentally friendly approach to reducing postharvest losses, increasing the value of agricultural products, and promoting safe and sustainable agricultural practices.

Methodology

1) Study of the Causal Fungus of Crown Rot Disease in Namwa Banana

1.1. Isolation and Identification of the Pathogen

Fungi were isolated from crown rot–infected Namwa bananas by culturing diseased crown tissues on Potato Dextrose Agar (PDA) at room temperature. Emerging fungi were purified using the hyphal tip culture technique and identified based on their morphological characteristics under a light microscope.

1.2 Preparation of Clove and Sweet Flag Extracts for Antifungal Activity

Dried clove buds and sweet flag (*Acorus calamus*) rhizomes were extracted with 95% ethanol for 3 days at room temperature. The extracts were filtered, concentrated using a rotary evaporator, and stored in amber bottles at 4°C until use.

1.3 Antifungal Activity of Plant Extracts

Clove and sweet flag extracts were incorporated into PDA at concentrations of 1,000, 5,000, and 10,000 ppm. Fungal agar plugs were placed onto the treated media and incubated for 5 days. Colony diameters were measured and compared with those of the untreated control.

Percentage inhibition of mycelial growth (%) = $\frac{A-B}{A} \times 100$

* A = Mean colony diameter of the fungus on the control PDA plates

* B = Mean colony diameter of the fungus on PDA plates containing clove or sweet flag extract

1.4 Selection of Appropriate Chitosan Concentrations for Fungal Growth Inhibition

Chitosan was incorporated into PDA at concentrations of 1,000, 2,000, and 3,000 ppm. Fungal agar plugs were cultured on the treated media for 5 days, and colony diameters were compared with those of the control.

Percentage inhibition of mycelial growth (%) = $\frac{A-B}{A} \times 100$

2) Evaluation of Edible Coating for Controlling Crown Rot Disease in Namwa Banana

2.1 Evaluation of Edible Coating Efficacy Against Crown Rot

An edible coating containing 0.67% chitosan, 0.67% clove extract, 6.67% gum arabic, and 33.33% acetic acid solution was applied to the crowns of Namwa bananas artificially inoculated

with *Fusarium spp.* using the artificial inoculation technique. Disease severity was compared with that of inoculated but uncoated control fruits. The percentage inhibition of fungal growth was calculated using the following equation:

Percentage inhibition of mycelial growth (%) = $\frac{A-B}{A} \times 100$

3) Evaluation of Banana Quality by Physical and Chemical Analyses

3.1 Determination of Percentage Weight Loss

Fruit weight was recorded on days 0, 1, 3, 5, and 7 of storage. Weight loss was expressed as the percentage reduction relative to the initial fruit weight. The percentage weight loss was calculated as follows: Percentage weight loss (%) = $\frac{\text{Initial weight} - \text{Weight on sampling day}}{\text{Initial weight}} \times 100$

3.2 Measurement of Banana Peel Color

Peel color was measured using a colorimeter. The color parameters were interpreted as follows:

* L* = Lightness value, ranging from 0 (black/dark) to 100 (white/light).

* a* = Red–green coordinate. Positive (+) values indicate redness, while negative (–) values indicate greenness.

* b* = Yellow–blue coordinate. Positive (+) values indicate yellowness, while negative (–) values indicate blueness.

3.3 Determination of Total Soluble Solids (TSS)

Total soluble solids (TSS) were determined using a Brix refractometer. Banana juice was diluted with distilled water at a ratio of 1:2 (v/v), and the measured value was multiplied by 3 to obtain the final TSS (%).

Result and Discussion

1) Study of the Causal Fungus of Crown Rot Disease in Namwa Bananas

1.1 Identification of the Fungal Pathogen

The fungus isolated from infected Namwa bananas was cultured on PDA medium and identified based on its morphological characteristics. The colonies showed white fluffy mycelia that later turned pink to light purple. Microscopic observation revealed septate hyphae and sickle-shaped macroconidia, confirming the fungus as *Fusarium spp.*

1.2 Preparation of Herbal Extracts

Dried clove and sweet flag (30 g each) were extracted with 99% ethanol for three days. The extracts were concentrated using a rotary evaporator to obtain concentrated herbal extracts, which were stored at 4°C until use.

1.3 Selection of the Optimal Clove Extract Concentration

The antifungal activity of clove extract against *Fusarium spp.* was evaluated on PDA medium at concentrations of 1%, 5%, and 10%, with three replicates. The inhibition of fungal growth was compared to determine the optimal concentration.The results are presented in Table 1.

Table 1 Effect of clove extract on the inhibition of *Fusarium spp.* growth.

Clove Extract		
Concentration	Fungal Mycelial Growth (cm)	Growth Inhibition (%)
1%	2.67 ± 0.25	70.37
5%	1.83 ± 0.36	79.63
10%	1.57 ± 0.12	82.59

The results showed that clove extract at concentrations of 1%, 5%, and 10% reduced the fungal growth to 2.67 ± 0.25, 1.83 ± 0.36, and 1.57 ± 0.12 cm, respectively. The corresponding

percentages of growth inhibition were 70.37%, 79.63%, and 82.59%, respectively.

The antifungal activity of sweet flag extract against *Fusarium spp.* was evaluated on PDA medium at concentrations of 1%, 5%, and 10%, with three replicates. The results are presented in Table 2.

Table 2 Effect of sweet flag extract on the inhibition of *Fusarium spp.* growth.

Sweet flag Extract		
Concentration	Fungal Mycelial Growth (cm)	Growth Inhibition (%)
1%	2.67 ± 0.15	70.37
5%	2.30 ± 0.26	74.44
10%	1.70 ± 0.20	81.11

The results showed that sweet flag extract at concentrations of 1%, 5%, and 10% reduced fungal growth to 2.67 ± 0.15, 2.30 ± 0.26, and 1.70 ± 0.20 cm, respectively. The corresponding growth inhibition percentages were 70.37%, 74.44%, and 81.11%, respectively

1.4 Selection of the Optimal Chitosan Concentration

The antifungal activity of chitosan solution against *Fusarium spp.* was evaluated on PDA medium at concentrations of 1%, 2%, and 3%, with three replicates. The results are presented in Table 3.

Table 3 Effect of chitosan solution on the inhibition of *Fusarium spp.* growth

Chitosan Solution		
Concentration	Fungal Mycelial Growth (cm)	Growth Inhibition (%)
1%	4.93 ± 0.15	45.19
2%	4.03 ± 0.26	55.19
3%	2.93 ± 0.20	67.41

The results showed that chitosan solution at concentrations of 1%, 2%, and 3% reduced fungal growth to 4.93 ± 0.15, 4.03 ± 0.26, and 2.93 ± 0.20 cm, respectively. The corresponding growth inhibition percentages were 45.19%, 55.19%, and 67.41%, respectively.

2) Evaluation of the Edible Coating for Crown Rot Control in Namwa Bananas

2.1 Evaluation of the Edible Coating for Crown Rot Control

The edible coating, consisting of 0.67% chitosan, 0.67% clove extract, 6.67% gum arabic, and 33.33% acetic acid solution, was applied to the crown of Namwa bananas. The fruits were artificially inoculated with *Fusarium spp.* using the artificial inoculation technique. Disease development on coated bananas was compared with the untreated control after 1, 3, 5, and 7 days. The results are presented in Table 4.

Table 4 Effect of the edible coating on the control of crown rot disease in Namwa bananas.

Storage Time (Days)	Fungal Growth in the Untreated Control (cm)	Fungal Growth in the Coated Group (cm)	Growth Inhibition (%)
1 day	0.60	0.20 ± 0.03	66.67
3 days	1.80	0.70 ± 0.08	61.11
5 days	3.00	1.50 ± 0.15	50.00
7 days	4.20	2.80 ± 0.22	33.33

The results showed that the edible coating reduced fungal growth to 0.20 ± 0.03, 0.70 ± 0.08, 1.50 ± 0.15, and 2.80 ± 0.22 cm after 1, 3, 5, and 7 days, respectively. The corresponding growth inhibition percentages were 66.67%, 61.11%, 50.00%, and 33.33%, respectively.

3) Evaluation of Banana Quality by Physical and Chemical Properties

3.1 Percentage of Weight Loss

The percentage of weight loss was evaluated in coated Namwa bananas with an average initial weight of 368.09 g after 1, 3, 5, and 7 days, and

compared with the untreated control (average initial weight 360.10 g). The results are presented in Table 5.

Table 5 Percentage of weight loss of Namwa bananas.

Storage Time (Days)	Weight of the Untreated Control (g)	Weight Loss of the Untreated Control (%)	Weight of the Coated Group (g)	Weight Loss of the Coated Group (%)
1 day	355.80	1.19%	365.90 ± 0.30	0.59%
3 days	348.20	3.30%	361.20 ± 0.45	1.87%
5 days	339.00	5.86%	354.80 ± 0.60	3.61%
7 days	329.50	8.49%	347.00 ± 0.75	5.73%

The results showed that the average weight of the coated bananas was 365.90 ± 0.30, 361.20 ± 0.45, 354.80 ± 0.60, and 347.00 ± 0.75 g after 1, 3, 5, and 7 days, respectively. The corresponding percentages of weight loss were 0.59%, 1.87%, 3.61%, and 5.73%, respectively.

3.2 Peel Color Evaluation

The peel color of coated Namwa bananas was evaluated and compared with the untreated control after 1, 3, 5, and 7 days of storage. The results are presented in Table 6.

Table 6 Peel color changes of Namwa bananas during storage.

Storage Time (Days)	control	L*	a*	b*
initial	untreated	52.30 ± 0.80	−8.20 ± 0.50	18.40 ± 0.70
	coated	52.30 ± 0.80	−8.10 ± 0.45	18.20 ± 0.65
1 day	untreated	54.80 ± 0.90	−6.50 ± 0.55	22.60 ± 0.80
	coated	53.40 ± 0.85	−7.30 ± 0.50	20.10 ± 0.75
3 days	untreated	58.90 ± 1.10	−3.20 ± 0.60	28.90 ± 0.95
	coated	56.20 ± 0.95	−5.10 ± 0.55	24.80 ± 0.85
5 days	untreated	63.70 ± 1.25	+0.80 ± 0.70	34.50 ± 1.10
	coated	60.10 ± 1.05	−2.40 ± 0.65	30.20 ± 0.95
7 days	untreated	67.90 ± 1.40	+3.50 ± 0.85	38.80 ± 1.25
	coated	64.30 ± 1.20	+0.90 ± 0.75	34.60 ± 1.10

The L*, a*, and b* values changed during storage. The L* and b* values gradually increased, while the a* value shifted from negative toward positive values, indicating normal peel ripening and color development.

3.3 Total Soluble Solids (TSS) Evaluation

The total soluble solids (TSS) of coated Namwa bananas were evaluated and compared with the untreated control on Days 1 and 7 of storage. The results are presented in Table 7.

Table 7 Total soluble solids (TSS) of Namwa bananas

Storage Time (Days)	control	Measured Value (°Brix)
1 day	untreated	6.3 ± 0.6
	coated	6.0 ± 0.6
7 days	untreated	23.4 ± 1.2
	coated	19.5 ± 0.9

The results showed that the total soluble solids (%TSS) increased during storage in both the coated and untreated bananas. The %TSS values were lower on Day 1 and gradually increased by Day 7. Differences in %TSS were also observed between the coated and untreated groups throughout the storage period.

Conclusions

The isolated fungus showed morphological characteristics typical of Fusarium spp., including white fluffy colonies that later turned pink to light purple, septate hyphae, and sickle-shaped macroconidia. Clove and sweet flag extracts were successfully prepared using 99% ethanol and produced concentrated extracts suitable for antifungal testing.

Both herbal extracts inhibited the growth of *Fusarium spp.*, and their antifungal activity increased with concentration. Clove extract at 10% showed the highest inhibition (82.59%), followed by sweet flag extract (81.11%). Chitosan also inhibited fungal growth in a concentration-dependent manner, with 3% chitosan giving the highest inhibition (67.41%).

The edible coating effectively reduced crown rot development on artificially inoculated Namwa bananas. Although its inhibitory effect gradually decreased during storage, fungal growth remained lower than in the untreated control throughout the experiment.

The coated bananas also showed lower weight loss, slower peel color changes, and lower total soluble solids (TSS) than the untreated control. These results indicate that the edible coating delayed ripening and maintained fruit quality during storage.

Overall, the edible coating containing gum arabic, chitosan, and clove extract effectively inhibited Fusarium spp., reduced crown rot disease, delayed fruit ripening, and extended the postharvest shelf life of Namwa bananas. The developed coating shows strong potential as a safe and environmentally friendly alternative to chemical fungicides for postharvest disease management.

Acknowledgments

Future studies should evaluate the effectiveness of the clove extract under different storage conditions, such as varying temperatures and relative humidity levels, to better simulate practical postharvest conditions.

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