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Effect of Moringa Extracts Against Gray Mold Disease of Strawberry After Harvest

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THE AIM of this work is to reduce incidence of strawberry fruit by gray mold and improve quality parameters through an experimental investigation utilizing inexpensive, environmentally safe of natural extracts. *Botrytis cinerea*, commonly known as gray mold, is a significant threat to global strawberry production. Its presence leads to fruit rejection due to the adverse effects on fruit quality, posing a major concern for the production. The use of chemical fungicides to control this pathogenic fungus has drawbacks, emphasizing the need for alternative solutions. Extracts from *Moringa Oleifera* leaves, known for their antifungal properties, present a potential option for addressing this challenge. Our study emphasizes the potential of *M. oleifera* leaves as a natural solution for controlling post-harvest gray mold in strawberries, along with its positive impact on various quality parameters of the fruit. We assessed the effect of Moringa leaves extracts against *Botrytis cinerea* on strawberry fruit as well as its quality parameters. The findings revealed the presence of numerous compounds in *M. oleifera* extracts obtained using different solvents, as analysed by GC/MS. The antifungal characteristics of these compounds against gray mold were illustrated and all extractions at various concentrations effectively reduced gray mold disease incidence, thereby improving disease control. Particularly, the methanol extraction exhibited the most significant effectiveness across all concentrations. There existed a direct correlation between the concentrations and its effectiveness against the disease. It is fortunate that all the treatments improved most of the quality parameters of the fruits, with particular emphasis by the methanol extract treatment.

Keywords: Strawberry; Gray mold; Quality parameters; *Botrytis cinerea.*

1. Introduction

Strawberry (*Fragaria x ananassa* Duch.) fruits are the greatest widespread berries for the reason that of their exceptional flavor, diverse and abundant phytochemical contents (Shala, *et al*. 2024; Kahramanoglu *et.al.*, 2022), It is regarded as one of Egypt's most significant cash crops for export (El-Aidy et al., 2016). strawberries are significant commercial value that are rich in bioactive compounds such tannins, anthocyanin, phenolic acid, and flavonoids. But the fruit is extremely perishable because of its rapid rates of respiration, water loss, and softening, leaving it subject to deterioration before and even after reaching customers (Hussain *et al*., 2019). Pathogen attacks, particularly by the gray mold fungus are among the most economically significant issues in strawberry storage and marketing causing large losses in both quantity and quality of the fruits. This pathogen has the ability to remain dormant during the growing process and then rapidly develop during storage, resulting in fruit deterioration and disease sporulation (Stefan *et al*., 2019). One of the worst post-harvest illnesses impacting strawberry worldwide is gray mold, which is brought on by the fungus Botrytis cinerea. The infection resulted in damages at different stages of the strawberry plant that includes the foliage, fruit, and flowers, resulting in severe economic losses for growers.

In damp conditions, the fungus can penetrate the

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strawberry fruit through damaged areas such as wounds and spread swiftly. Gray mold causes dark or grayish patches on the fruit and other plant components, as well as a mushy and watery texture and a musty odor (Staudt *et al.,* 2020). To mitigate these challenges, various strategies have been proposed, ranging from improved storage techniques to the use of chemical fungicides. Gray mold management in strawberries often entails a combination of cultural practices, such as good sanitation, pruning, and regular inspection, as well as the application of synthetic fungicides. However, long-term usage of chemical fungicides might result in the establishment of resistant pathogen strains as well as environmental pollution (Brito *et al*., 2020). Because of this, there is a growing need for environmentally benign sustainable alternatives for post-harvest disease control in strawberries to synthetic fungicides for gray mold management in strawberries.

Natural materials with antifungal properties against *Botrytis cinerea* include organic acids, essential oils and plant extracts and other plant infection has been demonstrated (Koca *et al.,* 2017). *M. Oleifera*, known as the drumstick tree, is a well-known plant whose therapeutic benefits have been used for generations, Globally MO is generally spread over Caribbean islands, Asia, Africa and the Central America Abdelazim *et.al*.,2024). Moringa leaves and seeds are highly rich in many significant nutrients for human health, such as proteins, fibre, calcium, zinc, iron, and bioactive compounds (Al-Moalem, 2022) . Moringa's potential as a natural solution for a variety of agricultural and food-related uses has recently been investigated by scientists. (Gupta and Rao., 2010). M. oleifera has active biologically chemicals like phenols, flavonoids, and alkaloids, which have antibacterial and antifungal activities. Prior research has revealed that Moringa extracts have the capacity to manage post-harvest infection in a variety of crops. (Jaiswal and Watal., 2009). Moringa seed extracts have strong antifungal efficacy against a variety of isolated fungal infections, including *Alternaria alternata, Fusarium solani*, and *Aspergillus niger* (Hoda., 2016). Similarly, Moringa leaf extracts showed a powerful antifungal impact in tomato fruits against the post-harvest fungus *Fusarium oxysporum* and *Rhizopus stolonifer* (Choudhary and Rajvanshi 2017). The antifungal effect of Moringa extracts was linked to its high amount of phenolic chemicals, which have powerful antifungal characteristics (Cruz-Ortega *et al.,* 2020). Combining Moringa extract with chitosan, a natural polymer generated from crustacean shells, dramatically reduced gray mold incidence in post-harvest strawberries. According to the findings, the chitosan-moringa combination may be a promising natural alternative in the management of post-harvest strawberry infections (Silva., 2019). Overall, many investigators indicate that Moringa extracts may provide a sustainable and natural substitute for artificial fungicides for reducing post-harvest infections in strawberries, including gray mold. But more investigation is required to determine the effectiveness and viability of employing Moringa in large-scale agricultural production. The goal of this study is to examine potential of *M. oleifera* as a natural solution for strawberry post-harvest gray mold control. The experimental outcomes will be analyzed, and the consequences for the agriculture industry will be explored.

2.Materials and Methods

2.1. Materials

Source of Moringa oleifera leaves generously provided by National Research Center, Dokki, Cairo, Egypt; Egyptian Scientific Society of Moringa (ESSM).

2.2. Extraction

2.2.1. Solvents extraction

Organic solvents, namely Water, Methanol, Methylene chloride and Petroleum ether were used for small-scale extraction. The extraction method according to (Ahmadu *et al.* 2021).

2.2.2. Gas chromatography–mass spectrometry (GC-MS) analysis

Using a direct capillary column TG–5MS (30 m x 0.25 mm x 0.25 µm film thickness), the Trace GC-TSQ mass spectrometer (Thermo Scientific, Austin, TX, USA) was used to analyze the chemical composition of the extracts of methanol, methylene chloride, and petroleum ether. The column oven temperature was first maintained at 50°C, then raised by 5°C/min to 250°C and maintained for 2 minutes. Finally, it was raised by 30°C/min to the ultimate temperature of 300°C and maintained for 2 minutes. The temperatures of the injector and MS transfer line were maintained at 270 and 260°C, respectively. A steady flow rate of 1 ml/min of helium was employed as the carrier gas. Diluted samples containing 1 µl were automatically injected using an Auto sampler AS1300 connected to a GC in split mode, with a 4-

minute solvent delay. In full scan mode, EI mass spectra were obtained at 70 eV ionization voltages covering m/z 50–650. A temperature of 200 °C was chosen for the ion source. By comparing the components' mass spectra with those from the NIST 14 mass spectral database and WILEY 09 mass spectra, the components were identified (Mamoun., 2016).

2.3. Antifungal activity of moringa leaves extracts in the laboratory

The radial growth technique approach was utilized to investigate the antifungal efficacy of moringa extracts (Asthana *et al*., 2016). The formula used to calculate the percentage of mycelial growth suppression was [(DC-DT) /DC] × 100 (Hadian *et al.,* 2019). In this formula, DC and DT represent the average diameters of the fungal colonies under treatment and control, respectively. Using a linear regression approach, the concentration of extract that inhibits the fungal mycelial development by 50% (EC50) was evaluated (Finney, 1971).

2.4. **Moringa extracts and strawberry fruit gray mold disease progress**

An infected strawberry was used to isolate the fungus *Botrytis cinerea*. Potato Dextrose Agar medium was used to cultivate the causal pathogen. Ten milliliters of sterile water were added to each plate to recover fungal conidia from cultures that were 10–14 days old. A sterile cheesecloth filter with three layers was used to filter the mycelia suspension. The concentration of the conidial suspension was adjusted to 1 x 10^6 conidia /ml after conidia were counted using a hemocytometer Strawberries (*Fragaria ananassa* cv. Aromas) were harvested at a farm located in the west of Alexandria, in the Elhamam the region. The strawberries that were chosen were all the same size, unharmed physically, and showed no signs of fungal infection. After disinfecting the fruits' surface with 70% ethanol, they were rinsed three times with distilled water. Using a sterile corkborer, three 2-mm deep and 2-mm diameter wounds were made on one side of each strawberry. The moringa extracts were sprayed alongside on strawberry fruits concentrations 5, 10 and 20 mg/ml. Control fruits were sprayed alongside distilled water. A 10 µL conidial suspension of *B. cinerea* was applied to each wound in order to inoculate the fruits. Inoculated fruits were kept in closed plastic trays to maintain an adequate relative humidity and 5°C for 10 days. Nine fruits were used in each of the four replicates for each treatment. Every day, fruits were examined closely to check for signs of decay. According to (Hayat et al., 2017), a disease rating scale was used to score diseases: 1 denoted no disease affected fruit surface, 2 represented less than 1%, 3 represented 1-5%, 4 represented 6-10%, 5 represented 11-25%, 6 represented 26-50%, and 7 represented more than 50% disease affected fruit surface .Inhibition of fungi was evaluated using disease index, DI= ((∑ (No. of row× No. of strawberry fruits in each row))/(d.f× No. of total strawberry fruits)) ×100.

2.5. Moringa leaf extracts and quality measurements of strawberry fruits

In a separate experiment, all the treatments were applied on strawberry fruits, after that, they were kept at 5°C for 10 days to observe how different treatments modified the fruits' qualitative characteristics. At the conclusion of the trial, a few factors that effect on the quality of strawberry fruits were identified.

2.5.1 Weight Loss (%)

It was computed using the original and final weight differences, and the result was given as 0% of the initial fresh weight.

2.5.2 Determination of pH

The PH of the juice was determined according to the association of official agricultural chemists' method (A.O.A.C., 1984) by the digital PH-meter G-104

2.5.3 Total soluble solids T.S.S

A digital refractometer was used to measure the total soluble solid (TSS) in the fresh fruit sap (Cox and Pearson, 1962).

2.5.4 Titratable acidity (%)

Using the following formula, total acidity as citric acid was calculated in accordance with (Sabra.,1993): % Citric acid is equal to (((V1×N×E)/V2×1000) ×100). The needed volume (measured in milliliters) of the NaOH solution is V1, and its normalcy is N.

V2 = Strawberry Filtrate Volume (in milliliters), and E = Citric Acid Equivalent Weight

2.5.5 Ascorbic acid analysis

The ascorbic acid content was determined in accordance with (Lisiewska *et al*., 2006). Using the following formula, the ascorbic acid concentration was determined as mg/ml in relation to the standard curve. mg ascorbic acid /ml juice =((L1-L2)/K) *8)/1)

where, L1=absorbance of 1ml 0.4% oxalic acid +9ml dye at 520 nmL2=absorbance of 1 ml sample +9ml dye at 520nmK= extension coefficient =0.0040712 mg-1.

2.5.6 **Determination Total amount of sugars**

Total soluble sugars will be extracted by mixing 5 ml of strawberry juice with 100 ml of 80% ethanol and shaking for 2 min. and then filtration. The picric acid method was used to determine it (Thomas and Dutcher, 1924).

2.6 Statistical analyses

All of the data will be statistically processed using an analysis of variance (SPSS 14 software package), and Duncan's test at p = 0.05 will be used to assess mean differences (Anonymous, 2005).

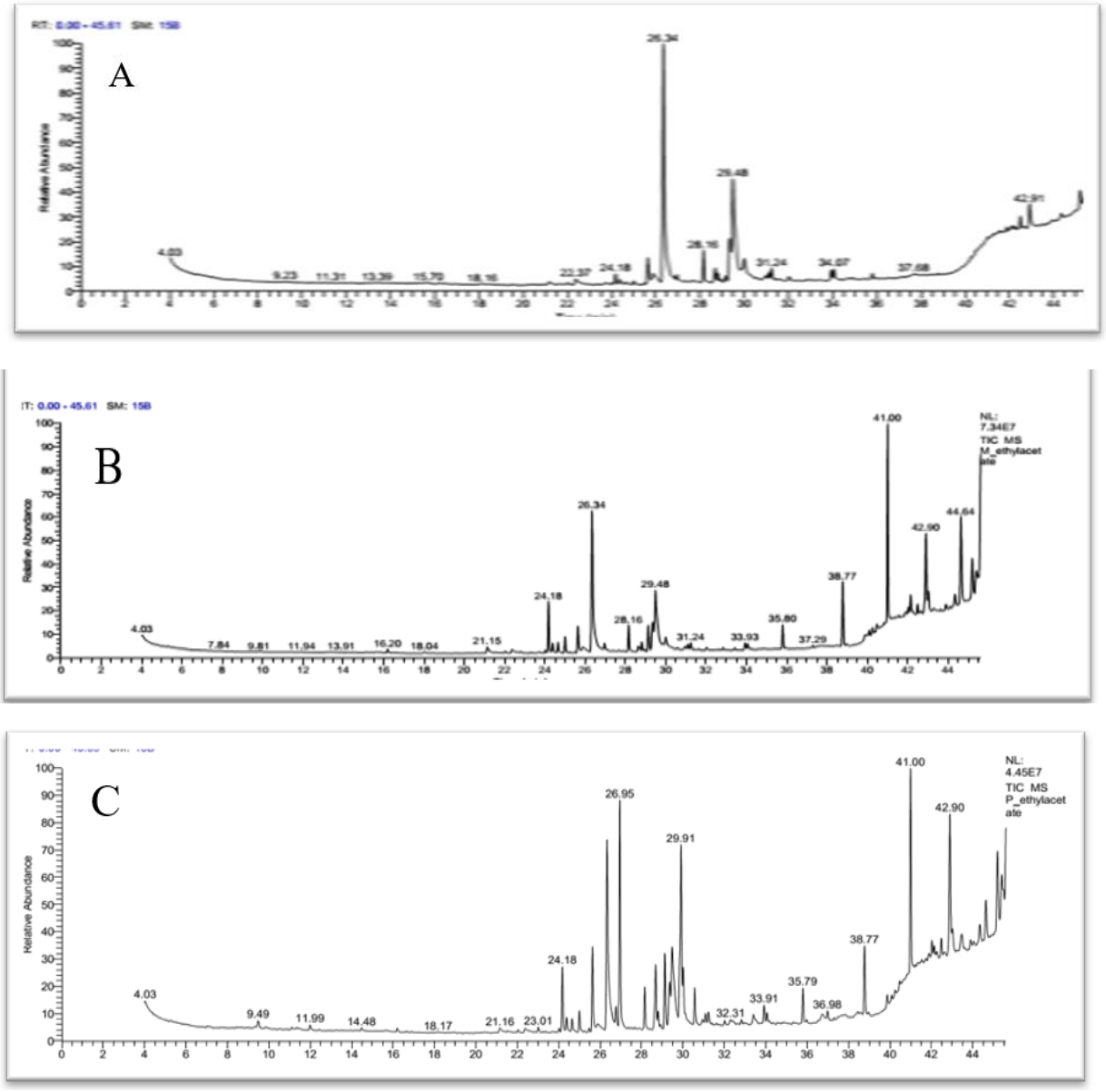

Fig. 1. Gas chromatography–mass spectrometry analysis of(A) petroleum ether extract, (B) methylene chloride extract and (C) methanol extract of moringa leaves.

3. Results and Discussion

3.1. Gas chromatography–mass spectrometry analysis for Chemical Compositions

Gas chromatography–mass spectrometry analysis of petroleum ether extract of moringa leaves obtained 14 chemical compounds (Figure (1a) and Table (1), representing n-Hexadecanoic acid (40.81%), Oleic Acid (18.76%) and Hexadecanoic acid, trimethylsilyl ester (5.99) were the major identified components in petroleumether extract. Gas chromatography–mass spectrometryanalysis of methylene chloride extract of moringa leaves evaluated 25 chemical compositions showed Figure (1b) and Table (2), representing .Pentacosane(16.88%), nHexadecanoicacid (14.57%), Hexadecanoic Octadecanal, 2-bromo (9.65%), Heptacosane (6.44%), cis-Vaccenic acid (6.44%) and

Phytol (2.77%) -were the major identified components in this solvent. Gas chromatography–mass spectrometry analysis of Methanol extract of moringa leaves raveled 39 chemical compositions showed (Figure (1c) and Table (3), The main components found in the methanol extract were Hexadecanoic acid, ethyl ester (10.19%), 9,12,15-Octadecatrienoic acid, ethyl ester, (Z,Z,Z)- (10.09%), Hexadecanoic Octadecanal, 2-bromo (9.65%), Hexadecanoic acid (9.53%), and Heptacosane (3.39%).39 chemical components were found from the crude methanol leaves extract by gas chromatography–mass spectrometry analysis. The majority of the chemicals detected in this study have also been found in other species at some point, which is in contrast to the previously published findings.We observed that the solvent used in extraction given the same chemical compositions but with different ratio. We agreed with (Safyah and Ghareeb.,2019) showed the presence of thirty-seven compounds from methanol extract of moringa includes 9,12,15-Octadecatrienoic acid, methyl ester (47.89%), Pentadecanoic acid, methyl ester (22.01%), 9,12-Octadecadienoic acid, methyl ester (10.37%), Octadecanoic acid, methyl ester (3.47%), and 1.06% of eicosanoic acid.(Jayanthi et al.,2015)reported that the methanolic extract of M. oleifera leaves contained 2-octyl-cyclopropaneoctanal, 6-octadecenoic acid,

Table 1. The petroleum ether extract of moringa leaves chemical profile.

RT	Compound Name	MW	Area (%)
24.18	17-Octadecynoic acid	280	1.71
25.63	Palmitic Acid methyl ester	270	4.35
25.63	Hexadecanoic acid, methyl ester	270	4.35
26.34	n-Hexadecanoic acid	256	40.81
28.16	HEXADECANOIC ACID,TRIMETHYLSILYL ESTER	328	5.07
28.69	9,12,15-Octadecatrienoic acid,(Z,Z,Z)-	278	2.83
28.81	trans-13-Octadecenoic acid, methylester	296	1.14
29.33	ETHYL(9Z,12Z)-9,12-OCTADECADIENO	308	5.99
29.48	Oleic Acid	282	18.76
31.24	2-HYDROXY-3-[(9E)-9-OCTADECENOYLOXY]PROPYL(9E)-9-OCTADECENOATE	620	2.02
33.9	6,9,12-OCTADECATRIENOICACID, METHYL ESTER	292	1.98
36.06	9-Octadecenoic acid (Z)-,2-hydroxy-1-(hydroxymethyl)ethyl ester	356	2.16
42.9	Propanoic acid,2-(3-acetoxy-4,4,14-trimethylandrost-8-en-17-yl)-	430	4.71
45.2	D-XYLITOL, PENTAACETATE	362	3.73

Table 2. the methylene chloride extract of Moringa leaves chemical profile.

RT	Compound Name	MW	Area (%)
24.18	24.18 2-HEXADECEN-1-OL,3,7,11,15-TETRAMETHYL-,[R-[R*,R*-(E)]	278	4.84
24.38	cis-1-Chloro-9-octadecene	286	0.85
24.65	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	296	1.05
25	Neophytadiene	296	1.66
26.34	n-Hexadecanoic acid	256	14.57
28.16	HEXADECANOIC ACID,TRIMETHYLSILYL ESTER	328	2.5
28.8	9-Octadecenoic acid, methyl ester,	296	0.81
29.13	Phytol	296	2.77
29.35	9,12-Octadecadienoic acid (Z,Z)-	280	2.49
29.48	cis-Vaccenic acid	282	6.44
29.99	HEXADECANOIC ACID,	330	0.95
35.8	2,3-DIHYDROXYPROPYL ESTER	446	2.04
38.77	Heptacosane	380	6.44
41	Pentacosane	352	16.88
42.03	9,12-OCTADECADIENOIC ACID(Z,Z)-,2,3 BIS[(TRIMETHYLSILYL)OXY]PROPYL ESTER	498	0.73
42.14	Ethanol, 2-(9-octadecenyloxy)-, (Z)-	312	2.04
42.49	3-Isopropyl-6a,10b-dimethyl-8-(2-oxo-2-phenyl-ethyl) dodecahydro-benzo[f]chromen-7-one	396	0.94
43.02	4H-1-BENZOPYRAN-4-ONE,2-(3,4-DIMETHOXYPHENYL)-3,5-DIHYDROXY-7-METHOXY	344	1.84
44.34	SILANE, TRIMETHYL[[(3á)-STIGMAST-5-EN-3-YL]OXY]-	878	1.68
44.64	OCTADECANAL, 2-BROMO-	346	9.65
45.19	STIGMAST-5-EN-3-OL, (3á,24S)	414	4.72
45.4	Cholest-5-en-3-ol, 24-propylidene-,(3á)	426	2.07
45.59	1-Hexacosene	812	0.34

Table 3. The methanol extract of moringa leaves chemical profile.

RT	Compound Name	MW	Area (%)
24.18	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	296	3
24.38	1-Hexadecanol, 2-methyl-	256	0.63
24.65	Ethanol, 2-(9-octadecenyloxy)-, (Z)-	312	0.6
25.00	9-Eicosyne	278	3.07
25.63	Hexadecanoic acid, methyl ester	270	3.98
26.33	HEXADECANOIC ACID	256	9.53
26.76	Ethyl 9-hexadecenoate	282	3.36
26.95	Hexadecanoic acid, ethyl ester	284	10.19
28.15	HEXADECANOIC ACID,TRIMETHYLSILYL ESTER	328	2.06
28.68	Linolenic Acid Methyl Ester	292	3.27
28.65	9,12,15-Octadecatrienoic acid,methyl ester, (Z,Z,Z)-	292	3.27
29.12	2-HEXADECEN-1-OL,3,7,11,15-TETRAMETHYL-,[R-[R*,R*-(E)]]-	296	3.67
29.36	13,16-Octadecadiynoic acid, methylester	290	1.68
29.48	9-Octadecenoic acid, (E)-	282	3.6
29.91	9,12,15-Octadecatrienoic acid, ethylester, (Z,Z,Z)-	306	10.09
30.01	Ethyl Oleate	310	2.211
30.57	OCTADECANOIC ACID, ETHYL ESTER	312	1.75
31.09	13-Octadecenoic acid, (E)-, TMSderivative	354	0.5
31.24	2-HYDROXY-3-[(9E)-9-OCTADECENOYLOXY]PROPYL(9E)-9-OCTADECENOATE #	620	0.63
33.14	9,10-SECOCHOLESTA-5,7,10(19)-TRIENE-3,24,25-TRIOL, (3á,5Z,7E)-	416	0.59
33.91	3-AMINO-4-[(1-BENZYL-2-METH OXY-2-OXOETHYL)AMINO]-4-OXOBUTANOIC ACID #	294	0.93
34.06	9-Octadecenoic acid (Z)-,2-hydroxy-1-(hydroxymethyl)ethyl ester	356	0.45
35.79	1,2-BENZENEDICARBOXYLIC ACID	390	1.66
36.98	Hexadecanoic acid, ethyl ester	284	0.41
38.77	Heptacosane	380	3.39
39.86	9,12-OCTADECADIENOIC ACID(Z,Z)-,2,BIS[(TRIMETHYLSILYL)OXY]PROPYL ESTER	498	0.6
40.46	9,12-OCTADECADIENOIC ACID(Z,Z)-, 2,3-BIS[(TRIMETHYLSILYL)OXY	498	0.4
40.99	Tetratetracontane	618	8.84
42.03	9,12-OCTADECADIENOIC ACID(Z,Z)-,2,3-BIS[(TRIMETHYLSILYL)OXY]PROPYL ESTER	498	0.88
42.14	2-Oleoylglycerol, 2TMS derivative	500	0.66
42.9	2,5,7,8-TETRAMETHYL-2-(4,8,12-TRIMETHYLTRIDECYL)-6-CHROMANOL.	430	7.43
43.02	DOTRIACONTANE	450	1.02
43.47	9,12,15-OCTADECATRIENOICACID,2,3-BIS[(TRIMETHYLSILYL)OXY]PROPYL ESTER, (Z,Z,Z)-	496	1.17
43.90	Loperamide	476	0.49
44.33	9-Octadecenoic acid,1,2,3-propanetriyl ester, (E,E,E)-	884	1.03
44.63	9-HEXADECENOIC ACID,9-OCTADECENYL ESTER, (Z,Z)-	504	2.19
45.19	STIGMAST-5-EN-3-OL, (3á,24S)-	414	4.55
45.5	Cholest-5-en-3-ol, 24-propylidene-,(3á)-	426	2.88

cis-vaccenic acid, and 9,12,15 octadecatrienoic acid ethyl ester. Additionally (Inbathamizhet.al., 2012), it was found that the main ingredients in the methanol extract of moringa were ethyl oleate and cis-9-hexadecenal. Furthermore, the methanolic extract of M. oleifera leaves revealed that methyl (11E)-11-octadecanoate and cisoctadecanoic acid were the main constituents. Based on prior studies (Emad El Din et al., 2016; Batista et al., 2014; Belay and Sisay, 2014 and DíazDellavalleet al., 2011) that showed Moringa oleifera's strong antifungal and antibacterial activity, the plant was chosen for this investigation

3.2. Antifungal activity of moringa leaf extracts in the laboratory

Figure (2) exhibits the mycelial growth inhibition (%) results and Table (4) shows the antifungal activity of moringa extracts against *Botrytis cinerea*, the causative agent of strawberry fruit gray mold disease.Activity of these extracts could be arranged in descending order as follow, methanol extract was the

best extract with EC_{50} (7.24mg/ml) followed by methylene chloride extract with EC_{50}(15.51mg/ml), petroleum ether extract with EC_{50} (30.06mg/ml) and the final one was water extract with EC_{50}(33.81mg/ml).The in vitro experiment demonstrated that the methanol extract exhibited much stronger antifungal activity compared to the aqueous extract when the solvent extracts were applied to the hyphal growth of B. cinerea. Methanol generally shown good extraction efficiency for – biomolecules having antifungal activity. Our results confirmed those of Ahmadu *et al*., (2021), Emad El Din *et al*., (2016), El–Mohamedy and Abdalla (2014), Gurjar *et al*., (2012), DíazDellavalle*et al*., (2011) and Das *et al.,* (2010), who noted that distinct variations in the level of biological activity were caused by the solvents' chemical characteristics. These outcomes matched the previous Banso *et al*., (1999) research. *M. oleifera* methanol crude extracts inhibited the diametric growth of *B. cinerea* isolates in *in vitro* research, confirming the antifungal effectiveness of plant.

3.3. Moringa extracts and progression of strawberry gray mold disease

Control of strawberry gray mold is problematic via the genetic diversity, *Botrytis cinerea* variety of infection and survival as conidia, mycelia and

Sclerotia. The best attitude to accomplish this fungal disease is to integrate cultural practices with the application of fungicides or/and biological and natural agents Rhouma *et al*., (2022). Table (5) demonstrated the impact of moringa plant leaf extracts, whether used as a water extract,Petroleum ether extract,methylene chloride extract and methanol extract with concentrationsof 5, 10 and 20 mg ml-1.The data demonstrated that every extraction, at every concentration, considerably inhibited the growth of gray mold disease on strawberry fruits, increasing the relative disease control in comparison to the control. The most effective one was methanol extraction with all its concentrations especially the highest one(20mg/ml) which gave a percentage of disease severity index of 19.87 (DSI) and 68.69% relative disease control (RDC) followed by methylene chloride at a concentration of20mg/ml which gave 26.17% DSI and RDC 58.76%. The effect of the petroleum ether extract was equal to the water extract, as they came in third place in terms of efficiency with RDC value of 34.38% for the petroleum ether extract and31.97% for the water extract. There was a positive significant relation between the concentration and its activity against the disease in all extracts.

Table 5: Disease severity index (DSI) and relative disease control (RDC) of moringa leaf extract at different levels on strawberries fruits postharvest B. cinerea infection.

Table 4. Moringa leaf extracts' antifungal efficacy against *Botrytis cinerea*.

Extract	EC_{50}	Confidence limit		Slope
		Lower	Upper	
Methanol	7.24	5.61	9.38	1.20
Methylene chloride	15.51	10.58	33.21	0.84
Petroleum ether	30.06	18.14	96.64	0.90
Water	33.81	19.33	136.06	0.85

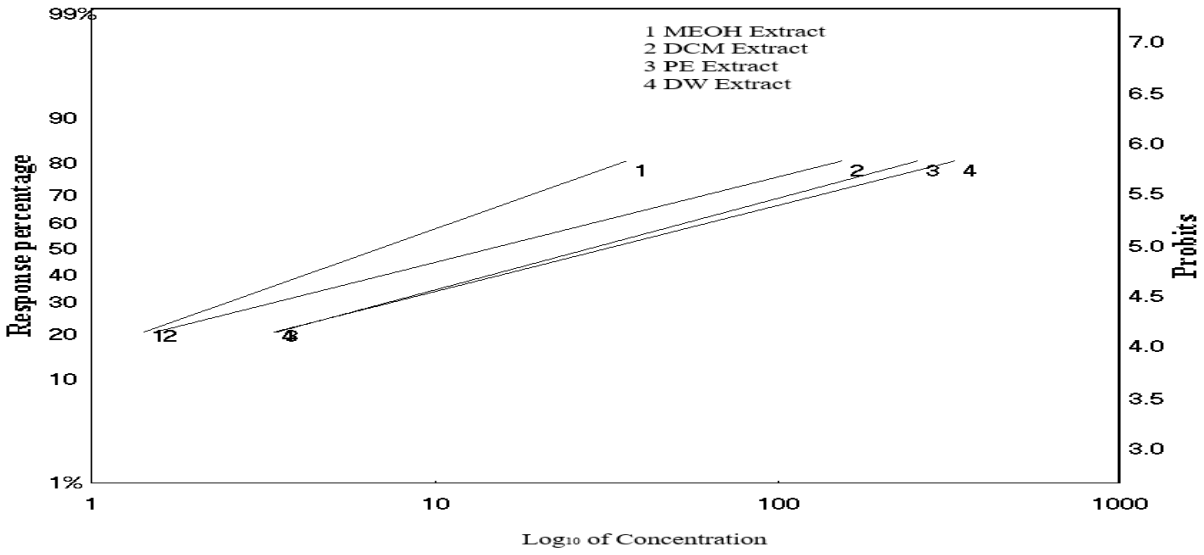

Fig. 2. Effect of moringa leaves extracts on the mycelial growth inhibition.

3.4. Moringa extracts and strawberry fruit quality parameters

Regarding the impact of the studied treatments on some strawberry fruit quality parameters, such as weight loss in fresh fruit, this is mostly due to the fruit tissue's respiration rate and moisture evaporation between it and the surrounding air storage. The weight loss percentage of the strawberry fruits during the experiment was significantly reduced in all different extracts, according to the data in Table (6). Methanol extract was the most effective treatment with 16.70% weight loss from strawberry fruits and the last one was water extract with 23.23% weight loss. We observed that moringa extracts were reported to prevent weight reduction of the fruits due to decrease gray mold illness.

According to our findings, utilizing moringa extracts reduced the percentage of weight loss in line with studies published by El Saedy and El nagger (2005), Ahmed &Yussain (2016) and Liamngee *et al.*, (2019).Table 6 displays the mean pH value for all treatments during the course of the trial, with a

Table 5. Disease severity index (DSI) and relative disease control (RDC) of moringa leave extract at different levels on strawberries fruits postharvest B. cinerea infection.

Treatments	Conc. (mg/ml)	DSI	RDC%
Methanol extract	5	34.72e ± 0.93	45.27c±1.46
	10	27.31f ±0.99	56.95b±1.57
	20	19.87g ±0.44	68.69a±0.70
Methylene chloride	5	41.41d ±1.10	34.73d±1.73
	10	33.04e ±0.64	47.92c±1.01
	20	26.17f ±1.15	58.76b±1.82
Petroleum ether	5	56.05b ±0.69	11.66f±1.09
	10	50.72c ± 0.77	20.05e±1.21
	20	41.64d ±0.94	34.38d±1.48
Water extract	5	58.05b ±1.04	8.50f±1.64
	10	52.50c ±0.77	17.24e±1.21
	20	43.16d ±0.81	31.97d±1.28
Control		63.44a ±0.76	-
		F= 240.95; df= 12; P<.0001	F=255.87;df= 12;P <.0001

computed PH ranging from 3.32 to3.66. The pH was significantly decreasing in all treatments compared to the control treatment. The pH results are also compatible with the research done by Hashemi *et al*., (2018) who applied an extract from *Moringa oleifera* leaves to increase the freshness and quality of fresh sweet orange juice.

The TSS ratio of fruit is basically a measurement of the sugar content that gives the fruits their distinctive flavor and taste. All of the treatments considerably reduced the TSS level of strawberry. Fruits treated with 20 mg/ml of moringa methanol extract had the lowest significant TSS, 7.27 TSS, when compared to the control. Reduced gas exchange leads to decreased respiration (Abdi et al., 2017, Pelayo et al., 2002, and Koyuncu et al., 2004). Degradation of carbohydrates, other material changes like acids, increased soluble pectin, and fruit corruption are other reasons for the rise in TSS (Guerreiro *et al*., 2015 and Treviño-Garza *et al*., 2015). Additionally, a correlation has been noticed between the reduction of TSS and the loss of weight. Our data in Table (6b) showed the proportion of titratable acidity (TA) was higher in all treatments than in the control treatment. The methanol extract provided the greatest acidity value, whereas the control provided the lowest. Fruit acidity (TA) plays a major role in preserving fruit quality. It is closely correlated with the amount of organic acid in fruit, and a reduction in TA content may result from fruit acid consumption during respiration (Khosroshahi *et al.*, 2007 and Ishaq *et al*., 2009).

Table 6a. Impact of moringa extracts on several strawberry fruit quality parameters.

Treatments	Conc. (mg/ml)	Weight loss (%)	pH	TSS (◦Brix)
	5	21.20ef±0.78	3.41g	8.60def±0.21
Methanol extract	10	19.30g±0.32	3.36i	7.90g±0.12
	20	16.70h±0.32	3.32j	7.27h±0.09
	5	23.87cd±0.23	3.51e	8.87de±0.12
Methylen chloride	10	20.87fg±0.39	3.46f	8.50ef±0.06
extract	20	19.24g±0.49	3.39h	7.97g±0.09
	5	26.73ab±0.46	3.53d	9.37bc±0.15
Petroleum ether	10	24.08cd±0.90	3.50e	8.63def±0.07
extract	20	22.70de±0.58	3.46f	8.40f±0.12
	5	25.93ab±0.67	3.62b	9.57ab±0.12
Water extract	10	25.53bc±0.68	3.57c	9.03cd±0.17
	20	23.23d±0.61	3.51e	8.83def±0.19
control		27.57a±0.50	3.66a	9.83a±0.20
		F=32.29p<.0001df =12	F=228.7P<0.001Df= 12	F=26.37p<.0001df= 12

Similar research has shown that treatments have a major impact on respiration, which may cause respiration to decrease or be delayed while maintaining TA content (Dhital *et.al.*, 2018). These findings correlated with those of Ahmed & Yussain (2016) and Dilawar et al., (2007).

Table 6b. Impact of moringa extracts on several strawberry fruit quality parameters.

Treatments	Conc.(mg/ml)	Titratable acidity (%)	Ripening index	Ascorbic acid (mg/100ml)
	5	0.36bcd±0.02	24.11cde±0.68	56.57b±0.018
Methanol extract	10	0.40ab±0.01	19.75gh ±0.49	56.84b±0.17
	20	0.41a±0.01	17.72h ±0.29	57.55a±0.29
	5	0.34d±0.02	26.08abcd±1.7	55.43c±0.15
Methylen chloride	10	0.39abc±0.01	21.79efg±0.28	55.60c± 0.14
extract	20	0.40ab±0.1	20.08fgh±0.60	56.46b±0.20
	5	0.36bcd±0.01	26.26abc±1.37	48.80g±0.17
Petroleum ether extract	10	0.37abcd±0.02	23.55cde±1.07	50.40f±0.49
	20	0.37abcd±0.1	22.91def±1.24	54.43d±0.18
	5	0.35cd±0.00	27.49ab ±0.26	48.73g±0.12
Water extract	10	0.36bcd ±0.01	25.33bcd±1.44	50.35f±0.25
	20	0.36bcd±0.02	24.54bcd±0.92	52.03e±0.35
control		0.34d±0.02	28.92a±1.29	46. 9h±0.15
		F=2.95 P=0.0101 Df=12	F=10.45P<<.0001 Df=12	F=248.43 P<<.0001 Df=12

The primary vitamin found in strawberries is ascorbic acid, which is also one of the foods highest concentrations of antioxidants. Table (6b) demonstrated a significant variation in the ascorbic acid-induced increase in fruit content. The highest vitamin C values were found in strawberry fruits treated with methanol extract at all concentrations, followed by treatments with methylene chloride extract, petroleum ether, and water in comparison to the control. Additionally in table (7), all treatments significantly affected on the total sugars and non-reducing sugars, with the exception of the petroleum ether extract treatment, which had a concentration of 10 mg/ml, and the treatment of methanol and methylene chloride extracts, which had the same impact at 10, 20, and 10 mg/ml. An assimilative tendency was seen in all quality criteria for the moringa extract.

Table 7. Impact of moringa extracts on total sugars, reducing sugars and non-reducing sugars strawberry fruit.

Treatments	Conc. (mg/ml)	Total sugars	Reducing sugars	Non-reducing sugars
Methanol extract	5	31.62 ±0.74	23.50 ±0.80	8.13b ±0.07
	10	32.14 ±0.65	23.80 ±0.67	8.34a ±0.02
	20	32.83 ±0.37	24.36 ±0.31	8.48a ±0.07
Methylen chloride extract	5	29.17 ±0.63	21.46 ±0.61	7.70d ±0.03
	10	30.11 ±0.90	22.08 ±0.94	8.03b ±0.05
	20	32.67 ±0.71	24.52 ±0.73	8.15b ±0.02
Petroleum ether extract	5	29.57 ±1.07	22.18 ±1.09	7.38e ±0.02
	10	30.12 ±1.11	22.46 ±1.14	7.65d ±0.05
	20	30.66 ±0.74	22.79 ±0.75	7.87c ±0.04
Water extract	5	29.17 ±1.03	21.81 ±1.04	7.36e ±0.05
	10	29.68 ±1.85	22.04 ±1.87	7.65d ±0.05
	20	29.97 ±0.67	22.31 ±0.64	7.66d ±0.04
control		28.74 ±1.27	21.63 ±1.24	7.11f ±0.08
		F=2.02 P= 0.065	F=1.09 P=0.406	F=67.42
		D F=12	Df=12	P<<.0001
				Df=12

4. Conclusion

Our findings demonstrated that several compounds were detected by GC/MS in various M. oleifera extract solvents; the availability of these compounds is dependent upon the organic solvent employed. B. cinerea is susceptible to the antifungal effects of several substances. In conclusion, M. oleifera leaves are thought to be a viable source of organic antifungal compounds that also improve quality parameters.

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تأثير مستخلصات المورينجا ضد مرض العفن الرمادي في الفراولة بعد الحصاد

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الهدف من هذا العمل هومكافحة مرض العفن الرمادي علي ثمار الفراولة وتحسين معايير الجودة من خلال دراسة تجريبية باستخدام مستخلصات طبيعية غير مكلفة وآمنة بيئيًا حيث يشكل *Botrytis cinerea*، المعروف باسم العفن الرمادي، تهديدًا كبيرًا لإنتاج الفراولة العالمي. ويؤدي وجودها إلى رفض الثمار بسبب تأثيرها السلبي على جودة الثمار مما يشكل مصدر قلق كبير للمنتجين واستخدم مبيدات الفطريات التقليدية ضد هذا المرض له عيوبه، مما يؤكد الحاجة إلى حلول بديلة.وتمثل مستخلصات المورينغا أوليفيرا، المعروفة بخصائصها المضادة للفطريات، خيارًا محتملاً لمواجهة هذا التحدي. ويؤكد هذا البحث على إمكانات المورينغا أوليفيرا كحل طبيعي للسيطرة على العفن الرمادي بعد الحصاد في الفراولة، إلى جانب تأثيرها الإيجابي على معايير جودة الثمار المختلفة. فقد تم تقييم مستخلصات أوراق المورينغا ضد *Botrytis cinerea* على ثمار الفراولة بالإضافة إلى تأثير معايير الجودة الخاصة بها. كشفت النتائج عن وجود مركبات عديدة في مستخلصات M. oleifera التي تم الحصول عليها باستخدام مذيبات مختلفة، كما تم تحليلها بواسطة GC/MS. وكانت الخصائص المضادة للفطريات لهذه المركبات ضد العفن الرمادي واضحة، وجميع عمليات الأستخلاص بتركيزات مختلفة خفضت بشكل فعال مرض العفن الرمادي في الفراولة، وبالتالي تحسين مكافحة المرض. وعلى وجه الخصوص، وقد أظهر مستخلص أوراق المورينجا باستخدام مذيب الميثانول الفعالية الأكثر أهمية في جميع التراكيز. وكان هناك ارتباط مباشر بين التراكيز وفعاليته ضد المرض. ومن الملاحظ أن جميع المعاملات حسنت معظم معايير جودة الثمار .

الكلمات المفتاحية: ثمار االفراولة، مرض العفن الرمادي، معايير الجودة، المورينجا أوليفرية.