Original Research Article

Effect of aqueous extract of *Moringa* leaves on postharvest shelf life and quality of tomato fruits inoculated with fungal pathogens in Makurdi

Abstract

The effect of aqueous extract of *Moringa* leaves on postharvest shelf life and quality of tomato fruits inoculated with fungal pathogens in Makurdi was determined. Fresh leaves of *Moringa* were collected, washed, surfaced sterilized, air dried at room temperature and grounded to powder. Tomato fruits of the Roma variety were collected at breaker stage; surface sterilized, rinsed in several changes of sterile distilled water and dipped in conidia suspensions of *Aspergillus flavus, Penicillium waksmanii, Botryodiplodia theobromae, Fusarium oxysporum* and *Colletotrichum asianum* respectively. After 24 hours, the fruits were dipped in *Moringa* leaf extract concentrations of 80g/ml and 100g/ml respectively and stored at room temperature in completely randomized design. Data collected were analyzed using Analysis of Variance and the Fishers least significant difference was used to separate means at 5% level of significance. The results revealed an increase in marketability, postharvest decay in control fruits and shelf life respectively from 1.00 to 8.40, 0.00 to 5.67 and 1.00 to 25.00 while weight decreased from 44.3 to 20.27 across all treatment concentrations. Treated tomato fruits showed significantly lower postharvest decay (0.00 – 1.02) compared to the control. Aqueous extracts of *Moringa* leaves possess antifungal potential and can increase the shelf life and maintain the quality of tomato

Keywords: Pathogens, leaf extract, *Moringa*, Quality, shelf life, tomato fruits

1. Introduction

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae and is one of the most popular crops grown widely for its edible fruits, diversified usage and nutritional value [1]. In Nigeria, tomato accounts for about 18% of daily consumption of vegetables which averages 50.6 grammes of tomato fruits consumed per person [2].

Tomato fruits are rich sources of vitamins such as A, B, C and E and minerals such as calcium, iron, phosphorus, magnesium, potassium, zinc and iron [3]. It is also rich in lycopene, an antioxidant and carotenoid that has attracted interest because of its role in preventing cancer [4].

Control of tomato fruit rot has been by application of chemicals on the fruit.

However, there is increasing concern over the use of synthetics on horticultural food crops as well as development of resistance by pathogenic organisms to synthetics. Furthermore, synthetic fungicides are expensive and in accessible to farmers who are the bulk producers of tomato fruits in Nigeria [5] hence the need for alternative low cost technologies without mammalian toxicity and negative impact on the environment.

Plant extracts and their analogues have been reported as important sources of agricultural biopesticides [6]. [7] reported that herbs, spices, leaves and other plant materials possess antifungal activity. Therefore, the objective of the study is to investigate the antifungal activity of *Moringa* leaf extract on tomato fruits during storage in a bid to extend its shelf life and maintain its quality.

2. Materials and Methods

2.1 Collection and disinfection of plant leaves

Fresh leaves of *Moringa oleifera* (Drumstick tree) were collected from different locations in Makurdi metropolis. A cutlass was used to cut branches while the leaves were harvested by handpicking. The leaves were put in clean polythene bags and taken to the laboratory. In the laboratory, the leaves of the plant were first prewashed carefully under a gentle stream of tap water for one to two minutes to remove surface dirt. This was followed by washing for thirty seconds in sterile distilled water containing 1% sodium hypochloride. The leaves were then removed and rinsed in three successions of sterile distilled water.

2.2 Preparation of leaf powders

The disinfected plant leaves were air dried on the laboratory bench for 7 - 9 days after which they were ground into fine powder first, with mortar and pestle and then with a blender. The powders of the plant were stored in a well-covered clean jar and kept in a dust free locker.

2.3 Preparation of plant extracts.

Dried and ground plant leaves were weighed for water extractions. The weighed powdered leaves of the plant species were soaked in 100mls of sterile distilled water for 1 hour after which sieving was done using a muslin cloth into a beaker.

2.4 Extract concentrations.

Concentrations of the plant species were prepared to give 80g/ml and 100g/ml respectively. Extract concentration of 80g/ml was obtained by dissolving 80g of the plant leaf powder of the plant species in 100mls of sterile distilled water in a beaker. Extract concentration of 100g/ml was obtained by dissolving 100g of the plant leaf powder of the plant species in 100mls of sterile distilled water in a beaker.

2.5 *In vivo* potential of *Moringa* leaf extract to retard postharvest decay on tomato fruits after artificial inoculation.

Semi ripe, firm and healthy tomato fruits (Roma variety), collected from the experimental farm were surfaced sterilized by dipping them in 1% sodium hypochloride solution for thirty seconds and rinsed in three changes of sterile distilled water. The fruits were then inoculated by dipping them in spore suspensions of 4×10^3 conidia / ml each of *Aspergillus flavus, Penicillium waksmanii, Botryodiplodia theobromae, Fusarium oxysporum* and *Colletotrichum waksmanii* for 1 - 2 minutes and incubated for 24 hours at room temperature. After incubation, the fruits were dipped into the aqueous extract of *Moringa* leaves at different concentrations of 80g/ml and 100g/ml. Control fruits were dipped in sterile distilled water only.

Data collected include:

i. Weight (g)

Tomato fruits were placed on a digital weighing balance and each reading was recorded throughout the storage period.

ii. Shelf Life

Shelf lives of tomato fruits were evaluated by counting the number of days tomato fruits were still acceptable for marketing

and consumption. It was decided based on appearance and spoilage of fruits.

iii. Marketability

Marketable quality was evaluated according to the scoring method used by [8] with slight modification based on a 1 – 9 rating scale. Thus;

1 – 2.49 = unsalable

2.5 - 4.49 = saleable

4.5 - 6.49 = Good

6.5 - 8.49 = Very good

8.5 – 9.00 = Excellent

The marketable attributes were determined by observing colour, firmness, surface defects and signs of mould growth as visual parameters.

iv. Postharvest decay (%) (PD)

The numbers of decaying fruits were counted on each day of storage and calculated using the formula;

$$decay = \frac{number\ of\ fruits\ decaying}{Total\ number\ of\ fruits\ in\ the\ plot} \times 100$$

3. Results

Figure 1 shows a general increase in the marketability of tomato fruits during storage from 1.00 to 8.37 and then a decrease for treated fruits while marketability of control fruits increased from 1.20 to 5.00 then decreased towards the end of storage. Figure 2 shows a general increase in the postharvest decay (PD) of tomato fruits dipped in conidia suspensions of the fungi species from 0.00 to 4.33 during storage while treated fruits had lower PD. The effect of *Moringa* leaf extract at 80g/ml on tomato fruits inoculated with organism 1 (*Aspergillus flavus)* revealed that marketability of the fruits treated with the plant leaf extracts ranged from 1.20 to 8.37 while that of the control started from 1.33 to 4.80. Statistically, there was no significant difference in marketability between the treated fruits and the controls on days 5 and 9 except on days 1, 13, 17, 21 and 25 where the treated fruits showed significantly higher marketability. Also, postharvest decay (PD) of the fruits treated with the plant extracts ranged from 0.00 to 1.00 from days 1 to 25 while that of the

control ranged from 0.00 to 4.33 from days 1 to 25 respectively. There was significant difference in PD between the treated and the control fruits where the control showed significantly higher postharvest decay from days 9 to 25 except on days 1 and 5 where no significant difference was shown as seen in Table 1.

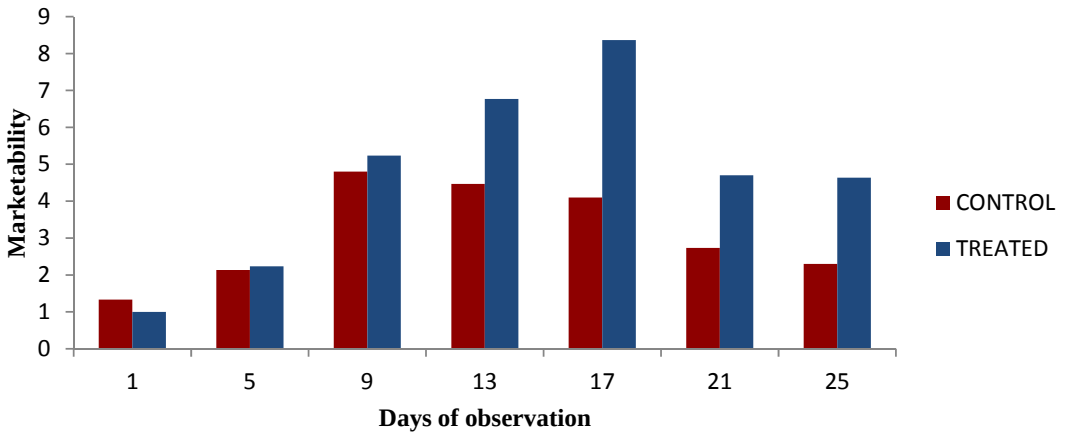

Figure 1: *In vivo* effect of *Moringa* leaf extract on marketability of tomato fruits during storage.

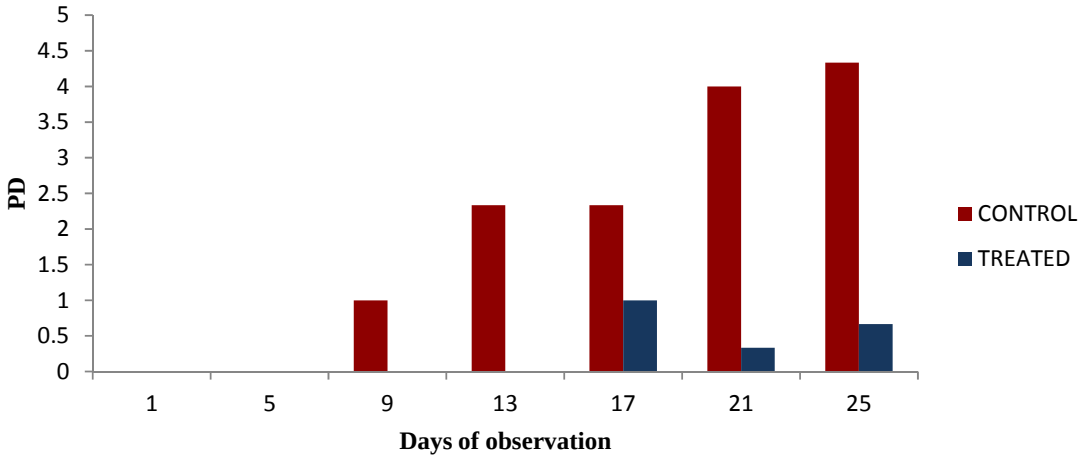

Figure 2: *In vivo* effect of *Moringa* leaf extract on postharvest decay (PD) of tomato fruits during storage.

Table 1: *In vivo* effect of *Moringa* leaf extract at 80g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 1 (*Aspergillus flavus*)

Marketability	1	5	9	13	17	21	25	(DAYS)
Control	1.33	2.13	4.80	4.47	4.10	2.73	2.30	
Treated	1.20	2.23	5.23	6.77	8.37	4.70	4.63	
F-LSD (0.05)	**0.25**	**NS**	**NS**	**0.13**	**0.86**	**0.59**	**0.29**	
PD								
Control	0.00	0.00	1.00	2.33	2.33	4.00	4.33	
Treated	0.00	0.00	0.00	0.00	1.00	0.33	0.67	
F-LSD (0.05)	**NS**	**NS**	**0.90**	**1.85**	**0.93**	**1.85**	**2.62**	

NS – No significant difference

Figure 3 shows a general decrease in the weight of tomato fruits from 33.13 to 23.83 during storage while Figure 4 shows a general increase in shelf life from 1 to 25 of tomato fruits during storage. Shelf life and weight of treated tomato fruits ranged from 1.00 to 25.00 and 25.80 to 34.20 respectively while their controls ranged from 1.00 to 21.00 and 23.83 to 33.13 respectively. There were no significant differences between the treatments and their controls for both shelf life and weight as shown in Table 2.

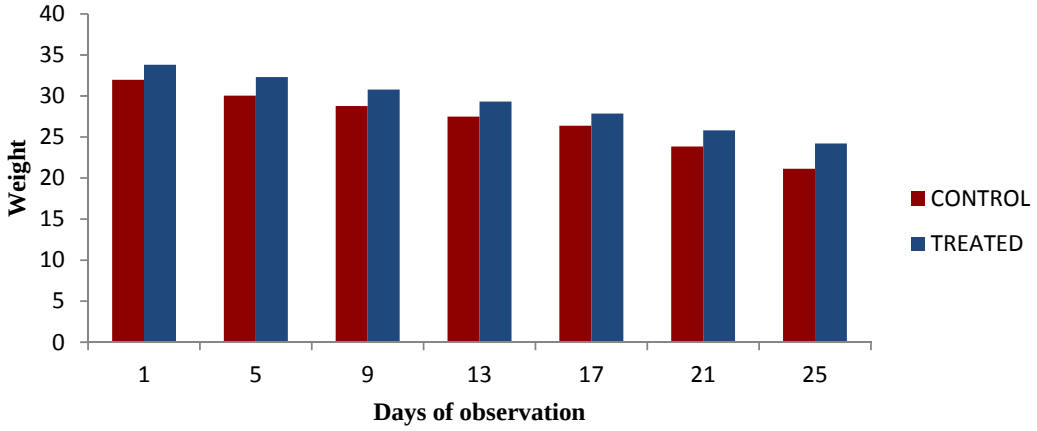

Figure 3: *In vivo* effect of *Moringa* leaf extract on weight of tomato fruits during storage

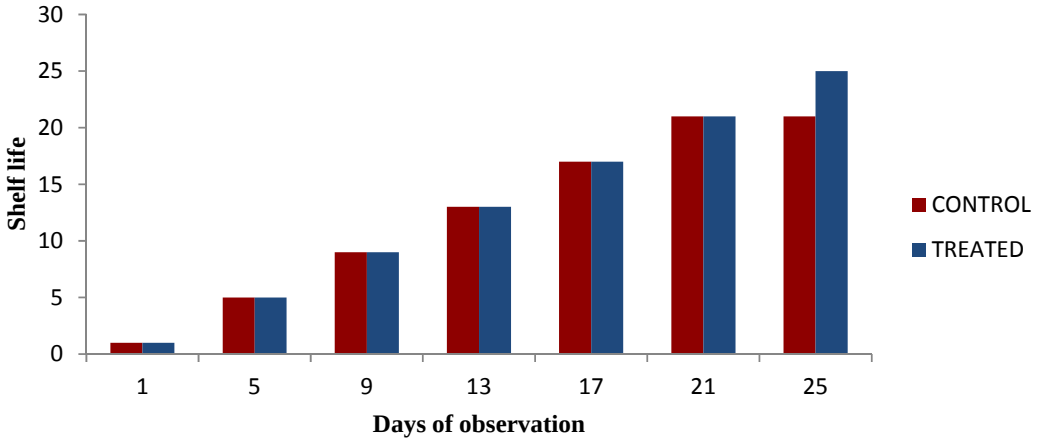

Figure 4: *In vivo* effect of *Moringa* leaf extract on shelf life of tomato fruits during storage

Table 2: *In vivo* effect of *Moringa* leaf extract at 80g/ml on shelf life and weight of tomato fruits inoculated with organism 1 (*Aspergillus flavus)*

Shelf life	**1**	**5**	**9**	**13**	**17**	**21**	**25**	**(DAYS)**
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	33.13	32.0	30.0	28.80	27.50	26.37	23.83	
Treated	34.20	33.80	32.30	30.80	29.33	27.87	25.80	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No significant difference

The effect of *Moringa* leaf extract at 100g/ml on tomato fruits inoculated with organism 1 (*Aspergillus flavus*) showed that marketability and postharvest decay ranged from 1.30 to 7.87 and 0.00 to 1.00 respectively while their controls ranged from 1.20 to 4.63 and 0.00 to 4.67 respectively. There was no significant difference in marketability between the treated and the control on days 1, 5 and 9 and days 1 and 5 for postharvest decay while days 13, 17, 21 and 25 showed significantly higher marketability for the treated tomato fruits compared to the

control and days 9, 13, 17, 21 and 25 showed significantly higher postharvest decay for the control fruits compared to the treated as shown in Table 3.

Table 3: *In vivo* effect of *Moringa* leaf extract at 100g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 1 (*Aspergillus flavus*).

Marketability	1	5	9	13	17	21	25	(DAYS)
Control	1.20	2.07	4.13	4.63	4.50	2.53	2.13	
Treated	1.30	2.10	4.63	7.17	7.87	4.83	4.80	
F-LSD (0.05)	**NS**	**NS**	**NS**	**1.33**	**0.90**	**0.93**	**0.87**	
PD								
Control	0.00	0.00	1.00	2.33	3.33	4.67	4.33	
Treated	0.00	0.00	0.00	0.00	1.00	0.33	0.67	
F-LSD (0.05)	**NS**	**NS**	**0.92**	**0.93**	**0.93**	**1.31**	**2.62**	

NS – No Significant difference

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Shelf life and weight of treated tomato fruits ranged from 1.00 to 25.00 and 22.03 to 32.40 respectively while their controls ranged from 1.00 to 21.00 and 22.43 to 31.50 respectively. There was no significant difference between the treated and controls for both shelf life and weight on all the storage days as shown in Table 4.

Table 4: *In vivo* effect of *Moringa* leaf extract at 100g/ml on shelf life and weight of tomato fruits inoculated with organism 1 (*Aspergillus flavus)*

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	31.50	30.30	28.80	27.63	26.53	24.77	22.43	
Treated	32.40	30.90	29.33	27.90	26.43	24.53	22.03	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No Significant difference

The effect of *Moringa* treatment at 80g/ml on tomato fruits inoculated with organism 2 (*Penicillium waksmanii*) showed that marketability and postharvest decay (PD) of the fruits treated with the plant leaf extract ranged from 1.37 to 8.20 and 0.00 to 1.00 respectively while their controls ranged from 1.17 to 5.30 and 0.00 to 4.67 respectively. For marketability, there was no significant difference between the treated and the control on days 1, 5, 9 and 13 while days 17, 21 and 25 showed significantly higher marketability of the treated fruits compared to the control. For PD, there was no significant difference between the treated and control on days 1 and 5 while days 9, 13, 17, 21 and 25 reflected significantly higher postharvest decay in the control fruits compared to the treated as shown in Table 5.

Table 5: *In vivo* effect of *Moringa* leaf extract at 80g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 2 (*Penicillium waksmanii)*

Marketability	**1**	**5**	**9**	**13**	**17**	**21**	**25**	**(DAYS)**
Control	1.17	2.27	5.30	5.30	4.41	2.83	2.33	
Treated	1.37	2.10	5.40	6.77	8.20	4.70	4.67	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**0.33**	**0.63**	**0.38**	
PD								
Control	0.00	0.00	1.00	2.33	2.67	4.67	4.33	
Treated	0.00	0.00	0.00	0.00	1.00	1.00	1.00	
F-LSD (0.05)	**NS**	**NS**	**0.92**	**1.85**	**0.95**	**0.93**	**0.93**	

NS – No significant difference

Shelf life and weight of treated tomato fruits ranged from 1.00 to 25.00 and 19.63 to 28.80 respectively while their controls ranged from 1.00 to 21.00 and 21.83 to 31.50 respectively. There were no significant differences between the treatments and controls for both shelf life and weight as shown in Table 6.

Table 6: *In vivo* effect of *Moringa* leaf extract at 80g/ml on shelf life and weight of tomato fruits inoculated with organism 2 (*Penicillium waksmanii)*

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	31.50	29.70	28.57	27.87	25.70	23.7	21.83	
Treated	28.80	27.47	26.30	25.37	23.27	21.43	19.63	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No Significant difference

The effect of *Moringa* leaf extract at 100g/ml on fruits inoculated with organism 2 (*Penicillium waksmanii*) revealed that marketability and postharvest decay (PD) ranged from 1.07 to 7.80 and 0.00 to 1.00 respectively while their controls ranged from 1.33 to 5.17 and 0.00 to 4.67 respectively. For marketability, there was no significant difference between the treated and the control on days 5 and 9 while days 13, 17, 21 and 25 showed significantly higher marketability in treated fruits. For PD, there was no significant difference between the treated and control on days 1 and 5 while days 9, 13, 17, 21, and 25 showed significantly higher postharvest decay in control fruits as shown in Table 7.

Table 7: *In vivo* effect of *Moringa* leaf extract at 100g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 2 (*Penicillium waksmanii)*

Marketability	1	5	9	13	17	21	25	(DAYS)
Control	1.33	2.23	4.50	5.17	4.63	2.60	2.13	
Treated	1.07	2.13	4.70	7.50	7.80	3.87	4.50	
F-LSD (0.05)	**0.26**	**NS**	**NS**	**1.46**	**1.88**	**0.13**	**0.25**	
PD								
Control	0.00	0.00	1.00	2.33	3.33	4.67	3.67	
Treated	0.00	0.00	0.00	0.00	0.67	0.67	1.00	
F-LSD (0.05)	**NS**	**NS**	**0.92**	**0.93**	**1.39**	**1.31**	**2.45**	

NS – No Significant difference

Shelf life and weight of the treated fruits ranged from 1.00 to 25.00 and 48.40 to 61.20 respectively while their controls ranged from 1.00 to 21.00 and 34.50 to 59.40 respectively. There were no significant differences between the treated and the control for both shelf life and weight on all the storage days as shown on Table 8.

Table 8: *In vivo* effect of *Moringa* leaf extract at 100g/ml on shelf life and weight of tomato fruits inoculated with organism 2 (*Penicillium waksmanii)*

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	59.40	57.50	55.60	53.30	51.20	49.40	34.50	
Treated	61.20	59.50	57.60	55.50	52.20	51.30	48.40	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No Significant difference

The effect of *Moringa* leaf extract at 80g/ml on tomato fruits inoculated with organism 3 (*Botryodiplodia theobromae*) showed that marketability and PD ranged from 1.47 to 7.90 and 0.00 to 1.00 respectively while the controls ranged from 1.30 to 5.37 and 0.00 to 5.00 respectively. For marketability, there was no significant difference between the treated and control on days 1, 5 and 9 but significantly higher marketability was observed on days 13, 17, 21 and 25. For PD, there was no significant difference between the treated and control on days 1 and 5 while days 9, 13, 17, 21 and 25 showed significantly higher postharvest decay in control fruits as shown in Table 9.

Table 9: *In vivo* effect of *Moringa* leaf extract at 80g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 3 (*Botryodiplodia theobromae*)

Marketability	**1**	**5**	**9**	**13**	**17**	**21**	**25**	**(DAYS)**
Control	1.30	2.23	5.37	5.30	4.13	2.60	2.17	
Treated	1.47	2.27	5.17	7.43	7.90	4.83	4.80	
F-LSD (0.05)	**NS**	**NS**	**NS**	**2.14**	**1.04**	**0.94**	**0.90**	
PD								
Control	0.00	0.00	1.00	2.67	2.33	5.00	3.33	
Treated	0.00	0.00	0.00	0.00	1.00	0.67	0.33	
F-LSD (0.05)	**NS**	**NS**	**0.92**	**0.93**	**0.95**	**1.85**	**2.62**	

NS – No Significant difference

Shelf life and weight of the treated tomato fruits started from 1.00 to 25.00 and 27.00 to 38.60 respectively while their controls ranged from 1.00 to 21.00 and 24.60 to 36.20 respectively. For both shelf life and weight, there were no significant differences between the treated and controls on all the storage days as shown in Table 10.

Table 10: *In vivo* effect of *Moringa* leaf extract at 80g/ml on shelf life and weight of tomato fruits inoculated with organism 3 (*Botryodiplodia theobromae*).

Shelf life	**1**	**5**	**9**	**13**	**17**	**21**	**25**	**(DAYS)**
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	36.20	34.40	32.60	31.20	29.10	27.30	24.60	
Treated	38.60	37.00	35.00	33.40	31.20	29.20	27.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No Significant difference

The retarding effect of *Moringa* leaf extract at 100g/ml on fruits previously dipped in conidia suspensions of organism 3 (*Botryodiplodia theobromae*) showed that marketing and PD ranged from 1.33 to 8.37 and 0.00 to 1.00 respectively while their controls started from 1.07 to 5.27 and 0.00 to 4.33 respectively. The treated tomato fruits showed significantly higher marketability compared to the control on days 13 to 25 while days 1 to 9 showed no significant differences in marketability. For postharvest decay, treated tomato fruits showed significantly lower postharvest decay compared to the controls on days 9 to 25 while days 1 to 5 showed no significant difference between the treated and the control in postharvest decay as shown on Table 11.

Table 11: *In vivo* effect of *Moringa* leaf extract at 100g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 3 (*Botryodiplodia theobromae*)

Marketability	1	5	9	13	17	21	25	(DAYS)
Control	1.07	2.17	4.93	5.27	4.47	2.60	2.17	
Treated	1.33	2.20	5.40	7.90	8.37	4.53	4.50	
F-LSD (0.05)	**NS**	**NS**	**NS**	**1.95**	**0.26**	**0.20**	**0.25**	
PD								
Control	0.00	0.00	1.00	2.33	2.67	4.33	4.00	
Treated	0.00	0.00	0.00	0.00	0.67	1.00	0.33	
F-LSD (0.05)	**NS**	**NS**	**0.83**	**0.95**	**1.31**	**0.93**	**0.91**	

NS – No Significant difference

Shelf life and weight of the treated tomato fruits began from 1.00 to 25.00 and 25.90 to 37.60 respectively while their controls ranged from 1.00 to 21.00 and 24.93 to 33.60 respectively as shown on Table 12. Both treated and control tomato fruits showed no significant difference in shelf life and weight on all the days of storage.

Table 12: *In vivo* effect of *Moringa* leaf extract at 100g/ml on shelf life and weight of tomato fruits inoculated with organism 3 (*Botryodiplodia theobromae*)

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	33.60	32.60	31.10	29.50	28.00	26.63	24.93	
Treated	37.60	35.30	33.80	31.70	29.83	27.80	25.90	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No Significant difference

The effect of *Moringa* leaf extract at 80g/ml on tomato fruits inoculated with organism 4 (*Fusarium oxysporum*) showed that marketability and PD ranged from 1.23 to 8.13 and 0.00 to 1.00 respectively while their controls ranged from 1.43 to 5.80 and 0.00 to 4.33 respectively. Treated tomato fruits showed no significant difference in marketability compared to the control on days 1, 5 and 9 while significant higher marketability in treated fruits compared to the control were observed on days 13, 17, 21 and 25. For postharvest decay, treated tomato fruits showed significantly lower postharvest decay compared to the control on days 9, 13, 17, 21 and 25, but days 1 and 5 showed no significant differences as shown in Table 13.

Table 13: *In vivo* effect of *Moringa* leaf extract at 80g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 4 (*Fusarium oxysporum*)

Marketability	**1**	**5**	**9**	**13**	**17**	**21**	**25**	**(DAYS)**
Control	1.43	2.23	5.80	4.57	4.30	2.53	2.00	
Treated	1.23	2.13	5.80	7.67	8.13	4.67	4.63	
F-LSD (0.05)	**NS**	**NS**	**NS**	**1.30**	**0.98**	**0.47**	**0.40**	
PD								
Control	0.00	0.00	1.00	2.33	2.33	4.33	4.00	
Treated	0.00	0.00	0.00	0.00	1.00	0.67	1.00	
F-LSD (0.05)	**NS**	**NS**	**0.91**	**1.85**	**0.93**	**1.31**	**1.94**	

NS – No Significant difference

Shelf life and weight of the treated fruits ranged from 1.00 to 25.00 and 23.16 to 33.80 respectively while their controls ranged from 1.00 to 21.00 and 22.67 to 32.90 respectively as shown in Table 14. There was no significant difference between the treated and the control for shelf life and weight on all the days of storage.

Table 14: *In vivo* effect of *Moringa* leaf extract at 80g/ml on shelf life and weight of tomato fruits inoculated with organism 4 (*Fusarium oxysporum*).

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	32.90	31.07	29.87	28.77	26.63	24.73	22.67	
Treated	33.80	33.83	30.67	29.33	27.23	25.33	23.16	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS - No Significant difference

The inhibitory effect of *Moringa* leaf extract at 100g/ml on tomato fruits previously dipped in conidia suspensions of organism 4 (*Fusarium oxysporum*) showed that marketability and PD ranged from 1.33 to 8.30 and 0.00 to 1.00 respectively while their controls ranged from 1.23 to 5.17 and 0.00 to 5.00 respectively. Treated tomato fruits showed no significant difference in marketability compared to the control on days 1, 5 and 9 while on days 13, 17, 21 and 25, the treated fruits reflected significantly higher marketability. For postharvest decay, the treated tomato fruits reflected no significant differences on days 1, 5 and 9 while on days 13, 17, 21, and 25 treated fruits showed significantly lower postharvest decay compared to the control as shown on Table 15.

Table 15: *In vivo* effect of *Moringa* leaf extract at 100g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 4 (*Fusarium oxysporum*)

Marketability	1	5	9	13	17	21	25	(DAYS)
Control	1.23	2.33	4.93	5.17	4.43	2.57	2.00	
Treated	1.33	2.13	5.77	8.23	8.30	4.63	4.53	
F-LSD (0.05)	**NS**	**NS**	**NS**	**1.75**	**0.43**	**0.13**	**0.19**	
PD								
Control	0.00	0.00	1.00	2.00	2.67	5.00	4.33	
Treated	0.00	0.00	0.00	0.00	1.00	0.33	0.00	
F-LSD (0.05)	**NS**	**NS**	**0.92**	**1.60**	**0.95**	**0.93**	**2.45**	

NS – No Significant difference

Shelf life and weight of tomato fruits treated with *Moringa* leaf extract previously dipped in conidia suspensions of organism 4 (*Fusarium oxysporum*) ranged from 1.00 to 25.00 and 30.20 to 43 .20 respectively while their controls ranged from 1.00 to 21.00 and 31.20 to 44.00 respectively. There were no significant differences between the treated and the controls for shelf life and weight on all the days of storage as shown in Table 16.

Table 16: *In vivo* effect of *Moringa* leaf extract at 100g/ml on shelf life and weight of tomato fruits inoculated with organism 4 (*Fusarium oxysporum*)

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	44.00	42.30	40.20	38.00	35.70	33.80	31.20	
Treated	43.20	41.20	39.00	36.90	34.90	32.70	30.20	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No significant difference

The effect of *Moringa* leaf extract at 80g/ml on tomato fruits inoculated with organism 5 (*Colletotrichum asianum*) showed that marketability and PD ranged from 1.50 to 8.50 and 0.00 to 1.33 respectively while their controls ranged from 1.17 to 5.43 and 0.00 to 5.00 respectively. There were no significant

differences between the treated and the control for marketability on days 1, 5 and 9 while on days 13 to 25, the treated reflected significantly higher marketability compared to the control. For postharvest decay, treated tomato fruits showed significantly lower postharvest decay compared to the control on days 9 to 25 while no significant differences were observed on days 1 to 9 as shown in Table 17.

Table 17: *In vivo* effect of *Moringa* leaf extract at 80g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 5 (*Colletotrichum asianum*).

Marketability	**1**	**5**	**9**	**13**	**17**	**21**	**25**	**(DAYS)**
Control	1.17	2.27	5.43	4.60	4.30	2.57	2.10	
Treated	1.50	2.30	6.03	7.77	8.50	5.40	4.70	
F-LSD (0.05)	**NS**	**NS**	**NS**	**0.90**	**0.45**	**0.33**	**0.62**	
PD								
Control	0.00	0.00	2.00	2.00	4.00	5.00	3.33	
Treated	0.00	0.00	0.00	0.00	1.00	1.00	1.33	
F-LSD (0.05)	**NS**	**NS**	**1.03**	**1.03**	**1.60**	**1.83**	**1.21**	

NS – No Significant difference

Shelf life and weight of the treated fruits ranged from 1.00 to 25.00 and 22.67 to 33.60 respectively while their controls ranged from 1.00 to 21.00 and 19.80 to 30.10 respectively as shown in Table 18. There were no significant differences between the treated and the control for both shelf life and weight on all the days of storage.

Table 18: *In vivo* effect of *Moringa* leaf extract at 80g/ml on shelf life and weight of tomato fruits inoculated with organism 5 (*Colletotrichum asianum*).

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	30.10	28.50	27.57	26.53	24.47	22.37	19.80	
Treated	33.60	31.80	30.23	29.20	27.10	25.23	22.67	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No Significant difference

The retarding effect of *Moringa* leaf extract at 100g/ml on organism 5 (*Colletotrichum asianum*) inoculated on tomato fruits showed that marketability and PD ranged from 1.40 to 8.33 and 0.00 to 1.00 respectively while their controls ranged from 1.50 to 4.73 and 0.00 to 4.33 respectively. For marketability, there was no significant difference between the treated and the control on day 1 whereas, significant higher marketability by the treated compared to the control was observed on days 5, 9, 13, 17, 21 and 25 respectively. For postharvest decay, treated tomato fruits showed significantly lower postharvest decay compared to the control on days 9 to 25, but no significant differences were observed on days 1 to 5 as shown in Table 19.

Table 19: *In vivo* effect of *Moringa* leaf extract at 100g/ml on marketability and postharvest decay (PD) of tomato fruits inoculated with organism 5 (*Colletotrichum asianum*).

Marketability	1	5	9	13	17	21	25	(DAYS)
Control	1.50	2.10	4.73	4.57	4.50	2.63	1.97	
Treated	1.40	2.33	5.77	7.67	8.33	5.60	4.53	
F-LSD (0.05)	**NS**	**0.19**	**1.01**	**1.56**	**0.40**	**0.19**	**0.21**	
PD								
Control	0.00	0.00	1.67	3.33	4.33	4.33	2.67	
Treated	0.00	0.00	0.00	0.00	1.00	1.00	1.00	
F-LSD (0.05)	**NS**	**NS**	**0.93**	**2.45**	**0.93**	**1.85**	**0.91**	

NS –No Significant difference

Shelf life and weight of the tomato fruits treated with *Moringa* leaf extract ranged from 1.00 to 25.00 and 22.60 to 33.30 respectively while their controls ranged from 1.00 to 21.00 and 22.10 to 33.00 respectively. There was no significant difference between the treated and the control for shelf life and weight on all the days of storage as shown in Table 20.

Table 20: *In vivo* effect of *Moringa* leaf extract at 100g/ml on shelf life and weight of tomato fruits inoculated with organism 5 (*Colletotrichum asianum).*

Shelf life	1	5	9	13	17	21	25	(DAYS)
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
Treated	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Weight								
Control	33.00	31.40	30.50	29.17	27.30	25.30	22.10	
Treated	33.30	31.70	30.20	28.83	26.93	25.17	22.60	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No Significant difference

4. Discussion

There was significant reduction in disease development/ postharvest decay due to the dipping of the fruits in aqueous extracts of the selected plant species. Higher postharvest decay was recorded on the untreated fruits (control). This was due to the fact that the leaf extract possess phytochemicals such as tannins, alkaloids, flavonoids which are inhibitory to most fungi pathogens. Similar findings were reported by [9] who stated that chitosan could effectively inhibit postharvest disease of fruits by direct inhibition of spores' germination, germ tube elongation and mycelia growth of phytopathogens as well indirect inducement of defence-related enzymes. Also, [10] reported the use of Neem and *Moringa* seed extracts against potato wet rot caused by *R. stolonifer*.

Dipping tomato fruits in aqueous extracts of the selected plant species showed a significant difference in their potential to maintain fruit marketability. Untreated fruits (control) were unmarketable while the highest marketable fruits were obtained from fruits treated with aqueous plant leaf extracts of the plant species. This might be because the plant leaf extracts checked the growth of microbes that were responsible for rotting and reduced metabolic rate of the fruits, which caused loss of weight through respiration [11], [12].

The treatment of tomato fruits with aqueous leaf extracts of plant species previously inoculated with conidia suspensions of fungal isolates was observed to be effective in extending their shelf life during storage compared to the untreated (control). This might be because of the antimicrobial components (alkaloids, tannins, flavonoids and saponins) reported to be present in the plant tissues (roots, leaf, stem and bark) [13], [14]. [15] reported on the preservative effect of aqueous suspension of *P. biglobosa* pods and leaves of *Guera senegalensis* on tomato fruits and oranges in storage.

During the study, the weight of the tomato fruits treated with the plant leaf extracts as well as the untreated fruits (control) decreased during the storage period. However, significantly lower weight loss was observed in the tomato fruits dipped in the extract of the plant species than the untreated (control) fruits. The *Moringa* leaf extract was able to form a coating on the tomato fruit which reduced the rate of respiration in the fruit and therefore lowered the weight loss because an increase in respiration results in an increase in metabolic rate and higher weight loss due to the expiration of moisture from the fruit. Similar results were reported by [16] who observed that a combination of Neem leaf extract at 20% plus UV radiation exposure for 10 minutes plus rice starch 6% proved to be the most appropriate treatment in minimizing the reduction of juice contents and fruit rotting.

5. Conclusion

The results of the study have established that aqueous extracts of *Moringa* leaves possess antifungal potential and can increase the shelf life and maintain the quality of tomato fruits during storage. This is an important step in developing plant based biopesticides as ideal treatments for future plant disease management programmes.

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