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In Vitro Efficacy of Aqueous Turmeric (Curcuma longa L.) Extract on Radial Growth of Fungi Causing Postharvest Decay of Mango (Mangifera indica L.) Fruits During Storage in Makurdi, Benue State.z

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Abstract

Mango (Mangifera indica L.) is a vital fruit crop that contributes significantly to food security and income generation worldwide. However, it is highly susceptible to fungal infections during postharvest storage, resulting in spoilage and losses. This study assessed the in vitro effectiveness of aqueous turmeric (Curcuma longa L.) powder extract in controlling fungal pathogens responsible for postharvest decay of mango fruits. Mango fruits were sourced from farms in Gboko and Ushongo Local Government Areas of Benue State, Nigeria. After harvesting, fruits were washed, air-dried, and stored for 15 days. Those showing decay symptoms were collected and taken to the Botany Laboratory at Benue State University for fungal isolation. Decayed portions were sterilized and cultured on Potato Dextrose Agar (PDA), and pure cultures of isolated fungi were used for pathogenicity tests on healthy mangoes. Three concentrations of turmeric extract (0%, 10%, and 25% w/v) were tested in vitro against Mucor sp., Alternaria sp., and Colletotrichum sp. The fungi were cultured on PDA mixed with the different extract concentrations and incubated for seven days. Results showed that Colletotrichum sp. caused the most rot (10.46 cm^2), followed by Alternaria sp. (9.60 cm^2) and Mucor sp. (8.33 cm^2), with no decay in uninoculated controls. Fungal radial growth was significantly inhibited by turmeric extract, with the greatest suppression observed at 25% concentration. For instance, Mucor sp. showed reduced growth from 4.07 cm (0% extract) to 1.15 cm (25% extract) by day 7. Similar inhibitory trends were recorded for the other fungi. Phytochemical analysis of the turmeric extract confirmed the presence of active compounds including saponins, tannins, terpenoids, steroids, flavonoids, alkaloids, phenols, and hydrogen cyanide. The study concludes that turmeric extract is a promising, natural alternative to chemical fungicides and recommends its formulation for broader agricultural use.

Keywords: Mango fruits; Tumeric extract; Fungi; Incidence; Radial growth; Phytochemical analysis.

1.0 Introduction

Mango (*Mangifera indica*) belongs to the fruit family *Anacardiaceae* and is popularly known as "The king of fruits". Mango is one of the most popular fruits grown and consumed extensively throughout the tropical and subtropical region of the world. With a total production of 57.87 million metric tons, mango ranks third among the tropical fruits grown throughout the world (FAO, 2020). Owing to its unique fragrance, delicious taste and high nutritive value, the level of demand for mango fruits increased relatively more than other fruits. Mango contains significant amount of carbohydrates, provitamin A, vitamin C and soluble sugar (Khan and Rahim, 2018). Nigeria is one among the highest world ranking producers of mango however, the main mango producing states in the country include Benue, Jigawa, Plateau, Yobe, kebbi, Niger, Kaduna, Kano, Bauchi, Sokoto, Adamawa and Taraba (Singh *et al.,* 2013). Mango production can serve as a source of food and income for most producers, consumers and traders in most developing countries of the world like Nigeria.

Fungi are the most important and prevalent pathogens, infecting a wide range of fruits and causing destructive and economically important losses of the fruits during post-harvest operations like transportation, physical handling and storage (Onu *et al.,* 2019). This high (30-50%) wastage of fruits is due to the high perishable nature and climacteric pattern of respiration (Islam *et al.,* 2013). In addition to natural deterioration, various post-harvest disease infections also play a major role in post-harvest losses of fruits. These diseases cause rapid degradation and faster decay of fruits decreasing the quality and postharvest life of fruits. Among various diseases *anthracnose*, stem end rot and *alternariose* are the major ones that infect mango fruits (Haggag, 2010).

Over the years, various fungicides like *mancozeb, benomyl, carbendazim, thiabendazol*, etc. have gained popularity among growers to control the post-harvest diseases of mango and to enhance the storage life of fruits (Lee *et al.,*2009). However, the use of these pesticides poses serious health hazards and leads to environmental contamination (Okinbo and Osuinde, 2003). In addition, due to their frequent application, there is a possibility of development of resistance in pathogen populations (Kumar *et al*., 2007). With growing health consciousness among people and increasing consumer demand for pesticide residue free agricultural commodities (Serrano *et al*., 2005) it is therefore important to find better alternatives that are cost effective, non-toxic and ecofriendly with low residual action to prevent disease infections and maintain post-harvest qualities of mango fruits. The necessity of developing eco-friendly post-harvest treatment methods as alternative to hazardous chemicals has become scientists' priority worldwide over the years (Phongpaichit *et al*., 2001). According to kumar *et al*. (2007), natural plant extracts from higher plants that are non-hazardous to both human health and environment are better alternatives to chemicals for controlling post-harvest diseases of mango. The botanical extracts can provide an excellent opportunity to avoid or replace the use of harmful chemicals in postharvest treatment of fruits for controlling various diseases as these extracts have been found to possess several antimicrobial properties. Moreover, plant extracts have the ability to decompose rapidly and do not cause any negative hazards to the environment unlike chemical pesticides (Fokialakis *et al*., 2006). So, the present study seeks to evaluate the *in vitro* efficacy of

aqueous turmeric extract on radial growth of fungi isolated from mango (*Mangifera indica*) fruits and identify the phytochemical constituents present in the turmeric extract.

2.0 Materials and Methods

2.1 Experimental Location

The experiment was conducted at the Biological Sciences Laboratory, Benue State University Makurdi, Benue State, Nigeria which is located in North central Nigeria along the Benue river, on latitude 07°73'N and longitude 08°52'E. It is situated at elevation 98 meters above sea level within the Benue trough, at the lower Benue valley and found in the Guinea Savannah region. The research was carried out between May and October, 2023..

2.2 Collection of Samples

Freshly harvested matured mango varieties (Mabrouka and Julie) were harvested at harvest maturity. Fruits with uniform size, good quality and free from any injury or disease were acquired directly from a commercial farmer's field at Gboko, and Ushongo local Governments, all of Benue State. The mango samples were transported immediately to the laboratory where they were sorted and graded. Tumeric (*Curcuma longa* L.) was harvested from turmeric farms around, Makurdi metropolis, Benue State.

2.3 Preparation of Experimental Materials

2.3.1 Preparation of mango fruits for storage

Mature, wholesome and healthy varieties of mangoes (Mabrouka and Julie) of uniform sizes were selected for the experiment. The selected mangoes were washed under running tap water and allowed to dry at room temperature so as to get rid of surface contaminants and opportunistic microbes (Bdliya and Dahiru, 2006). The mango fruits were arranged on laboratory desk and stored at room temperature for a period of fifteen (15) days.

2.3.2 Preparation and concentration of turmeric extracts

Turmeric rhizomes were subjected to washing under running water for about 2 minutes in order to remove surface dirt and particles then surface sterilized in sterile distilled water containing 1% sodium hypochlorite (NaOCl). The rhizomes were dried separately on a laboratory bench for 7 days. Thereafter, the rhizomes were grounded in a coarse mill and finally into a powder with a Moulinex electric blender to obtain turmeric powder. The plant extract concentrations were prepared by following the procedure highlighted by Ekefan *et al.* (2018) with slight modifications. In this method, extracts were obtained by weighing 10g and 25g of the turmeric powder on an electronic weighing balance. For extract concentration, the weighed 10g turmeric powder was dissolved in 100ml of sterile distilled water separately in a beaker and the mixture was stirred and left for 3 hours and subsequently filtered using sieve cloth to obtain 10%w/v filtrate of turmeric concentration. Similar procedure was employed to obtain extract concentration of 25% w/v of turmeric.

2.4 Isolation, Identification and Pathogenicity of Fungi Pathogens Causing Decay of Mango Fruits during Storage

2.4.1 Collection of Diseased mango fruits

Mango fruits with physical symptoms of disease after storage for fifteen (15) days were sorted out

and used for fungi isolation.

2.4.2 Media Preparation

The Potato Dextrose Agar (PDA) media was used for isolation of fungi from the decaying mango fruits. The media was prepared according to the manufacturer's instruction by dissolving 40 grams of the dehydrated media in 1000 ml of sterile distilled water. The solution was heated on a heating mantle to dissolve the medium completely. The medium was then sterilized by autoclaving at 121°C for 15 minutes, at 15psi pressure after which it was removed and allowed to cool to a temperature at which it could be held with hands. About 2-3 drops of streptomycin sulphate were added to inhibit the growth of bacteria. The prepared media was poured into sterile Petri dishes and allowed to solidify before being used for fungi culture.

2.4.3 Isolation of Fungal Pathogens from Decaying Mango Fruits during Storage

With the aid of sharp razor blade, small sizes were cut from the decayed portion of the mango fruits. The excised parts were surface sterilized by dipping them in a concentration of 5% NaOCl solution for 1 minute. The pieces were then removed and rinsed in three changes of sterile distilled water and placed on Whatman's filter paper to mop up excess moisture. They were then placed on solidified PDA medium using sterile forceps. Three replicates were made for each sample. The inoculated Petri plates were incubated at ambient temperature and observations were made daily for possible microbial growth. After 5-7 days of growth, sub-culturing was done to obtain pure cultures of the isolates as reported by Liamngee *et al*, (2015). To subculture the fungal isolates, an inoculation needle was flame sterilized and used to pick a little quantity of each fungi colony and inoculated in another Petri dish containing freshly prepared solidified PDA. The plates were sealed with PVC tapes to avoid contamination. Plates were incubated for 7 days at ambient temperature for fungi growth.

2.4.4 Identification of Fungal Isolates

The identification of the isolates was done by examining the isolates macroscopically and microscopically. For macroscopic identification, colony characteristics such as appearance, change in medium colour and growth rate was observed on the Petri plates. For microscopic identification, a thin smear of fungi isolates from 5–10day old cultures were inoculated aseptically on a clean glass slide using a sterile inoculating loop. A drop of lactophenol cotton blue was added and the mixture was covered with a cover slip and viewed under 40x objective of the light microscope. Shapes of the conidia and conidiophores was taken note of and these features were matched with standards described in Barnett and Hunter (1972) as reported by Liamngee *et al.*, (2015).

2.5 Pathogenicity of Fungal Isolates on Healthy Mango Fruits

The ability of the pure cultures of fungi isolates to initiate disease in healthy mango fruits was tested. A 5mm cork borer was used to make holes in healthy mango fruits. Thereafter, 5mm agar plugs from 5-7days old pure cultures were used to plug the holes made in the fruits. The site of inoculation was sealed with sterile PDA. The treatments consist of fungal isolates for each treatment, three fruits were inoculated and replicated 3 times. The inoculated fruits were labelled, arranged accordingly and incubated at room temperature for 7-10 days. Control fruits were mango fruits

inoculated with sterile PDA only. After 7-10 days post inoculation, the margin around the area of inoculation was cut open with the aid of a knife and lesion length and diameter were measured using a metre rule. The area of rot was calculated using the formula adopted by Ezeibekwe and Ibe (2010) as follows:

Area of rot = πdl

Where π = 22/7

d = diameter of rot

l = depth

On appearance of symptoms, tissues at the margins of healthy and diseased part was excised, surface sterilized, placed on freshly prepared PDA and incubated at room temperature for 5-7 days. Morphological characteristics/growth patterns observed in each case was compared with the original isolates.

2.6 *In vitro* Effect of Aqueous Turmeric Extract on Radial Growth of Fungi Causing Postharvest Decay of Mango Fruits

The pour plate method as reported by Liamngee *et al* (2018) was used to investigate the efficacy of the extract on the test fungi *invitro*. Two milliliters each of 0% w/v, 10%w/v and 25% w/v of the Turmeric extract was dispensed in sterile Petri dishes using sterile syringe after which 15-20mls of molten Potato Dextrose Agar (PDA) was added. The mixture in the Petri dishes was swirled gently on the work bench to give even dispersion of extracts. The agar extract mixture was allowed to solidify and then used for inhibition of mycelia growth of the test fungi. The medium was then inoculated centrally with 5mm diameter of mycelia discount obtained from the colony edge of 7 days old cultures of test fungi with the aid of 5mm cork borer. Four replications were used for each extract concentration. Control was Petri dishes containing PDA with no botanicals. The Petri plates was incubated at room temperature and measurement of the radial growth of fungi colony was done using a transparent metre rule on day 3, 5 and 7 and recorded respectively.

2.7 Determination of Phytochemical Constituents Present in the Aqueous Extracts of Turmeric

2.7.1 Flavonoids Test (Alkaline Reagent Test)

Each aqueous turmeric extract was combined with two (2) ml of a 2.0 percent sodium hydroxide (NaOH) combination to produce a concentrated yellow hue. The mixture was next treated with two (2) drops of sulphuric acid. The mixture was colorless if flavonoids were present (Gul *et al.,* 2017).

2.7.2 Test for hydrogen cyanide

Spot paper test: 1 ml of the extract was added with 2 - 3 drops of toluene solution. A change from the yellow colour of the paper to brick red colour indicated a positive result for hydrogen cyanide. (Riaz *et al.,* 2015).

2.7.3 Test for steroids

The extract (1ml) was dissolved in 2.0 ml of chloroform in a test tube, and then 1 ml of concentrated sulfuric acid was added. Formation of reddish brown colour at the inter-phase indicated the presence of steroids (Riaz *et al.,* 2015)

2.7.4 Alkaloids Test (Dragen-Droff's Test)

Three (3) ml of each tumeric extract was precisely measured and put into a conical flask using a measuring cylinder. Each extract species got 1ml of Dragen-reagent droff's (Potassium Bismuth

Iodine). The presence of alkaloids was indicated by the formation of a brick red precipitate (Sofawora, 2002).

2.7.5 Saponins Test (Frothing Test)

In two test tubes, five (5) ml of each turmeric extract was combined with five (5) ml of distilled water and vigorously shaken. The presence of saponins was indicated by the appearance of foaming upon shaking (Raiz *et al.,* 2015).

2.7.6 Test for Tannins

Separately, 10 ml bromine water was added to 0.5g of turmeric extract. The decolorization of bromine water showed the presence of tannins (Gul *et al.,* 2017)

2.7.7 Test for Total phenolic content

In a test tube, 0.1 ml of crude turmeric extract solution was put. A sample of 0.1 ml of distilled water was placed in the test tube as a control (blank). The combination was then given 0.5 ml of undiluted Folin–Ciocalteau reagent. After 30 seconds, a sample of 1.5 ml saturated sodium carbonate was added to the mixture and left to stand for 8 minutes. To make a final volume of 10 ml, a sample of 0.9 ml water was added to the solutions. After that, the mixture was vortexed and incubated for 2 hours at 400°C. A UV-Vis spectrophotometer was used to determine the absorbance of total phenolics at 765 nm. The absorbance value was translated to gallic acid equivalents (GAE) per gram of fresh weight, and the total phenolic content was evaluated against a standard gallic acid calibration curve.

2.7.8 Test for Terpenoids

1ml of turmeric extract was mixed with two (2) ml of chloroform. Following that, 3ml of concentrated H_2SO_4 was added. The presence of terpenoids was shown by a reddish-brown coating forming at the interface (Riaz *et al*., 2015).

2.8 Data Analysis

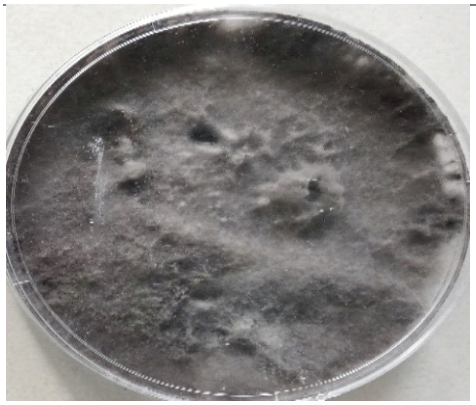
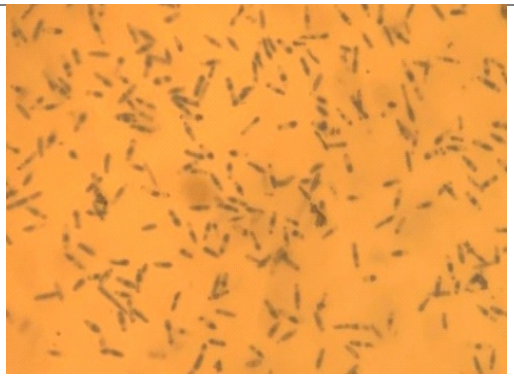
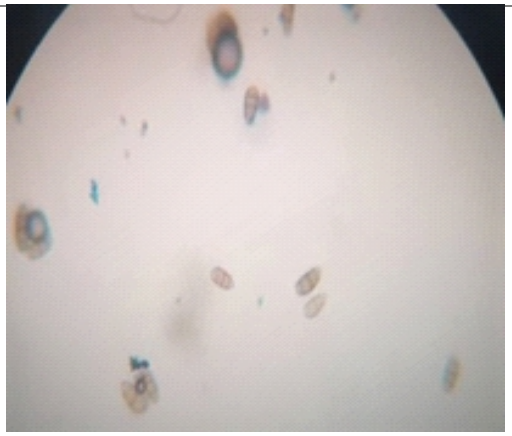
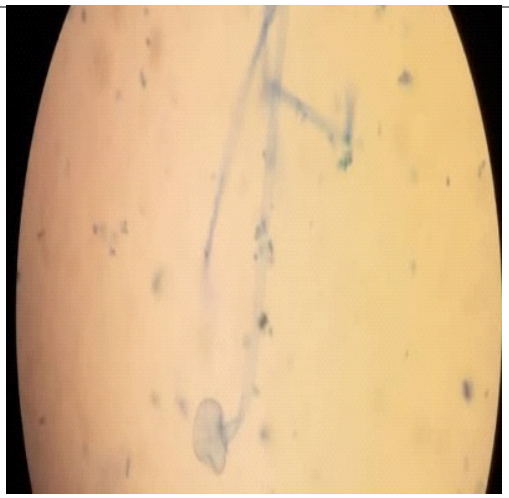
Data were subjected to Analysis of variance (ANOVA) using GENSTAT statistical package (2015). Means were separated using Fishers' Least Significance Difference (F-LSD) at 5% level of probability.

3.0 Results

3.1 Macroscopic and Microscopic characteristics of fungal isolates from decaying mango fruits during storage

The fungi organisms isolated from decaying mango fruits are; *Mucor* sp., *Colletotrichum* sp. and *Alternaria* sp. Their macroscopic and microscopic features are presented in Table 1. The colony of *Mucor* sp on PDA was white in colour with woolly appearance. When viewed under the microscope, the sporangiospores were hyaline with bulbous sporangia. The colony of *Colletotrichum* sp was pinkish in colour with traces of whitish cream around the edges which turns grayish pink as days' progresses and still retaining a clear ring shape on the edges. Under the microscope, the conidia were ovoid in shape with a septum and acutely pointed at the apex. The Colony of *Alternaria* sp is white and woolly in appearance but as days progressed, they turned dark due to spore formation with circular outline. The conidia were dark brown, typically elongated and spindle shaped.

Table 1. Macroscopic and Microscopic characteristics of fungal isolates from decaying mango fruits during storage

Appearance on PDA	Photomicrograph	Organism
		*Colletotrichum* sp
		*Alternaria* sp
		*Mucor* sp

3.2 Pathogenicity of Fungi Isolates on Healthy Mango Fruits

The disease-causing potential of fungi isolates on healthy mango fruits is shown in Table 2. The area of rot induced by *Colletotrichum* sp. (10.46) cm^2 was significantly higher compared with rot induced by *Alternaria* sp. (9.60) cm^2, *Mucor* sp. (8.33) cm^2 and the uninoculated (0.00) cm^2

Table 2. Pathogenicity of Fungi Isolates on Healthy Mango Fruits

Fungi	Area of Rot (Cm ^{2})
Mucor sp	8.33
Alternaria sp	9.60
Colletotrichum sp	10.46
Control	0.00
LSD (0.05)	**1.12**

3.2 Effect of Aqueous Turmeric Extract on Radial Growth of *Mucor* sp *in vitro*

The *in vitro* activity of aqueous extract of Turmeric on radial growth of *Mucor* sp is shown in Table 3. The result revealed that there was a significantly higher radial growth of Mucor sp in the untreated plates 0% w/v (2.37, 3.28, 4.07)cm at days 3,5 and 7 respectively compared with radial growth of *Mucor* sp treated with turmeric extract at 10% w/v (0.70, 1.27, 1.62) cm and 25% w/v (0.53, 0.90, 1.15) cm respectively. There was a significant decrease in the radial growth of *Mucor* sp. as concentration of turmeric extract increased.

Table 3 . Effect of Aqueous Turmeric E xtract on Radial Growth of *Mucor* sp *in vitro*

	Radial Growth (cm)		
Concentration (%w/v)	**3 DAI**	**5 DAI**	**7 DAI**
0	2.37	3.28	4.07
10	0.70	1.27	1.62
25	0.53	0.90	1.15
LSD (0.05)	**0.39**	**0.33**	**0.23**

DAI: Days after Inoculation

3.3 Effect of Aqueous Turmeric Extract on Radial Growth of *Colletotichum* sp *in vitro*

The effect of aqueous turmeric extract on radial growth of *Colletotichum* sp *in vitro* is presented in Table 4. Plates amended with 25% w/v aqueous turmeric extract gave significantly lower radial growth (0.47, 0.80, 1.06) cm compared with plates amended with 10% w/v (0.76, 1.11, 1.51) cm and 0% w/v (2.63, 3.31, 3.91) cm respectively at 3, 5 and 7 days after inoculation.

Table 4 . Effect of Aqueous Turmeric E xtract on Radial Growth of *Colletotichum* sp *in vitro*

	Radial Growth (cm)		
Concentration (%w/v)	**3 DAI**	**5 DAI**	**7 DAI**
0	2.63	3.31	3.91
10	0.76	1.11	1.51
25	0.47	0.80	1.06
LSD (0.05)	**0.25**	**0.33**	**0.41**

DAI: Days after Inoculation

3.4 Effect of Aqueous Turmeric Extract on Radial Growth of *Alternaria* sp *in vitro*

The *in vitro* activity of aqueous extract of Turmeric on radial growth of *Alternaria* sp. is shown in Table 5. The result revealed that there was a significantly higher radial growth of *Alternaria* sp. in the untreated plates 0% w/v (2.67, 3.45, 4.03) cm at days 3,5 and 7 respectively

compared with radial growth of *Alternaria* sp. treated with turmeric extract at 10% w/v (0.51, 1.06, 1.50) cm and 25% w/v (0.41, 0.71, 0.98) cm respectively. There was a significant decrease in the radial growth of *Alternaria* sp. as concentration of turmeric extract increased.

Table 5. Effect of Aqueous Turmeric Extract on Radial Growth of *Alternaria* sp. *in vitro*

	Radial Growth (cm)		
Concentration (%w/v)	**3 DAI**	**5 DAI**	**7 DAI**
0	0%	2.67	3.45
10	10%	0.51	1.06
25	0.41	0.71	0.98
LSD (0.05)	**0.18**	**0.39**	**0.41**

DAI: Days after Inoculation

3.5 Phytochemical Screening of Aqueous Turmeric Extract

Results of the qualitative phytochemical screening of Turmeric (Curcuma lunga) are shown in Table 6. The results of the phytochemical analysis revealed that all evaluated samples of Turmeric extracts tested positive for the presence alkaloids, saponins, tannins, steroids, phenols, flavonoids and terpenoids except for hydrogen cyanide that tested negative during the phytochemical screening test.

Table 6: Phytochemicals Screening of Aqueous Turmeric extract

Phytochemical components	Test	Observations	Inferences
Alkaloid	Wagner test	Brown reddish precipitate	+
Saponin	Froth	Emulsion foam	+
Tannin	Acid test	Reddish brown	+
Steroids	Salkoskis test	Red colour interface	+
Phenol	Feric Chloride	Bluish black colour	+
Flavonoid	Alkaline reagent test	Yellow colour	+
Hydrogen cyanide	Sodium picrate	Yellow to reddish brown colour absent	–
Terpenoids	Salkowskis test	Reddish brown	+

+ means Present; - means Absent

4.1 Discussion

During the storage period, the three (3) fungal pathogens isolated and identified from the decaying mango fruits were *Mucor* sp, *Colletotrichum* sp and *Alternaria* sp based on their cultural and microscopic features. Fungi are the most important and prevalent pathogens, infecting a wide range of fruits and causing destructive and economically important losses of fruits during storage, transportation and marketing (Beuchat, 2006). Different fungal species such as *Alternaria*, *Fusarium, Penicillium, Mucor, Rhizopus, Aspergillus* and *Colletotrichum* have been identified as Spoilage organisms (Akhtar and Alam, 2007). Olaniran *et al.* (2014) also isolated *Aspergillus niger, Fusarium* species and *Botryodiplodia theobromae* from orange fruits.

The pathogenicity test showed that all three identified fungal isolates possessed the capacity to cause diseases and further induce rot in a healthy mango fruits within a span of 10 days following inoculation. Morphological and microscopic

characteristics were compared with initial cultures after re-isolation and were found to be the same. Amongst the isolated fungal pathogens, *Colletotrichum* sp exhibited the highest level of virulence, resulting in 73% incidence rate of rot. This was followed by *Alternaria* sp with the rot incidence of 60% while *Mucor* sp showed the least virulence causing 50% rot incidence in infected mango fruits. However, the control (non-inoculated) mango fruits, showed no signs of decay after 10 days period. The ability of the fungal isolates to cause infection in healthy mango fruits was due to the fact that the pathogens are able to utilize the nutrients of the fruits as a substrate for growth and development (Liamngee *et al.,* 2015). Fruits due to their low pH, high moisture and nutrient composition, are very susceptible to attack by fungi pathogens which causes rot and make the fruits unfit for consumption by producing mycotoxins (Olaniran *et al.*, 2014).

The findings from the study revealed that aqueous extract of turmeric at 10% w/v and 25% w/v inhibited the radial growth of the test fungi. There was also an increased inhibition as the concentration of the extract increased. The inhibitory effect of this extract could be attributed to the presence of secondary metabolites such as alkaloids, saponins, tannins, steroids, phenols, flavonoids, hydrogen cyanide and terpenoids as revealed in the phytochemical screening. These metabolites interfere with fungal cell membrane by disrupting cell division, functions and also disrupt nutrient uptake which in turn might lead to the death of the fungi organisms. Findings from this study were in agreement with (Rahee *et al*., 2018 and Liamngee *et al.,* 2015), who reported that most of the mycelial growth of most isolates of L. *theobromae* and L. *pseudotheobromae* from mango and other crops were significantly inhibited by leaf extracts from various medicinal herbs such as acalypha (*Acalypha hispida*), *siam* weed (*Chromolaena odorata), aidan (Tetrapleura tetraptera),* and Neem (*Azadirachta* indica). Turmeric extract at higher concentrations gave significantly higher inhibition. This may be due to an increase in the active ingredients of the solution which act on the fungus thereby affecting its physiological processes consequently lowering the growth of the fungi (Liamngee *et al.,* 2015).

Phytochemical analysis of *Curcurma longa* extracts revealed the presence of alkaloids, saponins, tannins, steroids, phenols, flavonoids and terpenoids. The fungicidal and pharmacological potential of all these phytochemicals was proven by the report of several works and in agreement with the findings of this study, Nisar *et al.* (2011) and Palei and Dash, (2017) also reported the presence of flavonoids, alkaloids, saponins, tannins, terpenoids, and phenols in extracts of turmeric. Phytochemical screening of *Curcuma longa* by Chen *et al*. (2018) indicates the presence of alkaloids, flavonoids, saponins, tannins, phytates and phenols in the plant extract.

4.2 Conclusion

The study reveals that, different concentrations of plant extracts have significantly different fungi-toxic effects on the shelf life and quality of fruits by suppressing the growth of *Alternaria* sp, *Colletotrichum* sp and *Mucor* sp *in vitro*. The study also showed that, mango fruits treated with 25%w/v and 10%w/v turmeric extract concentration retained the physiological properties better than the untreated (control) mango fruits. Plant extracts offer a safe and affordable alternative to synthetic fungicides,

boosting nutritional value without negatively impacting mango fruits composition. These botanicals can be commercially utilized as they are readily available, accessible, and affordable for sustainable organic postharvest management of fruits and vegetables. Based on the findings from this research, the following recommendations are made:

i. The use of plant extracts formulations should be adopted and improved upon, so as to be integrated in disease management.
ii. It is also recommended that farmers, consumers and traders use a 25%w/v concentration of turmeric extract, as this has been shown to be the most effective in inhibiting fungal diseases and preserving the shelf life and quality of mango fruits.

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