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Disease dynamics, host susceptibility and postharvest pathogenicity of *Aspergillus fumigatus* in tropical fruits: Implications for food security, food safety and sustainable postharvest management

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ABSTRACT

Fruits and vegetables are essential components of the human diet because they provide rich sources of nutrients such as vitamins, mineral elements (e.g., K, Mg, and Fe), dietary fibre, and antioxidants, all of which are important for maintaining human health and preventing diseases. Unfortunately, postharvest fungal and bacterial diseases contribute significantly to food deterioration and losses, thereby exacerbating global food insecurity, particularly in Sub-Saharan Africa, including Ghana. In this study, isolates of *Aspergillus fumigatus* obtained from the aeromycoflora of markets in Accra, Ghana, were used to evaluate the pathogenicity of the fungus on selected fruits, namely mango, tomato, and orange, using conventional pathogenicity assessment methods. Disease development was monitored using the Disease Progress Curve (DPC) and the Area Under the Disease Progress Curve (AUDPC). The disease progression curves obtained over a 7-day period were sigmoid in shape, characteristic of a monocyclic disease pattern involving a single infection cycle. Mango recorded the highest AUDPC value (13.69 cm), followed by tomato (11.70 cm) and orange (3.98 cm), indicating varying levels of susceptibility among the fruits. Statistical analysis showed significant differences ($P \leq 0.05$) in the levels of infection and susceptibility to *Aspergillus fumigatus*. The relatively lower susceptibility of orange fruits was attributed to the protective three-layered structure of the peel (epicarp, mesocarp, and endocarp), which appeared to slow pathogen invasion and rot progression during the 7-day incubation period. The study demonstrates the potential role of *Aspergillus fumigatus* in contributing to postharvest fruit losses in major markets in Ghana.

KEY WORDS: *Aspergillus fumigatus*; *Disease Progress Curve (DPC)*; *Ghana*; *Fruit pathogenicity*

1. Introduction

Agriculture plays a critical role in ensuring food security by providing a sustainable supply of plant and animal products. Humans have domesticated plants and animals to ensure a stable food supply and enhance food security, which remains a priority for governments worldwide. The ability to feed a nation depends on the use of appropriate technologies for the cultivation and preservation of agricultural produce. Microorganisms (fungi, bacteria, viruses, mycoplasma *etc.*) are by far the greatest risk of food contamination, spoilage, intoxication and crop losses in the field

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(Odamtten, 2018). Fungi have an inherent ability to decimate crop production and cause food insecurity, sometimes acting in concert with adverse and favourable environmental parameters such as humidity, temperature, light duration and quality etc. to inflict serious crop loss devastation (Odamtten, 2018).

The food pipeline represents events spanning the cultivation, harvesting, pre-processing, transportation system, processing and packaging of food for the marketing of produce until it reaches the consumer's dining table. Plant diseases caused by fungi in the field and in storage products can make a difference between plenty and scarcity and starvation through hunger or even death.

In sub-Saharan Africa, nearly 40–50% of fruits and vegetables are lost postharvest, often before reaching the consumer (Etefa *et al*., 2022). These losses contribute not only to food shortages and income loss for farmers and traders but also to micronutrient deficiencies in vulnerable populations. Fruits and vegetables are inherently perishable and require careful handling, appropriate storage, and efficient transportation systems to maintain their nutritional quality. However, in many African countries, including Ghana, postharvest systems remain weak or fragmented (Twum-Dei *et al.*, 2026). In Ghana, fruits and vegetables are integral to the local diet, providing essential micronutrients such as vitamin A, vitamin C, iron, and dietary fibre, which are crucial for child growth, immune function, and the prevention of chronic diseases (Agyapong *et al*., 2022). In Ghana, plant diseases caused by fungi have been recorded for cereals, legumes, fruits, plantation crops, root crops, vegetables, spices and condiments etc. (Wongnaa *et al.*, 2023). The estimated average economic losses due to plant diseases in Ghana were over US$405,760,000 annually between 2000 and 2010 (Ghana Web, 2026; TUAL, 2025). Food imports for the same period was US$91,544,374.60. In addition, 2021 data estimated that 30% to 45% of crops such as vegetables, crops, and tubers produced were lost due to poor postharvest management and handling practices (Ali *et al*., 2021). According to Wongnaa *et al*. (2023), 25–50% of these foods are lost postharvest due to inadequate storage, poor handling, and inefficient distribution systems, which is consistent with data reported in previous years. The current estimate of crop losses due to biodeterioration, pests and diseases is 14–20% of the annual harvest (MoFA, 2025). These losses represent a significant setback to food production efforts. These losses are estimated at about US$ 1.9 billion annually, an amount equivalent to the value of food imports into the country (Ghana Web, 2026). These losses have significant economic and food-security implications, as farmers go through a tedious production process only for much of their produce to spoil due to the lack of proper storage facilities.

The relationship between a phytopathogen and a plant and the development of disease is influenced by the nature of the pathogen and host, and the prevailing environmental conditions; all three interact and form integral parts of what is called the disease triangle (Kavanagh, 2005). Each component of the triangle (Host, Pathogen, Environment) represents one side of the triangle and these interplay to determine the disease severity.

In order for plant disease to occur, a pathogen must be virulent towards, and compatible with, its host. The aggressiveness of a pathogen is often influenced by its pathogenic potential. Some pathogens have a broad host range, while others attack relatively few plant species. Infective propagules (spores, conidia, mycelium *etc*.) must be present for disease to occur and to some extent the amount of inoculum influences disease development (Kavanagh, 2005). It is also noteworthy that the length of time that a pathogen is in contact with a host is also critical for disease development. The pathogen must also be able to compete with other organisms present in the environment or on the plant. In Ghana, mangoes, oranges harvested from mature fruit plants are kept on farm and heaped into a pyramidal shape. The farm products are either covered with translucent polyethylene pouches or tarpauline or left on-farm to the vicissitudes of the weather. A variety of aeromycofloral spores settle on the harvest before being finally carried to the market, in wooden mammy trucks, for sale in the markets far and wide. Storage spaces in market stalls are limited and the produce is often lumped together stored in unventilated rooms or discharged in the open space covered or uncovered exposed to the changing vicissitudes of the weather.

A disease progress curve (DPC) in plant pathology is a graphical representation of disease intensity (e.g., severity or incidence) over time, used for understanding epidemic dynamics, comparing cultivar resistance, and evaluating management strategies. The purpose of DPC is to quantify temporal dynamics, allowing for the calculation of rates and identifying when epidemic is most severe.

The DPC's typically follow sigmoidal (Logistic and Gompertz) or monomolecular patterns, showing slow initial development, a rapid increase, and eventual saturation, analysed using metrics like the Area Under Disease Progress Curve (AUDPC). The AUDPC is frequently used to combine multiple observations of disease progress into a single value (Simko and Piepho, 2012). Vanderplank analysed the shapes of great number of disease progress or epidemic curves and classified the epidemics into two basic types: monocyclic or polycyclic (Vanderplank, 1963). Monocyclic (monomolecular) - characterised by a single infection cycle showing an exponential increase in the early stage whereas polycyclic is characterised by multiple infection from secondary inoculum produced during the epidemics in the same crop cycle.

Depending on the pathogen's life strategy and environmental interactions, disease progress curves (DPCs) typically follow mathematical forms such as monomolecular, logistic, Gompertz, and exponential models (Chandran *et al*., 2025; Xu, 2006). The cumulative disease intensity represented by these curves can be quantified using the Area Under the Disease Progress Curve (AUDPC), which integrates disease severity over time and provides a comparative measure of epidemic development. It often utilizes trapezoidal integration to summarize the total disease severity over a specified period. This method enables the comparison of different treatments or cultivars. Key parameters include the initial inoculum (y_0), representing the starting level of disease before intervention; the disease severity level at a given time; and the growth rate (r), which indicates how quickly the disease progresses. The slope of the resulting curve reflects the speed of disease spread, while the asymptote indicates the maximum level of disease severity achievable under specific conditions.

The key models for fitting DPC data are: (a) Logistic model - used for polycyclic diseases where the rate of increase is proportional to both the amount of disease and the healthy tissue.

(b) Gompertz model - is often used when the rate of disease increase is not proportional to the remaining healthy tissue.

(c) Monomolecular model - used for monocyclic diseases, where the rate of increase is proportional only to the remaining healthy tissue. This model is commonly used for soil-borne pathogens where the inoculum source is constant, but the pathogen does not multiply on the host.

There were several variants of *Aspergillus fumigatus* isolated from the Ghanaian aeromycoflora in different geographical locations (Accra markets e.g., Madina, Mallam Atta; Central Region; Breman Asikuma). Further morphological characteristics of the fungus include: colours (blue-green), suede-like surface consisting of a dense felt of conidiophores; conidial heads typically columnar; short-walled, green, with conidia borne on vesicles with globose and sub-globose conidia (Samson *et al*., 2007; Danso, 2025) (**Plate 1**).

One of the variants of *A. fumigatus* was sub-cultured on Potato Dextrose Agar and used for the subsequent experiments reported here to assess its pathogenic potential on three Ghanaian fruits namely oranges, mangoes, and tomatoes.

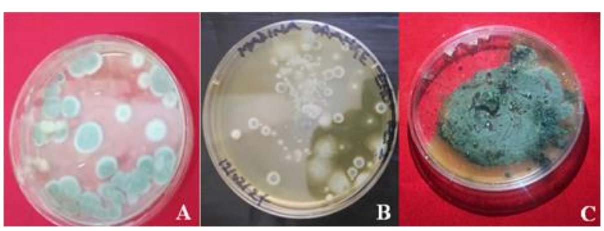

Plate 1: Pure cultures of colonies of *Aspergillus fumigatus* on Potato Dextrose Agar (A) and Malt Extract Agar (B &C) plate incubated at 30 ±2 °C

2. Materials and Methods

2.1 The test fungus

The test fungus, *Aspergillus fumigatus* Fresenius, was isolated from infected orange (var. Late Valencia), mango (var. Saloon), and tomato (var. Roma VF) fruits, as well as from aeromycoflora, and cultured on Potato Dextrose Agar (PDA; analytical grade) for 7 days. **Plates 2 - 4** show the culture of *A. fumigatus* on PDA and photomicrograph of the same showing gross morphological characteristics respectively.

The fungus was identified using the criteria spelled out by (Samson *et al*., 2014; Samson *et al*., 2007).

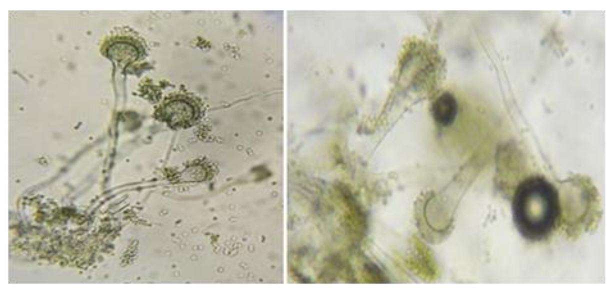

Plate 2: Photomicrographs of *A. fumigatus* showing the gross morphology and characteristic un-branched conidiophores and vesicle bearing uniseriate phialides and conidia (×400)

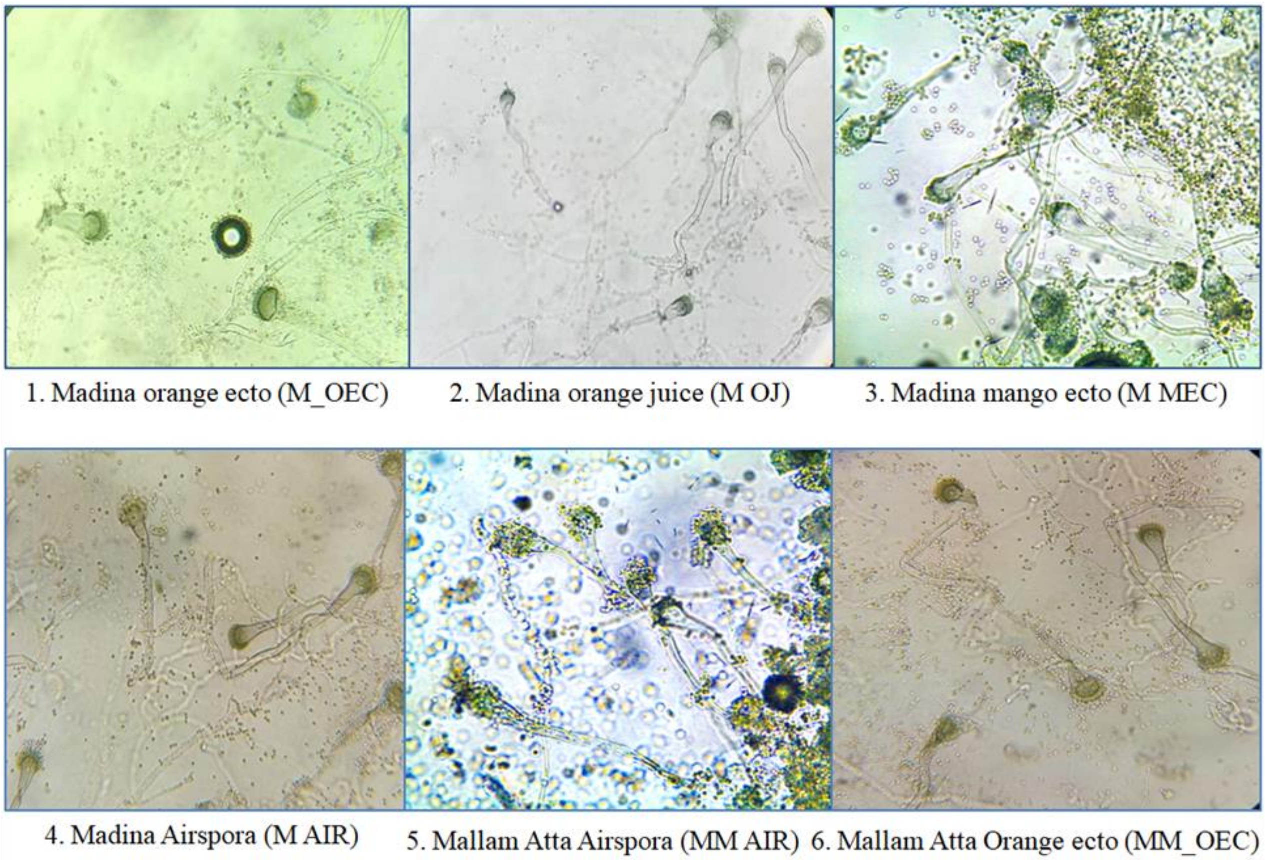

Plate 3: Photomicrographs of *Aspergillus fumigatus* culture showing variation in conidiophore morphology, vesicle structure, and phialide arrangement from substrates sourced from different geographical markets (×400)

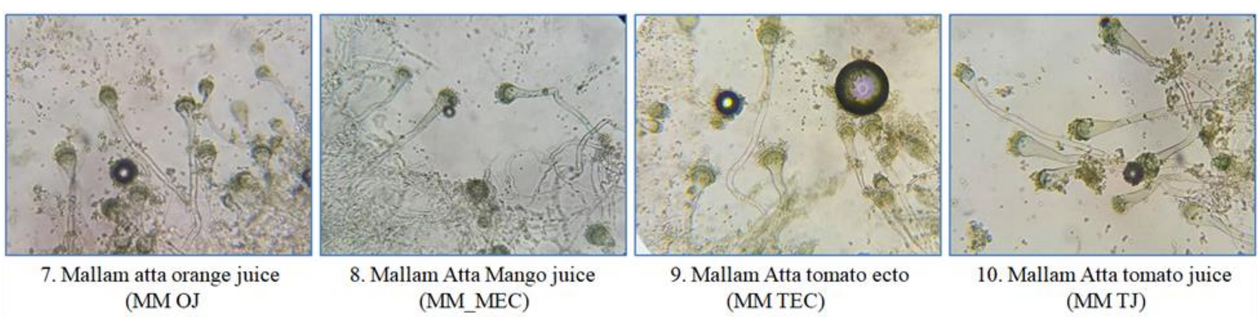

Plate 4: Photomicrographs of *Aspergillus fumigatus* culture showing variations in conidiophores morphology, conidial vesicles, and phialide arrangement from fruits (7-10) and dry cocoa bean testa (11) substrates sourced from different geographical markets, including Breman Asikuma, Central Region

2.2 Pathogenicity test and disease progress curves

This was carried out by using the conventional direct wounding method. Fruit samples without blemish were first obtained from a stock and thoroughly washed with sterile distilled water. The fruits were placed in 5-litre transparent rectangular plastic bowls and then covered. To augment the sterility of the chamber created by the plastic bowls, sterilized paper towels were laid at the base (bottom) of the plastic bowls, and the cleaned sterile fruits were arranged on top of the sterile paper towels moistened with sterile distilled water.

A cork borer of diameter 5 mm was used to excise plugs of the culture of the pathogen which was then transferred by inoculation into each fruit sample in triplicates. The bowls with the inoculated fruits were covered and incubated at 28 ± 2 °C for 7 days. Measurements were made daily to determine the diameter of the developing lesions and monitor disease progression to monitor the progression and severity of the infections. The data obtained were presented in **Fig. 1** and **Plate 5**.

2.3 Area Under the Disease Progress Curve (AUDPC)

The Area Under the Disease Progress Curve, AUDPC, is a metric used in Plant Pathology to combine multiple observations of disease progress into a single value described by Simko and Piepho (2012). It is a quantitative measure used to integrate disease severity data collected at multiple time points into a single value, reflecting both the intensity and duration of disease progression. The calculation follows the trapezoidal rule, as described by Madden and Campbell (1990):

$$\text{AUDPC}=\sum_{(i=1)}^{(n-1)}[[\frac{Yi+Y(i+1)}{2}]\times(T_{(i+1)}-T_i)]$$

Where:

- Y_i = Disease Severity at time T_i
- T_i = Time of disease severity recording
- n = Total number of observations

(Madden, and Campbell, 1990)

NB: This formula represents the trapezoidal integration of the disease progress over time, providing a reliable means to compare disease dynamics across different treatments, cultivars, or management strategies.

The fruits variations used for this study of disease progress curves (DPC) and area under disease progress curves (AUDPC) were:

a. Saloon mangoes or Sierra Leone mangoes; a specialized, highly regarded variety known in

Ghana. They are noted for being green on the outside but soft, succulent, and very sweet inside, sometimes with a strong aroma. While often associated with Sierra Leone, these mangoes are part of the broader improved variety market (including Kent and Keitt) cultivated in West Africa. These mangoes are often described as succulent, aromatic, and sometimes "watery" but intensely sweet, favoured by many in Ghana as a premium variety.

Anecdotal evidence suggests that this variety was brought back to Ghana by exiled Ashanti chiefs returning from Sierra Leone during the colonial era. In the Ghanaian market, they are frequently referred to as "saloon mangoes" which serves as a term for high-quality improved mango types such as Kent, Keitt and others. These mangoes are abundant in March–August (Komayire, 2017).

b. Late valencia Oranges

They are prominent, late-maturing, sweet orange grown in Ghana particularly in the Eastern Region, known for its high and sweet juice content and quality. They are crucial for extending the citrus season and are often cultivated on rough lemon rootstocks to improve yield. Late Valencia is a key commercial citrus variety found in the Kwaebibirem District and Okumanin in the Eastern Region. They are excellent juicy oranges that thrives in Ghana's tropical climate. In Ghana these are abundant at Achiase.

c. Roma VF Tomato

This popular plum tomato is used for canning and tomato paste production because of its slender, firm texture. It is commonly found in supermarkets. This tomato is usually grown in Upper East, Navrongo in the Northern Region of Ghana.

3. Results and Discussion

3.1 Disease Progress Curve (DPC's)

The disease progress curves (DPC's) obtained showed the intensity of the disease over time on each of type of fruit. DPC's are key tools for understanding how pathogens, hosts, and the environment interact to cause progress of disease on a particular plant or its products. The most common form is linear (rare and only early ones), exponential (common in the beginning), saturation or monomolecular / monocyclic exponential.

Results from the experiment showed that the disease progress curves obtained for mango, orange and tomato, using *A. fumigatus* as pathogen, were in each instance a sigmoid saturated curves characteristic of a monocyclic pathogen (**Fig. 1**). A monocyclic disease is caused by a pathogen that completes only one infection cycle during a growing season. Soil-borne pathogens like *A. fumigatus* are typically monocyclic in nature e.g., tomato wilt and cotton wilt, and are also known as simple interest disease.

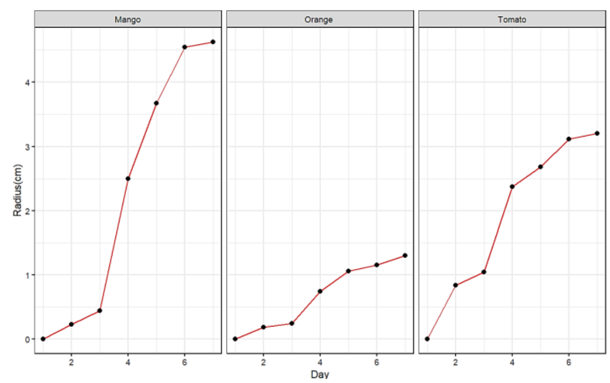

Fig. 1: Disease Progress Curves for Mango, Orange, and Tomato Fruits over a seven-day incubation period at 28 ± 2 °C showing the typical sigmoid curve of monocyclic disease.

Results in this present study showed significant differences ($p \leq .05$) between the infection and susceptibility of the fruits to the pathogen (**Plate 5**).

Plate 5: Photographs showing arrangement of uninfected fruits (left): top: oranges, middle: tomatoes, bottom: mangoes. The same arrangement is shown (right) of the extent of spread of *A. fumigates* infection after incubation for 7 days at 28 ℃ (×0.5).
NB: ** Arrows indicating the growth of *A. fumigatus* on fruit samples.

The pathogen grew faster on mango the peel attaining a diameter of 4.5 cm (45 mm) in 7 days. This was followed by tomato with a diameter of 3.25 cm (32.5 mm) over the same period of 7 days. Visual observations showed that mango and tomato samples were the most severely affected and turned softer by the inoculation of *A. fumigatus*.

3.2 Area Under Disease Progress Curve (AUDPC)

The Area Under Disease Progress Curve is a criterion or metric often used in plant pathology to combine multiple observations of disease progress into a single value. **Fig. 2** shows the graphical presentation of the AUDPC for the three types of fruit (mango, orange, tomato) after infection by *A. fumigatus* for 7 days.

The highest AUDPC value was obtained with the data on disease progress of the mango infection (13.68 cm) followed by tomato (AUDPC 11.17 cm); the least infected was orange with a calculated AUDPC of 3.98 cm. The higher values of AUDPC 13.69 cm with mango reflected the highest disease severity values for the three test fruits. Statistical analysis showed that disease progression in mango and tomato was significantly more severe and rapid ($P \leq 0.05$) with a p-values of 0.0104 on mango and tomato than an orange.

The observation agrees with the same trend obtained using the Disease Progress Curve of *A. fumigatus* (**Fig. 2** and **Plate 5**).

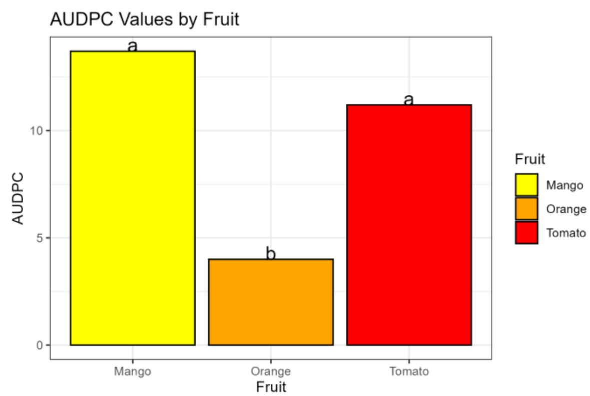

Fig. 2: A graphical comparison of Disease Severity (AUDPC) among Mango, Orange, and Tomato fruits infected with *A. fumigatus* for 7 days at 28 ± 2°C

Generally fruits and vegetables are essential components of the human diet containing nutrients and vitamins necessary for growth and longevity. They therefore provide a rich source of vitamins, minerals, fibers, antioxidants *etc*. It is also well-known that the consumption of fruits and vegetables has been consistently associated with a reduced risk of chronic diseases and illnesses including cardiovascular diseases, cancers, and diabetes (Slavin & Llyod, 2012). Fruits and vegetables also are primary sources of vitamins (C and A), folic acid, minerals (potassium, magnesium, calcium) etc. (Twum-Dei *et al*., 2026).

The oranges used in these experiments were the Late Valencia variety in Ghana cultivated on the Eastern, Western, Western North, Central and Greater Accra Regions. They contain powerful antioxidants that play roles in immune function, skin health and absorption of iron from plant-based foods (Carr & Maggini, 2017). Beyond vitamin C, oranges also contain a variety of other nutrients including fiber, folate and potassium, which contributes to heart health by helping to lower blood pressure and cholesterol levels (Potter & Hotchkiss, 1998). The presence of flavonoids like hesperidin in oranges further enhances their cardiovascular benefits by improving blood vessel function and reducing inflammation (Erlund, 2004).

Our markets are replete with Valencia oranges between March to June/July (Opoku & Asare, 2023). But these are stacked or piled in the open stalls under the vicissitude of the prevailing weather and sometimes accentuated by the covering with tarpaulin cloth to aggravate the quick rotting of the fruits by biodeterioration agents especially fungi of the genera of *Aspergillus*, *Penicillium*, *Fusarium* which invade damaged or over-ripened fruits under the humid and poorly ventilated conditions, leading to decay and spoilage. In many farmland settings, where oranges and mangoes are cultivated, the access roads are in poor conditions and the harvested produce is kept on-farm stacked into a pyramidal shape covered by either palm tree fronds, plantain fronds or where affordable by cloths made into a tarpaulin. Aeromycoflora can rapidly colonize harvested produce under favourable environmental conditions.

The Disease Progress Curve (DPC) reflects the intensity of a plant disease and shows how the pathogens, hosts and the environment interacts to cause disease in plants. The disease progress curves obtained in the study for mango, orange and tomato (**Fig. 1**) were sigmoid or S-shaped implying a monocyclic disease caused by the pathogen used (*Aspergillus fumigatus*) in a single cycle. Such curves are also known as simple interest disease. There were, however, significant differences ($P \leq 0.05$) between the infection and susceptibility of the fruit to the same pathogen. For example, infection of orange was slowest, followed by mango and tomato in the order: orange (12.0 cm^2) > tomato (32.5 cm^2) > mango (45.0 cm^2) in 7 days of incubation using DPC trend. Virtually, mango and tomato seem to be worst affected and covered by *A. fumigatus* growth (**Plate 4**). The Area Under Disease Progress Curve (AUDPC) confirmed the trend. The AUDPC used in plant pathology combines multiple observations of disease progress into a single value (Simko & Piepho, 2012) (**Fig 2**). Data in descending order of Mango (13.69 cm) > Tomato (11.17 cm) > orange (3.98 cm) in 7 days using AUDPC.

Statistical analysis shows that the infection in mangoes and tomatoes was statistically more severe and faster ($P \leq 0.05$) with a p-value of 0.0104 on orange and tomato than on orange. This was in agreement with the DPC in **Fig. 1**.

The difference in the severity of infections was due to the structure of the orange peel (pericarp) *i.e*., it is three layered the:

i. Exocarp (flavedo, outer layer). This is the colourful outermost layer which contains carotenoid pigment and oil glands. Its function is to act as a formidable physical barrier from fungal / microbial attack and damage (Opoku & Asare, 2023)

ii. Mesoderm (albedo or middle layer). This is the spongy, white and fibrous layer beneath the exocarp. It acts to reinforce the physical barrier defense against attack (Opoku & Asare, 2023).

iii. The Endocarp (Inner layer enclosing the juice): This is the thin membrane layer that surrounds the juice vesicles and internal fruit pulp (Opoku & Asare, 2023).

Again the disease severity using AUDPC was ranked: Mango > tomato > orange with corresponding AUDPC values (13.69 cm), (11.17) and (3.98 cm) respectively.

This observation agrees with the Disease Progress Curve, DPC. Clearly the orange contains essential nutrients for the growth and spread of *A. fumigatus* (e.g., Vitamin C, Vitamin A, Fibre, K^+, Ca^+, thiamin, anti-oxidants, Vitamin B complex, fructose, glucose, *etc*.). However, the formidable structure of the orange peel apparently prevented total invasion in 7 days.

Tomatoes are universally regarded as being the most popular and widely consumed vegetable globally and has anticancer properties because of lycopene in the peel. The fruits are perishable with high water content. It contains Vitamins C, E, β-carotene and flavonoids as well as glucose and sucrose; it also contains dietary fibre, pectins, protein, oil, antioxidants, K, Na, Ca, Mg, Zn, Fe, Mn, Cu, Cr, Ni, Co, and carotenoids (Bolaño *et al*., 2024). The one epidermal layer is hydrophobic covered with cuticle formed from polyhydroxy cutin. The rich nutrients in the tomato can support growth of fungi once the peel has been breached. It is not surprising that one single layered hydrophobic peel with cutin is broken by fungal attack was unavoidable.

Mango has a peel which is edible, nutrient dense and rich in fibre, antioxidants (polyphenols, carotenoids), Vitamins A, B6, C, E as well as K, Calcium (Winkler, 2025). Mangoes offer anti-inflammatory, antimicrobial and potential anticancer properties, supporting heart health and digestion. Peels can be utilized in teas, smoothies, pickles and peels are lined by thin fibrous layer enclosing the hard stone seed with the delicious golden juicy nutrients that contain mangiferin, which helps manage blood sugar with anti-inflammatory benefits. The skin is single-layered, thick and bitter.

The carriage of tomatoes for marketing is different for example, after harvesting on-farm, the fruits are packed in wooden boxes or baskets with little ventilation. By the time tomatoes arrive at the market gate in trucks, about 5–10% have been damaged by weight and fraction causing a de-novo infection by the aeromycoflora. The traders in some instances try to separate whole fruits from blemished ones in order to sell at reduced prices. The problem is accentuated by the lack of on-site cold storage facilities to preserve the healthy ones. In some instances, the "damaged ones are kept alongside leading to early biodeterioration of healthy ones as well.

Fungal mycotoxins are toxic secondary metabolites produced by moulds. The main mycotoxin-producing genera are *Alternaria*, *Aspergillus*, *Fusarium*, and *Penicillium* (Moretti, 2016) that contaminate crops such as cereals, nuts, spices, fruits and vegetables. Mycotoxins are heat-stable compounds that cause serious debilitating health issues ranging from acute poisoning to cancer in humans and livestock via ingestion or inhalation (Kushwaha *et al*., 2025). Favourable environmental factors such as humid conditions and availability of nutrients can cause toxins to be produced or imparted into crops, fruits and vegetables at harvest and improper storage. Common types of mycotoxins are aflatoxins (*Aspergillus flavus*, *A. parasiticus*), Fumonisins and trichothecenes (*Fusarium moniliforme*, *F. alcutacus etc*.); Ochratoxins (*Aspergillus ochraceus*, *Penicillium etc*.); Gliotoxin, Fumigallin, Tremorgenic Acid (*Aspergillus fumigatus*.

Aspergillus fumigatus used in this study is a saprophytic fungus that plays an essential role in the recycling of environmental carbon and nitrogen owing to its preponderance in the soil surviving and growing on organic debris (Abdolrasouli *et al*., 2015). It is ubiquitous causing Invasive Aspergillosis (IA) (Arastehfar *et al*., 2021) and about 90% of human infections like chronic lung disease (pulmonary aspergillosis) that can involve multiple invasion of organs. (Drummund, 2021). Interestingly, *A. fumigatus* is the most important pathogenic species of the genus *Aspergillus* (Sugui *et al*., 2014). Incidentally, *A. fumigatus* was the most prevalent *Aspergillus* species found infesting vegetables in the Metropolitan Markets of Accra (Danso, 2021).

A. fumigatus produces several mycotoxins of human health importance. For example, gliotoxin is a potent immunosuppressive agent that inhibits the function of immune cells e.g., neutrophils and macrophages, facilitated by the fungus ability to invade host tissues. It is also linked with cytotoxic effect on astrocytes in the brain. Fumagallin is an alkaloid mycotoxin produced by *A. fumigatus* that acts as an angiogenesis inhibitor. It is used in beekeeping to treat infections in honey bees but is highly cytotoxic and genotoxic to humans. The third mycotoxin produced by *A. fumigatus* is helvolic acid - a steroid antibiotic that exhibits cytotoxic activity and has been shown to inhibit the oxidative burst of macrophages in man. The fourth mycotoxin associated with *A. fumigatus* is tremorgenic toxins e.g., verruculogen, fumitremorgins B and C. These affect the central nervous system (CNS) causing tremors and convulsions in animals. Finally, other mycotoxins like Fumiclavine A, Trypacidin and Pseurotin A, are formed by some strains of *A. fumigatus* (Reduly *et al*., 2020).

Wiafe-Kwagyan *et al*. (2019) assessed the microbiological load and safety of selected pre-cut fruits and vegetables sold at two major markets in Accra-Ghana; Madina, and Makola. They isolated fungi such as *A. fumigatus, A. flavus, A. niger, A. candidus, A. parasiticus, A. oryzae* and *A. terreus* from mango, pawpaw, okra and cocoyam leaves. Danso (2025) recently reported that *A. fumigatus* could be isolated from the extracted juice of oranges and mangoes and ectoderm of fruits purchased from two markets (Mallam Atta; Madina) in the Greater Accra Region. Although mycotoxin analysis for *A. fumigatus* was not conducted, it gives credence to the fact that infected fruits that are stored in the markets could be laden with mycotoxins. There is another habit of market women, traders and their consumer client. Often, the infected portion of the fruits are severed and the healthy parts are eaten. This may lead to unintended mycotoxicosis of consumers and an irreversible health hazards.

Postharvest losses of fruits and vegetables represent one of the most pressing challenges for global food security and environmental sustainability. The global postharvest losses ranged between 20% and 40% (Rizzo, 2025; Ullah *et al*., 2025) with approximately $1 trillion dollars annually before reaching the consumers. This corresponds to over one-third of food intended for human consumption (Palumbo *et al*., 2022), creating significant impacts on economic stability, environmental health, and resource efficiency. Such losses are particularly severe in low- and middle-income countries (LMICs), where limited infrastructure and inadequate cold-chain systems often push losses above 30% (Oyewole *et al*., 2025; Verma *et al*., 2025). Sub-Saharan Africa faces up to 37% of losses in perishables severely impacting food availability.

The primary causes in Sub-Saharan Africa are, one, the inadequate storage facilities (*e.g*., lack of proper ventilation and cold storage) coupled with the poor handling before and after harvesting. Bruising fruits, vegetables and other perishables cause up to 76% losses in developing countries. Two, the routes leading to the farms and back are of poor quality accentuating the high perishable pace and physical damage. Three, rodents, insects, fungi cause damage before and after harvesting and the packaging devices and boxes leave much to be desired. Tomatoes, especially by their fragile nature, require proper packaging to preserve the integrity of the pericarp. In Africa, (including Ghana) 120 – 170 kg of food is lost per person annually, particularly affecting mangoes, tomatoes, oranges. Incidentally retail losses are high in fruits, vegetable, pawpaw, papaya in Ghana.

Aspergillus fumigatus was used as the test fungus in this study because of its ubiquitous nature and ability to tolerate a wide range of temperatures (20 °C to 52 °C) (Sugui *et al*., 2014). Its preferred pH range for growth is pH 2.1 – pH 8.8 (Sugui *et al.*, 2015). The substrates used for our studies are those commonly infected by *A. fumigatus* in supermarkets such as carrots, cabbages, onions, mangoes, tomatoes, oranges etc. (Saleh & Al-Thani, 2019; Mailafia *et al*., 2017).

The sigmoid disease progress curves obtained by DPC and AUDPC confirmed that the infection was a monocyclic disease pattern; but there were significant differences ($P \leq 0.05$) in the levels and susceptibility to the same pathogen. The highest Area Under the Disease Progress Curve AUDPC was recorded by mango (13.69 cm) followed by tomato (11.7 cm) and least in orange (3.98 cm). The severity of the infection could be classified as: mango > tomato > orange.

Assuming the fact that the intrinsic nutrients in mango, tomato and orange were sufficiently to support growth and dissolution enzymes for degradation of cell walls, the formidable three-layered structure of the orange peel (ectoderm, mesoderm and endoderm) apparently slowed down and prevented more invasion and advancing of the rot in 7 days.

Release of potent mycotoxins into foods contaminated by fungi is a potential health hazard to consumers. Although the mycotoxins produced by the growing *A. fumigatus* was not analyzed in this paper, their presence cannot be discounted. There are health implications for purchasing spoiled or decomposing mangoes, tomatoes and oranges including other stored fruits and vegetables (Wiafe-Kwagyan *et al.*, 2019). Potential toxin-producing species such as *Aspergillus flavus* (aflatoxins B1, B2, G1, G2, M1, *etc.*) may have immunosuppressant properties and are liver carcinogens. *A. alutaceus* (fr. *A. ochraceus*) produces ochratoxins, a nephrotoxin (which causes kidney failure). *Penicillium digitatum* produces patulin which has toxic effect on plants and animals with a role as carcinogen. *Fusarium verticillioides* (produces fumonisins) implicated in the induction of esophageal cancer in man and *Cladosporium* spp. producing several mycotoxins such as epi-cladosporic acid which causes Alimentary Toxic Aleukia (ATA) to mention but a few. It is therefore prudent to avoid disease by not purchasing and eating contaminated perishables fruits and vegetables often sold at a cheaper rate at the markets.

Quality control agents and authorities in the food quality standards must intensify efforts to help mitigate future health hazards due to consumption of contaminated foods due to mycotoxins (Odamtten, 2018). In developed countries, goods are categorized into Classes A, B, or C (depending on quality or blemishes), with pricing always being higher for Class A products. However, this practice may be difficult to implement in developing countries, where such categorizations are rarely followed. Therefore, to avert these potential hazards on fruits and vegetables strict good hygienic practice in combination with Hazard Analysis and Critical Control Point (HACCP) should be adhered to at all levels (Wiafe-Kwagyan *et al.*, 2019). Finally, there are about 180 species of *Aspergillus* (Bhetaria *et al.*, 2016) and they differ in micro- and macro-morphological features as well as molecular characteristics. The same is true for the *A. fumigatus* variants (Samson *et al.*, 2007). Only one variant of *A. fumigatus* was used in this report. Our sequel paper will provide information on the occurrence of *A. fumigatus* in the aeromycoflora of Ghana, their micro - and macro -

morphological features as well as their molecular characteristics.

4. Conclusion

The study demonstrated the pathogenic potential of *Aspergillus fumigatus* isolates from the aeromycoflora of markets in Accra, Ghana, on fruits such as mango, tomato, and orange. The Disease Progress Curve (DPC) and Area Under the Disease Progress Curve (AUDPC) revealed significant differences in the susceptibility of these fruits to *A. fumigatus*, with mango showing the highest level of infection, followed by tomato and orange. The results suggest that the three-layered structure of the orange peel provides some protection against fungal invasion, slowing the progression of the rot. These findings emphasize the need for effective postharvest management strategies to reduce fungal contamination and mitigate food loss, particularly in regions like Sub-Saharan Africa where food security is a major concern.

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