

CONTRIBUTION TO THE FIGHT AGAINST POST-HARVEST ROT OF TOMATO FRUITS (*SOLANUM LYCOPERSICUM*) THROUGH THE USE OF THE AQUEOUS EXTRACT OF *AGERATUM CONYZOIDES*

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Summary

Tomato production in Cameroon faces numerous constraints, including post-harvest rot. This study was carried out with the aim of contributing to the fight against post-harvest rot of tomato fruits through the use of the aqueous extract of *Ageratum conyzoides*. To achieve this objective, the pathogen responsible for tomato fruit rot was isolated and the microscopic and macroscopic characters determined; the antifungal activity of the aqueous extract of *A. conyzoides* was evaluated in vitro using three doses (30, 60, and 120 mg/ml) with three repetitions at three different periods (before, during and after) fruit treatment by the extract and inoculation of the pathogen on scarified and non-scarified fruits. A synthetic fungicide Pencozeb served as a positive control. Parameters such as mass loss of tomato fruits, surface area of lesions induced on scarified and non-scarified tomato fruits, were measured using a balance and graph paper respectively. The results show that *Fusarium oxysporum* was the pathogen responsible for rotting tomato fruits and having the macroscopic characteristic of a cottony texture and a white aerial mycelium, macroscopically, *Fusarium oxysporum* presents two types of asexual spores, namely macroconidia which are curved, pale-colored spores, and microconidia which are ovoid spores with septate and branched hyphae, a smooth and thin cell wall. The antifungal test revealed that the aqueous extract showed an effect inhibitor on the development of the lesion surface and mass loss at the highest dose 120 mg/ml when the extract applied twenty-four hours (24 hours) before inoculation on the fruits was fungicides at a concentration of 120 mg/ml on *Fusarium oxysporum*. The pathogen-induced lesion area and mass loss of scarified tomato fruits were 6.000 ± 3.09 and 10.04 ± 9.37 respectively. In non-scarified fruits these values were 8.45 ± 3.43 and $48,000 \pm 13.66$ respectively for lesion area and mass loss. This extract can therefore be used as an alternative to chemical pesticides in fruit preservation.

Keywords: plant extract, fusarium wilt, *Fusarium oxysporum*, scarified and non-scarified tomato fruits, antifungal activity.

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1. Introduction

Cameroon's economy, like most developing countries, is based mainly on its agricultural resources. The tomato (*Solanum lycopersicum*, L) of the Solanaceae family, is an annual herbaceous plant native to the Andes and America [1]. It is counted among the most important vegetable crops in the world [2]. According to the United Nations Food and Agriculture Fund (FAO), it occupies first place in vegetable production after the potato and is cultivated in more than 170 countries. The tomato has enormous therapeutic virtues thanks to its varied composition of organic substances and mineral elements. Indeed, it is rich in lycopene, a substance which can prevent certain pathologies such as cardiovascular diseases, cancers, and degenerative diseases linked to old age [3, 4]. It also reduces hypertension thanks to its richness in potassium and reduces salt in the body [5]. Due to the vitamins, mineral elements and fibers that it provides to the body, it occupies an essential place in the human diet since it effectively contributes to a balanced diet [6]. Tomato trade represents more than 17 % of global fruit and vegetable trade, with a monetary value of more than 8.5 billion USD [7]. Global tomato production has increased in recent years, from more than 130 million tons in 2014 to 182 million tons in 2017 [8]. In Cameroon, it is increasing over the years. With a production of 14 thousand tons in 2005, it increased from 88,980 tons in 2012 [9] with the main production area being the western region, notably the Foumbot, Bouda and Dschang basins [10]. The most recent studies, based on precise surveys and statistics in different countries, have shown that losses of fruit and vegetables at consumer level due to fungus were estimated at an average of 60 million tons per year. This mass represented 16 % of the food reaching the consumer. Of this mass, 80 % of food was considered avoidable or potentially avoidable by improving storage conditions in homes: i. e. 47 million tons per year that could be saved [11]. The main products thrown away are fruits and vegetables, particularly tomato fruits due to their short shelf life. In addition, once picked, tomato fruits are subject to various fungal changes which prevent producers from keeping them for more than a few days. This situation creates a long period of shortage, making it impossible to ensure the availability of tomatoes at a lower cost at all times, which would be at the origin of the price fluctuations observed in the markets [12]. [13] explain that tomatoes are very expensive in times of shortage (5 times the price in times of abundance), making them difficult for consumers to access. Among the fungal species responsible for the deterioration of tomato fruits, let's note those belonging to the genus *Fusarium* responsible for fusarium wilt of tomato [14, 15]. This pathogen is most common on tomato fruits, causing lesions and numerous rots of the different organs of the tomato, particularly on fruits [16]. This pathogen causes fruit discoloration ranging from brown to black and the fruits of affected plants are limp. The work of [17] showed that certain *Fusarium* species can cause yield losses of up to 90 %. Those of [18] reported that species such as *F. oxysporum* caused more than 60 % of post-harvest tomato fruit rots in India. Whatever the variety of tomatoes, this species is often present.

Preserving tomato fruits after harvest is a major problem among players in the sector. The fight against tomato fruit rot is most often done through the use of chemical fungicides. However, these chemicals are increasingly experiencing limits due to their high cost, the unavailability of some of these products in local markets and the induction of resistance in pathogens or the ineffectiveness of fungicides depending on production areas and times of the year [19, 20]. Faced with these inconveniences posed by these chemicals, it is necessary to develop new alternative control methods to chemical control such as control using plant extracts. Plant extracts have recognized antifungal properties and can either inhibit the growth of phytopathogens or act on plant tissues as elicitors of the fruit defense mechanism [21, 22]. The use of plant extracts to improve the conservation of fruits is becoming more and more widespread because these extracts guarantee the quality of the fruit as well as that of the environment where the treatment takes place since they are biodegradable. Numerous studies have shown the antifungal effect of plant extracts on certain fungal species in other production areas [23, 24]. However, little information is available on the fight against *Fusarium* associated with tomato fruit rots through the aqueous extract of *Ageratum conyzoides*. The general objective of this work is to contribute to the fight against post-harvest rot of tomato fruits through the use of the aqueous extract of *Ageratum conyzoides*.

2. Material and methods

2. 1. Material

The plant material consists of *Ageratum conyzoides* plants which, according to the literature, have antifungal activity against certain species associated with tomato fruit rot. As other plant material used, the fruits of tomatoes (*Solanum lycopersicum*) of the Raja variety, for its wide availability, as well as for its consumption. Pencozeb with the chemical formula $C_8H_{12}MnN_4S_8Zn$ was also used as a chemical fungicide to serve as a positive control.

2. 2. Methods

2. 2. 1. Plant collection

The plant used was collected in the Menoua department and identified at the Applied Botanical Research Unit (URBOA) of the University of Dschang (Cameroon). The young leaves of *Ageratum conyzoides* were dried in the shade for a few weeks, then finely ground in a mill. The powder obtained was packaged in jars protected from light until use.

2. 2. 2. Preparation of aqueous extract

The extraction by maceration of one hundred grams (100g) of powder from the plant for 48 hours in 500 ml of distilled water was carried out. The mixture was filtered in the Laboratory of the Research Unit of Phytopathology and Agricultural Zoology (UR-PHYZA) of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang using Whatman paper No. 1. The filtered aqueous solution obtained was freeze-dried to obtain the aqueous plant extract. The filtrate recovered from the aqueous extract of *Ageratum conyzoides* was dried in an oven at 40 °C for evaporation of the solvent (distilled water). The yield of the extract (Yield %) is calculated by the formula of [25]:

$$\text{Yield \%} = M1/(M0) \times 100.$$

Yield expressed as a percentage, $M0$ – the mass of the treated plant material (the plant organ powder), and $M1$ – the mass of the dry extract.

2. 2. 3. Isolation and characterization of the pathogen

Tomato fruits showing symptoms of rot will be harvested and transported to the laboratory where they will be washed and then superficially disinfected using cotton soaked in alcohol. Necrotic tissue fragments of approximately 2 mm will be collected under a microbial hood near a Bunsen burner flame using a sterile scalpel [26]. These fragments will be seeded aseptically in boxes. Petri dish containing 20 ml of culture medium (PDA) and placed in the dark in an incubator at a temperature between 24 ± 2 °C. Observations will be made every day in order to obtain visible fungal colonies around the seeded fragments, which will subsequently be taken and transplanted into new petri dishes containing the culture medium. After several successive transplants, the pure culture of the mushroom will be obtained. The identification and characterization of the pathogen will be done on the basis of the morphological characteristics of the mycelium, septate or not, and the fruiting bodies (conidia) which will be observed under a microscope based on mycological identification keys [27].

2. 2. 4. Tests of in vitro evaluation of the antifungal potential of the aqueous extract of *Ageratum conyzoides* on the development of *F. oxysporum* associated with post-harvest rot of tomato fruits

Apparently healthy tomato fruits of the Raja variety were collected in the field from gardeners. These fruits were washed in tap water then superficially disinfected in 75 % alcohol for 1 minute, rinsed 3 times successively with distilled water to eliminate traces of the disinfectant and placed on blotting paper to remove the excess water. On each of the fruits, a well of 5 mm in diameter was created using a sterile cookie cutter. Three different treatments were carried out for each dose (30, 60 and 120 mg/ml) of extract: – evaluation of the curative potential of the extracts: the evaluation of the curative capacity of the extract was carried out on previously scarified tomato fruits. For this a pure culture mycelial fragment (5 mm) was inoculated, after a few hours (24 hours) the different concentrations of the aqueous

extract of *Ageratum conyzoides* at respective concentrations 30, 60, and 120 mg/ml were sprayed. On inoculated (scarified) fruits. These fruits were sealed with petroleum jelly to avoid contamination by other pathogens;

– determination of the virulence of the pathogen in the presence of the extract: The virulence of the pathogen in the presence of the extract at different doses (30, 60, 120 mg/ml) was determined, using a Pasteur pipette a mixture (aqueous plant extracts+inoculum) was placed on the wells dug on each tomato fruit then sealed with petroleum jelly [28, 29] and incubated. The experiment was repeated three times;

– evaluation of the preventive power of the extracts: To evaluate the preventive power of the aqueous extract for the fight against the pathogenic agent of post-harvest rot of tomatoes, the scarified fruits were treated with the aqueous extract of *Ageratum conyzoides* at different concentrations (30, 60, 120 mg/ml) and incubated for 24 hours. Subsequently, these fruits were inoculated with pure cultures of the pathogen and then sealed with petroleum jelly.

The same protocol used for scarified fruits was carried out for non-scarified fruits. The inoculation of the pure culture of the pathogen as well as the application of the extract of *Ageratum conyzoides* were done on the surface of the epicarp.

Nine (9) fruits in total were inoculated and treated with synthetic fungicide (Pencozeb) at the manufacturer's dose 0.33 mg/ml at three different periods (before, during and after), served as a positive control. While the negative control consisted of three scarified and non-scarified fruits inoculated with the pure strain of the pathogen without being treated with the aqueous extract of *Ageratum conyzoides*. These fruits thus inoculated were placed in the crystallizers in which the humidity was maintained by cotton soaked in distilled water and the whole incubated at room temperature. All treatments were repeated three times.

2. 2. 5. Loss of tomato fruit mass

The mass loss (% M) of tomato fruits (scarified and non-scarified fruits) was evaluated by successive weighing's for eight days using a precision balance and calculated according to the formula below:

$$M=((Mi-Mt)/Mi)\times 100,$$

where M – the loss of mass expressed in %, Mi – the initial mass in g and Mt – the mass at a defined time in g.

2. 2. 6. Surface of lesions induced on fruits

The surface area of lesions induced by the pathogen was evaluated for eight days on each tomato fruit (scarified and non-scarified) using graph paper.

2. 2. 7. Statistical analyzes

The results of the tests for the evaluation of the antifungal activity of the extract on the fungal strain (*Fusarium oxysporum*) were expressed in the form of percentage of inhibition. ANOVA served as a model for comparing the effect of the extract for each concentration. When at the significance threshold $\alpha=0.05$, a difference is observed between the inhibitory effects of the extracts for the pathogen, the PPDS (Least Significant Difference) test was used to determine the concentration whose inhibitory effects differ significantly. On the other. The data collected (surface areas of lesions and mass losses of tomato fruits) were subjected to analysis of variance. SPSS version 22.0 software was used for this purpose.

3. Results and discussion

3. 1. Results

3. 1. 1. Macroscopic and microscopic characteristic of the isolated fungal species

The analysis of the macroscopic characterization of *Fusarium oxysporum* reveals that in the PDA culture medium the colonies of *F. oxysporum* developed and reached 5 cm in diameter in 8 days. They presented a cottony texture and white aerial mycelium (Fig. 1).



Fig. 1. Macroscopic appearance of *Fusarium oxysporum*

The analysis of the microscopic characterization of *F. oxysporum* revealed that it is a filamentous fungus belonging to the phylum Ascomycota and the class Sordariomycetes, producing two types of asexual spores: macroconidia which are curved spores tapering to the ends, microconidia which are ovoid, unicellular spores, smaller than macroconidia. In addition, the microconidia have septate and branched hyphae, a smooth, thin and hyaline cell wall (**Fig. 2**).

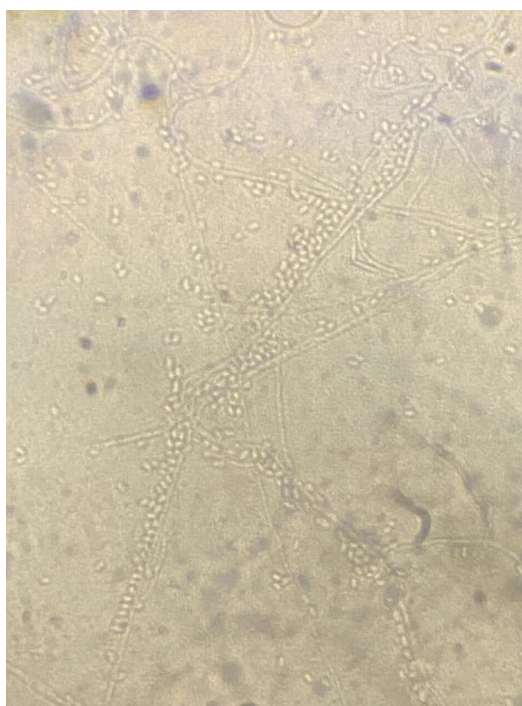


Fig. 2. Microscopic appearance of *Fusarium oxysporum*

3. 1. 2. Extraction yield

Extraction of 100 g of *Ageratum conyzoides* in 500 ml of distilled water gave an extraction yield of 17 %. The extract looked thick and blackish in color.

3. 1. 3. Loss of mass of scarified tomato fruits and surface lengths of lesions induced by *Fusarium oxysporum* on scarified tomato fruits treated with aqueous extract of *Ageratum conyzoides*

Table 1 presents the average values of mass losses as well as the areas of lesions induced by *F. oxysporum* on scarified tomato fruits. These parameters vary depending on the period of application of the extract and the concentration. Overall, the induced lesion areas vary from 18.31 ± 10.31 ; 16.19 ± 9.41 ; and 6.00 ± 3.09 mm² respectively for the treatments before, during and after application of the extract at a dose of 120 mg/ml after inoculation of the pathogen. For the negative control the lesion surface is 45.91 ± 26.09 mm² while that of the positive control is 6.53 ± 3.57 mm². The statistical analysis shows that there is a significant difference between the periods of application of the extract at different concentrations (before, during and after) and the negative control but no difference is observed between the 120 mg/ml treatment (after) and the chemical fungicide according to the Duncan test at the 5 % probability threshold. The reduction in the surface area of lesions depends on the dose of *A. conyzoides* extract and the period of application. The low value of the lesion surface is obtained at a dose of 120 mg/ml or 6.00 ± 3.09 mm². However, no significant difference is observed between this dose and the positive control. Regarding the mass loss of scarified tomato fruits treated with the aqueous extract of *A. conyzoides*, it is possible to note that the different treatments had a significant effect on the mass loss of tomato fruits. This mass loss decreases depending on the concentration of the extract. The lowest value of mass loss of scarified fruits is obtained with the dose 120 mg/ml provided 24 hours after inoculation of the pathogen, i.e. 38.04 ± 9.37 g. A significant difference is observed between the loss of fruit mass at this dose and the negative control whose mass loss value is 63.75 ± 35.75 according to the Duncan test at the 5 % probability threshold.

Table 1

Lesion surfaces and mass losses of scarified tomato fruits induced by *F. oxysporum* treated with *Ageratum conyzoides* extract

Application periods	Concentrations (mg/ml)	Lesion surfaces (mm ²)	Mass losses (g)
Inoculation of the pathogen and treatment 24 hours later	30	28.83 ± 15.81^a	36.28 ± 22.76^a
	60	19.56 ± 10.85^b	30.33 ± 22.39^a
	120	18.31 ± 10.31^b	20.75 ± 20.85^b
Inoculum plus extracted at the same time	30	26.29 ± 14.39^a	23.66 ± 28.30^a
	60	20.56 ± 11.20^a	20.62 ± 22.78^a
	120	16.19 ± 9.41^b	15.28 ± 10.66^b
Extract applied and inoculation of the pathogen 24 hours later	30	10.25 ± 12.41^a	20.19 ± 24.23^a
	60	9.56 ± 10.15^a	19.91 ± 20.00^a
	120	6.00 ± 3.09^b	10.04 ± 9.37^b
	0	45.91 ± 26.09^c	63.75 ± 35.75^c
Negative control Positive control	0.33	12.000 ± 9.01^a	28.28 ± 24.33^a
	0.33	9.559 ± 4.277^b	23.58 ± 28.11^a
	0.33	6.533 ± 3.57^b	12.62 ± 18.63^b

Note: a–c means with the same letters in the same column are not significantly different according to Duncan's test at $P \leq 0.05$.

3. 1. 4. Loss of mass and lesion surfaces induced by *Fusarium oxysporum* on unscarified tomato fruits treated with aqueous extract of *Ageratum conyzoides*

The results obtained on the inhibition of lesion surfaces as well as mass losses induced by *Fusarium oxysporum* on unscarified tomato fruits treated with different doses of aqueous extract of *Ageratum conyzoides* show that the inhibition of the surface was a function of the dose and the period of application, the smallest surfaces were obtained with the dose 120 ml/g whatever the period of application of the extract, i. e. 10.53 ± 7.41 ; 12.38 ± 9.35 and 8.45 ± 3.43 mm² respectively for the treatments (before, during and after). The greatest surface value of lesions was obtained in the negative control, i.e. 39.55 ± 13.77 mm², there is a significant difference between the fruits treated with different doses of extract and the control. Regarding the loss of mass of non-scarified fruits, it is possible to note that the different treatments had a significant effect on the loss of fruit

mass independently of the period of application and the concentration of the *Ageratum conyzoides* extract (Table 2).

Table 2

Lesion surfaces and mass loss of non-scarified fruits induced by *F. oxysporum* treated with aqueous extract of *Ageratum conyzoides*

Application periods	Concentrations (mg/ml)	Lesion surfaces (mm ²)	Mass losses (g)
Inoculation of the pathogen and treatment 24 hours later	30	13.05±10.89 ^a	64.833±27.44 ^a
	60	12.22±9.22 ^a	54.476±22.26 ^b
	120	10.53±7.41 ^b	52.166±21.31 ^b
Inoculum plus extracted at the same time	30	13.47±10.94 ^a	72.542±33.77 ^a
	60	12.95±9.67 ^a	68.928±29.56 ^b
	120	12.38±9.35 ^a	55.750±23.83 ^c
Extract applied and inoculation of the pathogen 24 hours later	30	16.97±13.470 ^a	59.083±24.70 ^a
	60	15.16±12 ^a	58.167±25.52 ^{ba}
	120	8.45±3.43 ^c	48.000±13.66 ^b
Negative control	0	39.55±13.77 ^c	83.750±38.75 ^d
	0.33	12.00±9.01 ^a	78.285±24.33 ^a
Positive control	0.33	9.55±4.27 ^b	73.583±28.11 ^a
	0.33	6.53±3.57 ^b	45.625±18.63 ^b

Note: a–c means with the same letters in the same column are not significantly different according to Duncan's test at $P \leq 0.05$.

4. Discussion

The isolation of the fungus from tomato fruits reveals that the latter harbors a species belonging to the genus *Fusarium*. Tomato fruits would constitute a susceptible host for *F. oxysporum*. Several studies have shown that *Fusarium oxysporum* causes Fusarium wilt on many fruits [30]. The results of the microscopic and macroscopic characteristics of *F. oxysporum* obtained corroborate with the work [31] on the characterization and identification of *Fusarium oxysporum* pathogen of tomato fruits in India. Aqueous extraction of 100 g of *Ageratum conyzoides* gave an extraction yield of 17 %. This low yield could be due to the physiological state of the plant material, the factors of the geographical harvest area, the period of the plant's plant cycle and/or the plant family to which the plant belongs. The work [26] indicated that some plant families offer higher extraction yields than others. This is how Annonaceae, Myrtaceae, Asteraceae and Zingiberaceae generally offer high extraction yields while Poaceae on the other hand give very low extraction yields. Additionally, [32] reported that environmental conditions, harvest time and age of plant material can influence extraction yields.

With the aim of contributing to the fight against Fusarium wilt of tomato fruits, the anti-fungal effect of aqueous extracts of *Ageratum conyzoides* on the development of *Fusarium oxysporum* was evaluated in the present study. At the end of this work, the results on the inhibition of necrosis lesion surfaces induced by *F. oxysporum*, the loss of mass of tomato fruits caused by this pathogen showed variable antifungal activity depending on the dose. Application of the aqueous extract, and application periods. These results show that the extract of *A. conyzoides* exerted an inhibitory effect on the development of necrosis. This effect would be due to the fact that the plant used would contain secondary metabolites (alkaloids, flavonoids, triterpenoids, tannins, saponins, anthocyanins and anthraquinones) having an inhibitory power which would have influenced the development of *Fusarium oxysporum*. The work [25, 33] showed that certain plants contain in their organ compounds with antifungal properties (alkaloids, phenols, sterols, terpenoids, flavonoids, anthocyanins, saponins or tannins) hence their sometimes use in traditional medicine. This inhibition was significant with the increase in the concentration of the extract applied, in particular at the dose 120 mg/ml. Similar results were reported by [34] who showed that *Carica papaya* extracts would further inhibit the respective radial growth of *Collectotrichum gloeosporoides* and *C. kawaii* with increasing concentration. Lesions were observed on fruits sprayed simultaneously with extracts and inoculum of *F. oxysporum*. This development could be explained by the fact that this pathogen would be less sensitive to the administered extracts. The surface areas of lesions devel-

oped on unscarified fruits that had been inoculated with *Fusarium oxysporum* were lower than those developed on scarified fruits. This difference could be due to the fact that the wounds created are entry points for the pathogen and could cause stress in the fruit. This could cause a progressive reduction of the elements involved in the fruit mechanism, thus promoting rotting and weight loss of the fruits. Furthermore, the loss of weight of the fruits could be justified by the fact that the fruits had reached the maximum stage of maturity, moreover the fruits of tomatoes being highly perishable foodstuffs, with a fairly short perishability time after maturation ranging from three to four days, the cellular elements experienced strong degradation. [34] on the characterization of stress inhibitory signals in tomato fruit following oxidative stress during storage showed that biotic and abiotic stress can accelerate the rotting of tomato fruits. The surface values of lesions developed on tomato fruits are significantly identical for certain treatments. This could be due to the fact that there were different morphotypes which would be of the same species, present in these treatments. Similar results were reported by [34] who showed that isolates of *Fusarium* spp inoculated on pineapple fruits produced similar *Fusarium* wilt symptoms. The extract of *Ageratum conyzoides* showed an effect comparable to that of the positive control (Pencozeb) by inhibiting the development of *Fusarium oxysporum* tested on scarified and non-scarified tomato fruits with the treatment applied 24 hours before inoculation of the pathogen at dose 120 mg/ml, more particularly all treatments had an inhibitory effect on the reduction of the surface of lesions induced by *F. oxysporum* comparable to the negative control, which allows to say that this extract would have both a curative potential, because it can be applied while the disease is developing, a preventive potential even before the disease sets in and a fungistatic effect which would make it possible to inhibit the development of the pathogen at a dose of 120 mg/ml. While the scarified fruits treated with the extract of *A. conyzoides* made it possible to understand that this extract would have a more pronounced effectiveness when it is applied before inoculation of the disease, thus giving it a preventive potential at a dose of 120 mg/ml. These results obtained with *Ageratum conyzoides* corroborate those of [34] who showed that extracts of *Cupressus lusitanica* would inhibit the development of fungi in preserved avocado fruits. Furthermore, the work of [14] on the study of the causes of post-harvest rot of tomatoes and the fight against pathogens associated with these fruits in Kenya reported that extracts of *Azadirachta indica* can extend the shelf life of tomatoes. Tomato fruits after harvest when applied before disease onset.

5. Conclusions

This work was carried out as part of the search for natural products which can be an alternative to chemical products used in the control of certain fungal pathogens, responsible for post-harvest rot of tomato fruits. At the end of this work which focused on the contribution to the fight against post-harvest rot of tomato fruits (*Solanum lycopersicum*) by the use of the aqueous extract of *Ageratum conyzoides*. The following results were obtained: *Fusarium oxysporum* was identified and associated with postharvest tomato fruit rot as the pathogen.

The study of the macroscopic and microscopic characteristics of *Fusarium oxysporum* revealed that it is a filamentous fungus belonging to the class Sordariomycetes, presenting a cottony texture and white aerial mycelium. This fungal species exhibits macroconidia with septate and branched hyphae, a smooth, thin, hyaline cell wall, macroconidia which are curved spores tapering at the ends.

The aqueous extract of the plant used exerted considerable inhibitory activity on the development of *Fusarium oxysporum* depending on the concentration, moreover, at the greatest dose, the aqueous extract of *Ageratum conyzoides* showed effectiveness comparable to that of the chemical fungicide Pencozeb on scarified and non-scarified tomato fruits. Thus, the extract of *Ageratum conyzoides* showed a curative potential on unscarified tomato fruits, and a preventive potential on scarified tomato fruits.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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