https://doi.org/10.26682/ajuod.2022.25.1.8
Journal of University of Duhok., Vol. 25, No.1 (Agri. and Vet. Sciences), Pp 66-78, 2022

MANAGEMENT OF FUNGAL POSTHARVEST DISEASES OF APPLE AND PEAR USING PLANT EXTRACTS

AZHEN **M**. **H**ASAN, **Q**ASIM **A**. **M**ARZANI and **D**LEEN **N**. **A**BDULRAHMAN
Dept. of Plant Protection, College of Agricultural Engineering Science, University of Duhok, Kurdistan Region-Iraq

(Received: June 20, 2021; Accepted for Publication: February 3, 2022)

ABSTRACT

Economic losses, due to postharvest pathogens in markets and storages, are magnificent. *Alternaria alternata* and *Penicillium expansum* are considered the most important postharvest pathogens of apple and pear fruits. This work was aimed to investigate the principal pathogens on apple and pear fruits, the pathogenicity of the main pathogens, and assess of *in vitro* and *in vivo* efficacy of peel extracts of pomegranate, orange, and rutabaga against the main studied pathogens. The results of isolation designated *A. alternata* and *P. expansum* as major postharvest pathogens. The artificial inoculations of both pathogens resulted in the prominence of typical symptoms and the reisolation of the fungi proved Koch's postulates. The results of *in vitro* assay revealed the highest inhibitory effect of rutabaga peel extract followed by orange peel extract while the pomegranate peel extract showed the least efficacy against both fungi. Another key fact that noticed is that both rutabaga and orange peel extract were most efficient against *A. alternata* than *P. expansum*. The results of *in vivo* assays have approved that pomegranate peel extract was the most effective plant extract against both pathogens of apple and pear fruits.

KEYWORDS: Management, Postharvest Diseases, Apple, Pear, Plant Extract.

1. INTRODUCTION

Apple (*Malus domestica* Borkh) and pear (*Pyrus communis* L.) are two major fruits with high consumer demand. The economic value of these fruits is vulnerable to plant pathogens that limit the period of availability of the fruits and log-term storage (Droby, 2005; Zhu, 2006). The decay caused by fungal pathogens is considered the main impediment in fruit industry (Janisiewicz, 1996). The losses of apple and pear fruits are mainly caused by principal fungal pathogens such as *Penicillium expansum* (blue mould), grey mould caused by *Botrytis cinerea*, Mucor rot caused by *Mucor piriformis* along with some weak pathogens like *Phialophora malorum*, *Alternaria* spp., and *Cladosporium herbarum* which they tend to infect wounds and senescent fruits (Mari, Bertolini, & Pratella, 2003; Novotný, Lukáš, Brožová, & Ružicková, 2019; Pierson, Ceponis, & McColloch, 1971; Sutton, Aldwinckle, Agnello, & Walgenbach, 2014). *P. expansum* is commercially important both as a major spoilage fungus, and as the main source of the mycotoxin patulin, which occurs in apple and pear juice as the result of rotting fruit (Hocking, 2014). These fungal pathogens may attack fruits during handling, transportation, and storage. The up-to-date studies revealed that waste of total vegetable and fruit production may reach as much as 33 % (Gustavsson, Cederberg, Sonesson, Van Otterdijk, & Meybeck, 2011; Okawa, 2015).

Several methods have been followed to limit the damages caused by decay pathogens. Cool storage, coating, biological control, and drenching in fungicides, are among the most common control methods (David Sugar & Spotts, 1999). Cooling is considered a good method and may prolong the shelf time of fruits but it is adding additional cost to fruit value. Besides, due to inadequate cold storage and transportation amenities in developing countries, the losses often become more severe. Coating with some materials like wax is also not favorable for consumers. Several modes for fungistatic activities of microbial antagonists have been suggested to limit the fruit damages and to protect postharvest fruits but they are not successful at pre-harvest application. Furthermore, they need to combine them with different physical and chemical substances and methods (Dukare et al., 2019). The application

qasim.marzani@su.edu.krd

of fungicides, such as dipping has its problems and therefore are progressively restricted due to the toxicity to consumers, short protective activity, and appearance of fungicide resistance or loss of sensitivity to specific fungicides (D Sugar & Powers, 1986) besides the increasing concern for health hazards and environmental pollution (Paulitz & Bélanger, 2001; Tripathi & Dubey, 2004; Yourman & Jeffers, 1999).

With exploring consumer concerns, the necessity for finding natural alternatives to chemical-based fungicides, and changes in legislation, the use of natural products such as plant extracts become imperative that may provide a solution for both industry and consumers. Recently, attention has been paid towards the exploitation of higher plant products as novel botanical fungicides in postharvest diseases' management. The advantages of plant extracts, as natural fungicides, are being biodegradable, and not phytotoxic, and therefore, the discovery of new natural fungicides from the exploitation of higher plants can replace synthetic ones (Tripathi, Dubey, Banerji, & Chansouria, 2004).

There are many plant species with potential sources of antimicrobial compounds in which more than 1340 are known to have biocidal activity against microbes, and about 10000 species with secondary plant metabolites have been chemically defined for their role as antimicrobials (Cowan, 1999; Tripathi & Dubey, 2004). Plant extracts, as alternatives to synthetic fungicides, have been attempted against several pre and postharvest vegetables and fruits. Phenolic extracts from wild edible plants have been used to control postharvest diseases of sweet cherry fruit (Feliziani, Santini, Landi, & Romanazzi, 2013; Gatto, Sergio, Ippolito, & Di Venere, 2016). Essential oils from *Mentha arvensis*, *Ocimum canum*, and *Zingiber officinale* were used against *Penicillium italicum*, the cause of citrus rot were found to exhibit absolute fungitoxic activity against the test fungus (Tripathi et al., 2004). Interestingly, some fruits, like apples and pears, produce certain volatile compounds such as acetaldehyde that have inhibitory effects and are effective in postharvest control of *Penicillium expansum* (Caccioni, Blanco, & Folchi, 1994).

Pomegranate (*Punica granatum* L.) peel has high bioactivities of phenolic compounds (Balasundram, Sundram, & Samman, 2006; Guo et al., 2003; Tomás-Barberán & Espín, 2001). Compared to other pomegranate extracts, the peel extract is showing the highest antimicrobial activity against selected bacteria and fungi (Dahham, Ali, Tabassum, & Khan, 2010). Orange peel on the other hand also has the potential of antioxidant and antimicrobial activities due to having good total radical antioxidants (Gorinstein et al., 2001; Hegazy & Ibrahium, 2012; Mathur et al., 2011). In the same manner, rutabaga (Swedish turnip, *Brassica napus*) the cruciferous root plant, have received considerable attention for being a source of potential protective phytochemicals against human diseases (Cartea, Francisco, Soengas, & Velasco, 2011) and against plant pathogens in which some contain a group of sulfur-containing phytoalexins following infection with pathogens (Morrissey & Osbourn, 1999). Brassinin, for example, is of great interest in the interaction of crucifers with their fungal pathogens due to its biological activity (Seifbarghi et al., 2017; Sexton, Minic, Cozijnsen, Pedras, & Howlett, 2009). This work was aimed to assess the antifungal activities of extracts derived from peels of pomegranate, orange, and rutabaga against common postharvest pathogens on apple and pear fruits.

2. MATERIALS AND METHODS

Sample collection

Decayed apple and pear fruits, which exhibited symptoms, were collected from different storages and markets in Erbil City, packed into sterilized polyethylene bags, and then immediately transferred to the laboratory for isolation of potential pathogens of the diseases. Apple samples were red, yellow, and green while the pear samples included the local pear and imported pear fruits.

Isolation of potential apple and pear pathogens

Potato dextrose agar (PDA) medium containing penicillin (50 mg L^{-1}) and streptomycin (150 mg L^{-1}) was used for fungal isolation. Fungal pathogens were isolated through surface sterilization technique described by (Abo-Elyousr, Abdel-Hafez, & Abdel-Rahim, 2014). Specimens showing rot and discolored symptoms were rinsed in tap water for 30 minutes and then surface sterilized with 70 % ethanol. Under a laminar airflow chamber, infected lesions were detached from fruits. The isolations were based on two pathways, those with vegetative structures of accompanying fungi were directly transferred from colonies on

the fruit surface to PDA surface while in the second method, portions (5 X 5 mm) from the suspected samples were taken, surface disinfected with 1% sodium hypochlorite for 3 min, rinsed twice in sterilized distilled water, dried with briefly blotting in sterile filter paper and placed on the PDA surface. Cultures were incubated at 25^{o} C for 7 days, and for isolation, identification, and inocula production, the developed fungal colonies were further sub-cultured, purified, and then diagnosed depending on cultural and microscopical characteristics described by (Watanabe, 2010). The cultures were stored at 4^{o}C in PDA agar slants for later use.

Preparation of plant extracts

The plant extracts (PE) had been prepared from dried peel samples of pomegranate (*Punica granatum*), rutabaga (*Brassica napus* L.), and orange (*Citrus sinensis*) in which 10 grams were ground into a fine powder using a stainless-steel grinder, placed in Erlenmeyer flasks contained 100 mL of 95% ethanol and were then placed in a shaker for 24 hours. The flasks were placed on a magnetic stirrer for 20 min then the mixtures were centrifuged at 12000 g for 20 min. The supernatant was separated using filter paper (Watman 5B). The extracts were concentrated by evaporation using a rotary vacuum evaporator at 40^{o} C by utilizing a water bath until dense liquid-like material was prepared. The gummy extract of the total plant extracts contents was weighed and placed in a refrigerator for later use (Qasim Abdullah Marzani, Mohammad, & Hamda, 2021).

Pathogenicity test

Koch's postulates were conducted to prove the pathogenicity of the most predominant pathogenic fungi. To do this, healthy and uniform yellow apple (Golden Delicious) and pear (local) fruit samples without physical injuries or disease infection, were sterilized by soaking in ethanol 70% for 3 minutes, washed with sterilized distilled water then kept to dry under room condition (Q. A. O. MARZANI, 2003). Using a sterilized cork-borer, each fruit was wounded (5 mm diameter and 3 mm deep) at a rate of 2 wounds per fruit at opposite equatorial lines of each fruit. Each wound site of the fruits is inoculated with a 5 µl spore suspension. Control fruits were treated the same way, but sterile distilled water was placed in wounded sites. The inoculated fruits were placed in sterilized transparent bags to retain moisture and then incubated at 25^{o}C for 2 weeks. The symptoms that appeared, along with the re-isolated fungal pathogens, were compared with that of previously observed on infected fruits.

***In vitro* bioassay of plant extracts**

The *in vitro* assay was conducted by utilizing the stock solution of each of pomegranate peel extract (PPE), rutabaga peel extract (RPE), and orange peel extract (OPE), in which 2 g of each of them was added to 10 mL of dimethyl sulfate (DMS) and from which three concentrations were prepared. Preparation of serial concentrations was according to the method used by (Qasim Abdulla Marzani, 2011). According to the procedure, PDA at 55^{o}C was amended with three concentrations of plant extracts (200, 400, 600 mg/L) with continuous agitation while pouring to ensure even distribution in the Petri plates. After agar solidification, the amended media were inoculated using a sterile cork-borer, with circular mycelium plugs of 5 mm at a rate of 5 plates per concentration. The experiment was a complete randomized design with 5 replicates. The untreated control was 5 fresh PDA plates filled with unamended PDA and inoculated in the same way. The mycelial plugs were placed face-down on the centre of the wells and then incubated in the dark at a temperature of 25^{o}C ± 2. The growth of each fungus was monitored daily until the fungus in unamended control plates reached the edge of the plate. The radial growth of each fungus was determined using digital caliper at two different angles at 90^{o} to each other and the mean calculated. After a deduction of 5 mm was made to account for the mycelium plug, percentage inhibition for each treatment and at each concentration was calculated relative to the untreated control according to the following formula:

Growth inhibition (%) = [(C-T)/C] ×100

Where:

C = fungal growth of unamended control

T= fungal growth of each treatment

***In vivo* bioassay of plant extracts**

The activity of plant extracts was assessed in vivo on fresh apple (yellow) and pear (local) fruits. Each fruit was wounded with a sterilized cork-borer (0.5 mm) at a rate of 2 wounded per fruit. The inocula of isolated fungi were prepared, as spore suspension, from 7-day old fungal cultures grown on PDA in 9 cm Petri plates. The spore suspensions were prepared by adding 10 mL of sterilized distilled water to the surface of each plate, conidia were carefully scraped with a sterilized metal loop and the resulting conidial suspension was used for

inoculations. The concentration of the conidial suspension was adjusted to 1 x 10^5 conidia/mL using a Haemocytometer. Five microliters of each conidia suspension were added to each wound and left for 1 hour then 100 microliters of each plant extract (with the concentration of 600 mg/mL) were added to the inoculated wound. The fruits were covered with sterilized transparent bags, sealed, and placed at 25^{o}C in an incubator. The experiment was a complete randomized design with 5 replicates. Rot progression was measured on days 4, 5, and 6, and the efficiency of each PE was measured using the same formula of *in vitro* bioassay.

Data analysis

The results have been analyzed statistically and data were analyzed using general analysis of variance (ANOVA) and for comparisons, multiple range tests (P=0.05) were made using StatGraphics Centurion software.

3. RESULTS

Isolation

The investigation of potential fungi associated with postharvest diseases of apple and pear fruits revealed there was diversity in fungal pathogens. Thirteen species belonging to 9 fungal genera were isolated from 150 samples of mouldy fruits collected from different localities of Erbil markets. *Alternaria alternata* and *Penicillium expansum* were the most predominant genera that colonized the all studied apple and pear varieties (table 1). In which *Penicillium* represented 4 species, while Aspergillus represented 2 species, and the rest of the fungal genera were represented by one species only. All fungal species were classified according to the descriptions listed by (Watanabe, 2010).

Table (1): Fungi isolated from different apple and pear fruits in Erbil storages and markets.

No.	Isolated fungus	Apple			Pear	
		Red	Yellow	Green	Local	Imported
1	*Alternaria alternata*	+	+	+	+	+
2	*Phialophora malorum*	-	-	-	-	+
3	*Rhizopus stolonifer*	+	+	-	+	+
4	*Aspergillus falvus*	-	+	-	-	+
5	*A. niger*	+	-	-	+	-
6	*Botrytis cinerea*	-	+	-	-	-
7	*Cladosporium herbarum*	+	+	-	-	-
8	*Gloeosporium perennans*	-	-	-	-	+
9	*Mucor piriformis*	+	-	-	-	-
10	*P. digitatum*	-	+	-	+	-
11	*P. italicum*	-	-	-	-	+
12	*P. viridicatum*	+	+	-	-	-
13	*Penicillium expansum*	+	+	+	+	+

Note: (+): present, (-): absent

Pathogenicity test

Based on the results obtained in the isolation section, the most common genera that colonized apple and pear were *A. alternata* and *P. expansum* (table 1). Thus, the pathogenicity test was conducted for both fungi. The artificial inoculation of apple and pear fruits has led to the presence of typical symptoms on the samples. The symptoms were identical to those initially observed on the collected samples. The symptoms on apple fruits, due to the infections by *A. alternata*, were showed shallow lesions which normally covered with dark, olive green to black mycelial growth. The whole appearance and infected tissue become brown, while on pear fruits were with water-soaked lesions, turned dark brown, later on, penetrate deeply (1-2 cm) into fruit tissue, older symptoms were cracked and sunken (figure 1).

While the symptoms caused by *P. expansum* on both apple and pear fruits were watery and soft spots, light brown, and with the appearance of grayish-blue masses (coremial fruiting structures) representing fungal conidia appeared

on the fruit surface (figure 2). Both fungi, *A. alternata* and *P. expansum*, were re-isolated fom apple and pear inoculated with the fungi, completing Koch's postulates.

Fig, (1): Pathogenicity test of *A. alternata* on apple fruit (left) and pear fruit (right), exhibiting typical symptoms of alternaria rot. Note the brown color penetrating deep to fruit tissues.

Fig. (2): Pathogenicity test of *P. expansum* on apple fruit (left) and pear fruit (right), exhibiting typical symptoms of blue rot disease.

Bioassay tests

Based on the dominancy of both *P. expansum* (apple and pear blue mold) and *A. alternata* (apple and pear rot) during isolation and the pathogenicity tests, they were chosen for *in vitro* and *in vivo* bioassays.

***In vitro* bioassay**

In vitro growth of plant pathogens, was significantly ($P < 0.01$) inhibited by plant extracts. The efficacy of plant extracts on *A. alternata* was obvious. The RPE was the most efficient with the least fungal growth of 2.83 cm and inhibition of 63.63 % followed by OPE with radial growth of 3.39 cm and growth inhibition of 56.33 % (figure 3a and 3b). The concentrations were also exhibited significant ($P < 0.01$) effects on the pathogen's growth. Plant extracts at 600 mg/L were the most effective exhibiting the minimum growth of 0.58 cm and the highest inhibition of 92.49 % (figure 4a and 4b).

In the same manner, plant extracts also had significant effects on the *in vitro* growth of *P. expansum*. Similar significant effects were shown by RPE and OPE and were the most effective extracts compared to PPE, in which the fungal growth was 4.06 and 4.18 cm, and with the inhibition of 46.48 and 44.89 %, respectively (figure 5a and 5b). The differences among the concentrations were also significant ($P < 0.01$). None of the concentrations could eliminate the *in vitro* growth of *P. expansum*. However, the least fungal growth (2.44) and the highest growth inhibition (67.77 %) occurred at 600 mg/L (figure 6a and 6b).

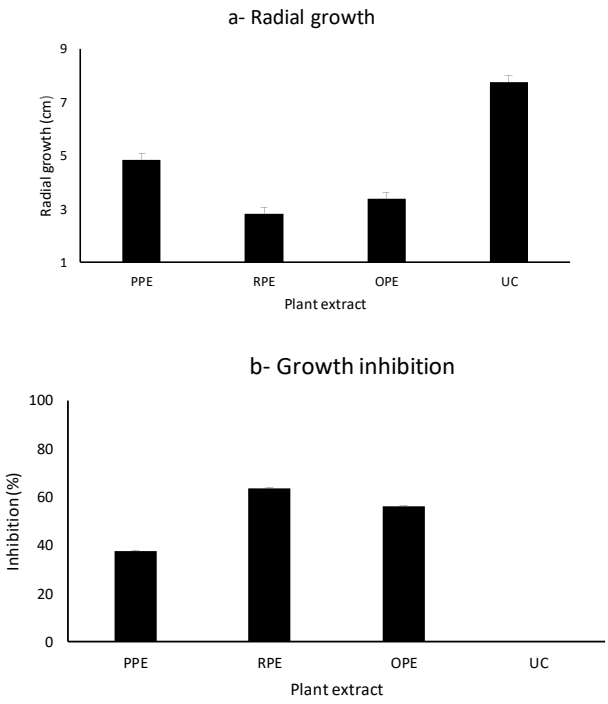

Fig. (3): *in vitro* assay of different plant extracts against *A. alternata*, where: a: radial growth, b: growth inhibition.

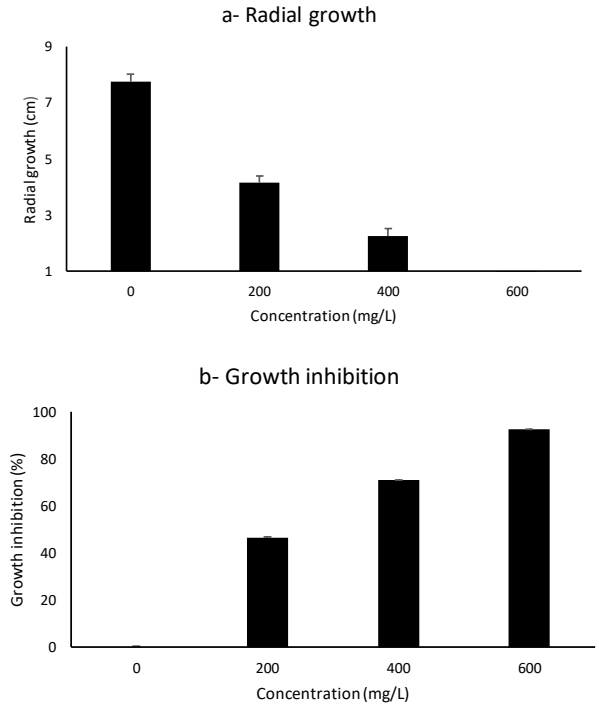

Fig. (4): *in vitro* assay of different concentrations of plant extracts on *A. alternata*, where: a: radial growth, b: growth inhibition.

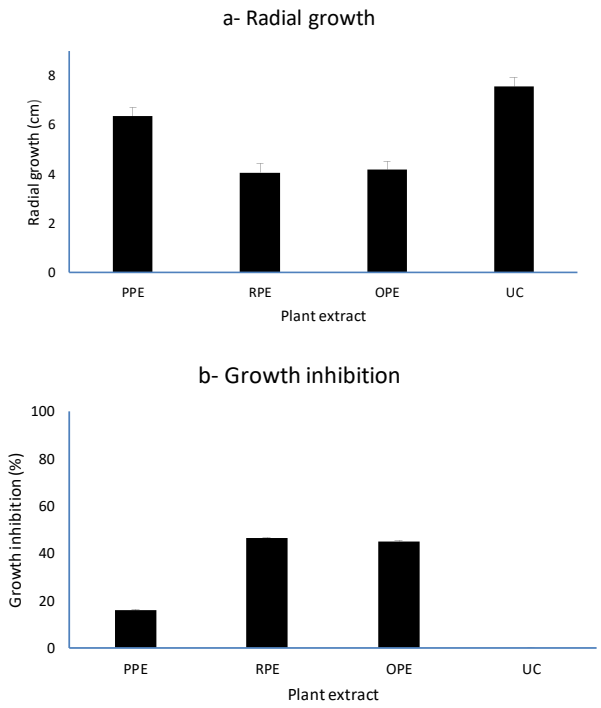

Fig. (5): *in vitro* assay of different plant extracts against *P. expansum*, where: a: radial growth, b: growth inhibition.

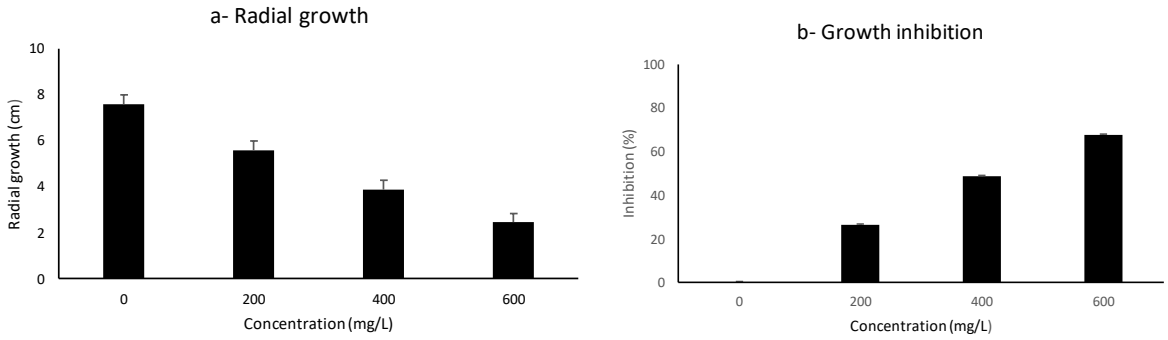

Fig. (6): *in vitro* assay of different concentrations of plant extracts on *P. expansum*, where: a: radial growth, b: growth inhibition.

***In vivo* bioassay**

The results of *in vivo* assays exhibited that the PE had different effects on the disease suppression on apple and pear fruits. On apple fruits, PPE decreased significantly the lesion progress caused by *P. expansum* (table 2). The rot diameter was 0.85 cm with the disease progression inhibition of 66.64 %. PPE was also effective against *A. alternata* on apple fruits, the lesion growth was as less as 0.63 cm and the inhibition achieved was 31.44 % (table 3). On both pathogens, however, OPE and RPE were less effective showing similar effects with no significant differences between them (table 2 and 3). On pear fruits, both PPE and OPE were superior on suppression of lesion development caused by *P. expansum* (table 4) but PPE, OPE, and RPE were showed similar effects on *A. alternata* with no significant differences between them (table 5).

The effect of the period of incubation was obvious on the disease progression. On apple fruits, on either *P. expansum* and *A. alternata*, a significant difference was found among the times of incubation. The highest lesion diameter occurred with the increase of elapsed time (at day 6) while the lowest was at day 4 (figure 7a and 7b). In the same way, on pear fruits, the progression of rots caused by both pathogens was also increased significantly with the increase of time (figure 7c and 7d).

Table 2: *in vivo* bioassay of PE against *P. expansum* on yellow apple fruits.

Plant extract	Rot diameter (cm)	Disease inhibition (%)	LSD (0.05)
PPE	0.85	66.64 ± 0.046	0.13
OPE	1.66	34.43 ± 0.080	0.13
RPE	1.72	31.97 ± 0.046	0.13
PC	2.53	00.00 ± 0.046	0.18

Abbreviations: PPE: pomegranate peel extract, OPE: orange peel extract, RPE: rutabaga peel extract, and PC positive control. Data represent means of 5 replicates ± standard error (SE).

Table 3: *in vivo* bioassay of PPE against *A. alternata* on yellow apple fruits.

Plant extract	Rot diameter (cm)	Disease inhibition (%)	LSD (0.05)
PPE	0.63	31.44 ± 0.031	0.089
OPE	0.72	21.52 ± 0.031	0.089
RPE	0.73	20.68 ± 0.031	0.089
PC	0.92	00.00 ± 0.055	0.125

Abbreviations: PPE: pomegranate peel extract, OPE: orange peel extract, RPE: rutabaga peel extract, and PC: positive control. Data represent means of 5 replicates ± standard error (SE).

Table 4: *in vivo* bioassay of PE against *P. expansum* on local pear fruits.

Plant extract	Rot diameter (cm)	Disease inhibition (%)	LSD (0.05)
PPE	1.56241	28.44 ± 0.050	0.140
OPE	1.67593	23.24 ± 0.050	0.140
RPE	1.88222	13.79 ± 0.050	0.140
PC	2.18333	00.00 ± 0.087	0.198

Abbreviations: PPE: pomegranate peel extract, OPE: orange peel extract, RPE: rutabaga peel extract, and PC: positive control. Data represent means of 5 replicates ± standard error (SE).

Table 5: *in vivo* bioassay of PE against *A. alternata* on local pear fruits.

Plant extract	Rot diameter (cm)	Disease inhibition (%)	LSD (0.05)
PPE	1.017	34.27 ± 0.051	0.143
OPE	0.99	36.13 ± 0.051	0.143
RPE	1.01	35.06 ± 0.051	0.143
PC	1.55	00.00 ± 0.088	0.203

Abbreviations: PPE: pomegranate peel extract, OPE: orange peel extract, RPE: rutabaga peel extract, and PC: positive control. Data represents means of 5 replicates ± standard error (SE).

qasim.marzani@su.edu.krd

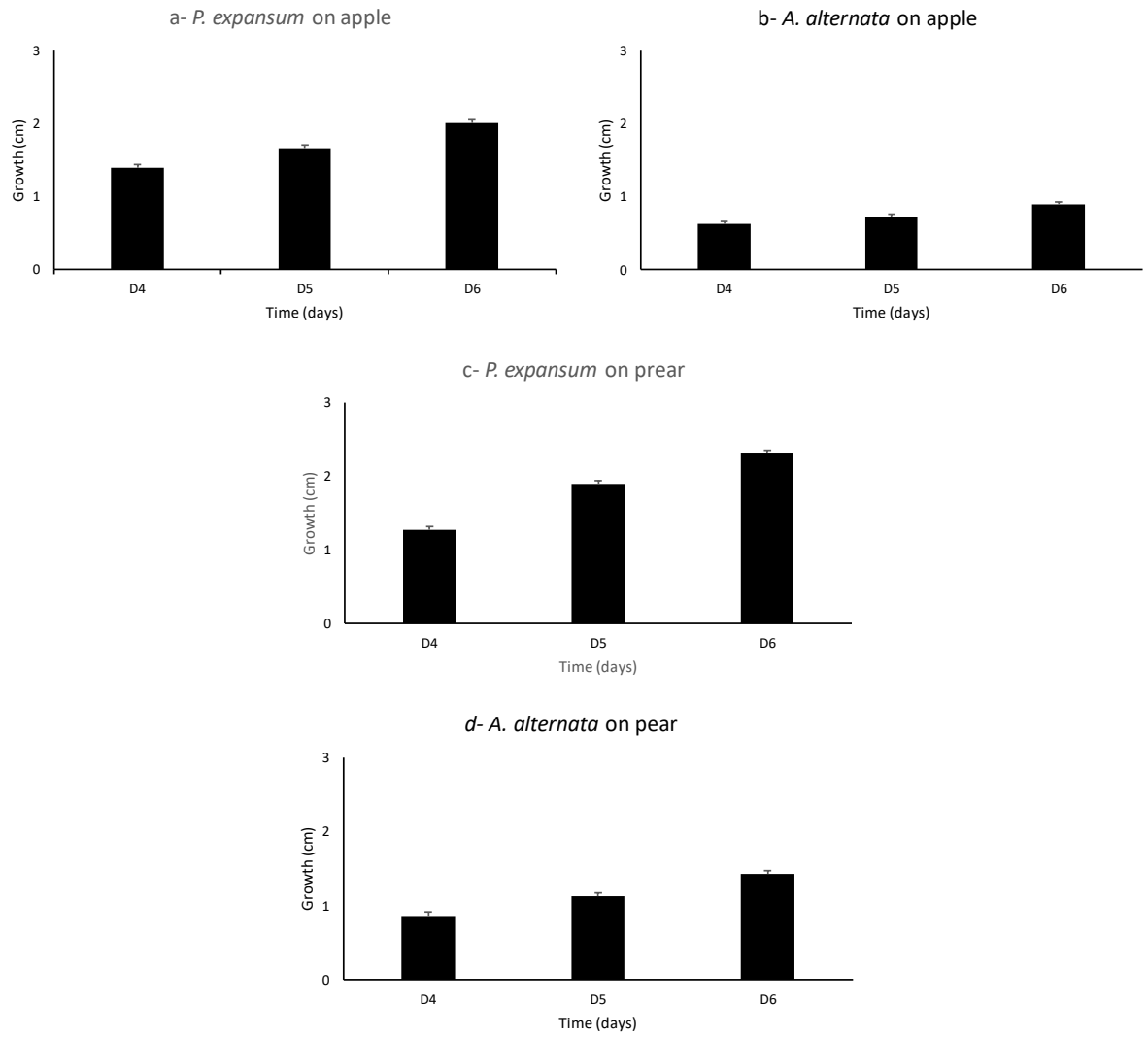

Fig. (7): Effect of PE on the progression of fungal growth in apple and pear fruits. The fruits were inoculated with pathogens inocula and then treated with PE. Lesion diameters on each fruit were recorded 4, 5, and 6 days after the inoculation, where: a: yellow apple fruits inoculated with *P. expansum*, b: yellow apples inoculated with *A. alternata*, c: local pear fruits inoculated with *P. expansum*, and d: local pear fruits inoculated with *A. alternata*.

4. DISCUSSION

The results of isolation exhibited that *A. alternata* and *P. expansum* were the principal genera that established all apple and pear varieties. Previous research has revealed that *P. expansum* is usually considered to be the most important species causing blue rot to apples and pears (Aldwinckle & Jones, 1990). Investigations of (Basson, Meitz-Hopkins, & Lennox, 2019) also found that *P. expansum* and *A. alternata* the major causative agents and most destructive postharvest fungi encountered in apples and pears.

The pathogenicity of *A. alternata* and *P. expansum* on apple and pear fruits was conducted successfully, in which typical symptoms appeared on both types of fruits. Infections by *A. alternata*, were exhibited shallow lesions which normally covered with dark, olive green to black mycelial growth. The whole appearance and infected tissue become brown. This is following the finding of (Jurick, Kou, Gaskins, & Luo, 2014), who isolated the fungus for the first time on apple fruits is Pennsylvania, USA, during cold storage. Water-soaked lesions caused by *A. alternata*, appeared on pear fruits, turned dark brown, later on, penetrate fruit tissue. Other investigations have

also found *A. alternata* infecting pear fruits with symptoms like the one described here or sometimes remain latent in the fruit peel during fruit development (Li, Bi, & An, 2007). Symptoms similar to our observation were also shown by (Abdel-Rahim, 2016) on the pear fruits naturally infected with *A. alternata* and on artificially infected fruits. the symptoms caused by *P. expansum* on both apple and pear fruits were very similar represented as watery and soft spots, light brown, and with the appearance of grayish-blue masses. The symptoms observed by (Vico, Duduk, Vasić, & Nikolić, 2014) were identical to those showed by the current study. *P. expansum* is a broad spectrum pathogen, it has been isolated from a wide range of other fruits, including tomatoes, strawberries, avocados, mangoes, and grapes, (Snowdon, 1990).

The results indicated that the selected plant extracts can effectively inhibit both postharvest pathogens in *vitro* and *in* vivo. In the *in vitro* assays, all PE showed antifungal activity against tested pathogenic fungi. However, different antimycotic activities of PE were noticed against *A. alternata* and *P. expansum*. The least growth (the most inhibitory effect) of both pathogens was achieved by RPE followed by OPE while the PPE showed the least efficacy against both fungi. Interestingly, it was further observed from the present study that both RPE and OPE were most efficient against *A. alternata* than *P. expansum* and this is may refer to the differences between both pathogens in the mechanism of infection and invasion. The investigations conducted by (Koka, Bhat, & Wani, 2020) also revealed the least inhibitory effect of the aqueous extract of pomegranate showed the least inhibitory effect against *P. expansum* but maximum activity against *A. alternata*. orange peel polyphenolic extracts at 1.5 g/L used by (Hernández et al., 2020) were also effective against *A. alternata* in which the total mycelial growth was achieved by the PPE. They also stated that varied effects were noticed at lower concentrations. Antifungal activity increased with the increased concentrations of plant extracts. However, higher concentrations proved more effective than lower concentrations. All PE used were most efficient at 600 mg/mL but this didn't result in total inhibition of these fungi.

The results of *in vivo* assays revealed the PPE, despite having the least activity in *in vitro* assays, was the most effective PE *in vivo* on both pathogens on apple and pear fruits. Previous studies also showed the powerful effects of essential oils incorporated-pomegranate peel fibers against mango postharvest pathogens (Nandhavathy et al., 2020), against apple decay caused by *P. expansum*, lemon decay caused by *P. digitatum* and *Penicillium italicum*, grapefruits by *P. italicum* (Nicosia et al., 2016).

Several antimicrobial compounds were found to have activity against microbes. Compounds such as glucosinolates (GLs) and isothiocyanates (ICs), for instance, have been paid attention recently by food science researchers who are seeking ways to recover them from bioresources and reutilize them as bioactive compounds due to their antimicrobial and health properties (Galanakis, 2020). In pomegranate peel, punicalagin isomers and bis-hexahydroxydiphenoyl-glucoside isomer were the most abundant phenolic compounds found in the extracts that demonstrate antimicrobial activity against fruit pathogens (Alexandre et al., 2019). Rutabaga, *Brassica napus* L., pulp, and peel extracts possess tyrosinase and glucosidase inhibitory activities together with moderate antioxidant ability. Results of (Stefanucci et al., 2020) show a high level of glucosinolates, in particular, neoglucobrassicin in the peel extract, which is supposed to have a potential antimicrobial application in crop protection. Biotransformations of some compounds in rutabaga, such as rapalexin A is resistant to fungal transformation, these fungal transformations have detoxifying reactions when combining with other phytoalexines that enable to protect against fungal pathogens (Pedras & Abdoli, 2017). The inhibitory activity of OPE may be attributed to an additive effect of phenolic acids, the ferulic acid and p-coumaric acid in particular, which have significant inhibitory capacity against *A. alternata* and other fungi in synthetic medium. Orange waste being an excellent source of anti-fungal compounds will suggest the possibility of using ferulic acid or ferulic acid-rich extracts, either alone or in

combination with other post-harvest treatment, as a natural alternative to reduce post-harvest losses and, also, enhance the shelf-life of fruit (Hernández et al., 2020).

5. CONCLUSIONS

Overall results of current work show that *A. alternata* and *P. expansum* are the most common pathogens of apple and pear fruits in storages and markets. Plant extracts investigated in this study, explains the feasibility of using them as alternatives to synthetic fungicides in combating postharvest pathogens. Although none of the PE could eliminate the diseases at the specific concentration of 600 mg/L they can play a magnificent role to reduce losses and prolong the shelf life of fruits.

6.REFERENCES

Abdel-Rahim, I. (2016). Control of Alternaria rot disease of pear fruits using essential oil of Viola odorata. *Journal of Phytopathology and Pest Management, 3*, 71-84.

Abo-Elyousr, K. A., Abdel-Hafez, S. I., & Abdel-Rahim, I. R. (2014). Isolation of *Trichoderma* and evaluation of their antagonistic potential against *Alternaria porri*. *Journal of Phytopathology, 162*(9), 567-574.

Aldwinckle, H., & Jones, A. L. (1990). *Compendium of apple and pear diseases*: APS press.

Alexandre, E. M., Silva, S., Santos, S. A., Silvestre, A. J., Duarte, M. F., Saraiva, J. A., & Pintado, M. (2019). Antimicrobial activity of pomegranate peel extracts performed by high pressure and enzymatic assisted extraction. *Food research international, 115*, 167-176.

Balasundram, N., Sundram, K., & Samman, S. (2006). Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food chemistry, 99*(1), 191-203.

Basson, E., Meitz-Hopkins, J. C., & Lennox, C. L. (2019). Morphological and molecular identification of fungi associated with South African apple core rot. *European Journal of Plant Pathology, 153*(3), 849-868.

Caccioni, D., Blanco, M., & Folchi, A. (1994). Prevenzione delle infezioni postraccolta da Penicillium expansum Link. su pere (cv Conference) con vapori di acetaldeide (Vol. 3, pp. 55-62).

Cartea, M. E., Francisco, M., Soengas, P., & Velasco, P. (2011). Phenolic compounds in Brassica vegetables. *Molecules, 16*(1), 251-280.

Cowan, M. M. (1999). Plant products as antimicrobial agents. *Clinical microbiology reviews, 12*(4), 564-582.

Dahham, S. S., Ali, M. N., Tabassum, H., & Khan, M. (2010). Studies on antibacterial and antifungal activity of pomegranate (Punica granatum L.). *Am. Eurasian J. Agric. Environ. Sci, 9*(3), 273-281.

Droby, S. (2005). *Improving quality and safety of fresh fruits and vegetables after harvest by the use of biocontrol agents and natural materials.* Paper presented at the I International Symposium on Natural Preservatives in Food Systems 709.

Dukare, A. S., Paul, S., Nambi, V. E., Gupta, R. K., Singh, R., Sharma, K., & Vishwakarma, R. K. (2019). Exploitation of microbial antagonists for the control of postharvest diseases of fruits: a review. *Critical reviews in food science and nutrition, 59*(9), 1498-1513.

Feliziani, E., Santini, M., Landi, L., & Romanazzi, G. (2013). Pre-and postharvest treatment with alternatives to synthetic fungicides to control postharvest decay of sweet cherry. *Postharvest Biology and Technology, 78*, 133-138.

Galanakis, C. M. (2020). Recovery techniques, stability, and applications of glucosinolates *Glucosinolates: Properties, Recovery, and Applications* (pp. 251-280): Elsevier.

Gatto, M. A., Sergio, L., Ippolito, A., & Di Venere, D. (2016). Phenolic extracts from wild edible plants to control postharvest diseases of sweet cherry fruit. *Postharvest Biology and Technology, 120*, 180-187.

Gorinstein, S., Martín-Belloso, O., Park, Y.-S., Haruenkit, R., Lojek, A., Ĉíž, M., . . . Trakhtenberg, S. (2001). Comparison of some biochemical characteristics of different citrus fruits. *Food chemistry, 74*(3), 309-315.

Guo, C., Yang, J., Wei, J., Li, Y., Xu, J., & Jiang, Y. (2003). Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay. *Nutrition research, 23*(12), 1719-1726.

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., & Meybeck, A. (2011). Global food losses and food waste: FAO Rome.

Hegazy, A., & Ibrahium, M. (2012). Antioxidant activities of orange peel extracts. *World applied sciences journal, 18*(5), 684-688.

Hernández, A., Ruiz-Moyano, S., Galván, A. I., Merchán, A. V., Nevado, F. P., Aranda, E., . . . Martín, A. (2020). Anti-fungal activity of phenolic sweet orange peel extract for controlling fungi responsible for post-harvest fruit decay. *Fungal Biology*.

Hocking, A. (2014). SPOILAGE PROBLEMS| Problems Caused by Fungi.

Janisiewicz, W. (1996). Ecological diversity, niche overlap, and coexistence of antagonists used in developing mixtures for biocontrol of postharvest diseases of apples. *Phytopathology, 86*(5), 473-479.

Jurick, W., Kou, L., Gaskins, V., & Luo, Y. (2014). First report of *Alternaria alternata* causing postharvest decay on apple fruit during cold storage in Pennsylvania. *Plant disease, 98*(5), 690-690.

Koka, J. A., Bhat, M. Y., & Wani, A. H. (2020). Allelopathic effect of leaf extracts of Punica granatum and Spiraea prunifolia against post-harvest rot of tomato and brinjal. *Journal of Drug Delivery and Therapeutics, 10*(2-s), 1-6.

Li, Y., Bi, Y., & An, L. (2007). Occurrence and latent infection of alternaria rot of pingguoli pear (Pyrus bretschneideri Rehd. cv. Pingguoli) fruits in Gansu, China. *Journal of Phytopathology, 155*(1), 56-60.

Mari, M., Bertolini, P., & Pratella, G. (2003). Non-conventional methods for the control of post-harvest pear diseases. *Journal of Applied Microbiology, 94*(5), 761-766.

Marzani, Q. A. (2011). *Fungicide resistance and efficacy for control of Pyrenophora teres and Mycosphaerella graminicola on barley and wheat. PhD thesis,*. University of Nottingham, Nottingham, UK.

Marzani, Q. A., Mohammad, A. O., & Hamda, O. A. (2021). Ecofriendly approaches for the management of rose powdery mildew (Podosphaera pannosa var. rosae). *Zanco Journal of Pure and Applied Sciences, 33*(4), 100-110.

MARZANI, Q. A. O. (2003). *Epiphytotic and control of Ascochyta blight of chickpea caused by Ascochyta rabiei (Pass.) Labr. in Erbil Province.* (MSc), Salahaddin university-Erbil.

Mathur, A., Verma, S. K., Purohit, R., Gupta, V., Dua, V., Prasad, G., . . . Singh, S. (2011). Evaluation of in vitro antimicrobial and antioxidant activities of peel and pulp of some citrus fruits. *Journal of Biotechnology and Biotherapeutics, 1*(2), 1-17.

Morrissey, J. P., & Osbourn, A. E. (1999). Fungal resistance to plant antibiotics as a mechanism of pathogenesis. *Microbiology and Molecular Biology Reviews, 63*(3), 708-724.

Nandhavathy, G., Dharini, V., Babu, P. A., Nambiar, R. B., Selvam, S. P., Sadiku, E. R., & Kumar, M. M. (2020). Determination of antifungal activities of essential oils incorporated-pomegranate peel fibers reinforced-polyvinyl alcohol biocomposite film against mango postharvest pathogens. *Materials Today: Proceedings*.

Nicosia, M. G. L. D., Pangallo, S., Raphael, G., Romeo, F. V., Strano, M. C., Rapisarda, P., . . . Schena, L. (2016). Control of postharvest fungal rots on citrus fruit and sweet cherries using a pomegranate peel extract. *Postharvest Biology and Technology, 114*, 54-61.

Novotný, D., Lukáš, J., Brožová, J., & Ružicková, P. (2019). Comparison of the occurrence of fungi causing postharvest diseases in apples grown in organic and integrated production systems in orchards in the Czech Republic. *Czech Mycol, 71*, 99-121.

Okawa, K. (2015). Market and trade impacts of food loss and waste reduction. OECD Food, Agriculture and Fisheries Papers, No. 75, OECD Publishing, Paris. http://dx.doi.org/10.1787/5js4w29h0wr2-en.

Paulitz, T. C., & Bélanger, R. R. (2001). Biological control in greenhouse systems. *Annual review of phytopathology, 39*(1), 103-133.

Pedras, M. S. C., & Abdoli, A. (2017). Biotransformation of rutabaga phytoalexins by the fungus Alternaria brassicicola: unveiling the first hybrid metabolite derived from a phytoalexin and a fungal polyketide. *Bioorganic & Medicinal Chemistry, 25*(2), 557-567.

Pierson, C., Ceponis, M., & McColloch, L. (1971). Market Diseases of Apples Pears, and Quinces. In Agricultural Handbook 376. Washington, DC, USA: US Department of Agriculture.

Seifbarghi, S., Borhan, M. H., Wei, Y., Coutu, C., Robinson, S. J., & Hegedus, D. D. (2017). Changes in the Sclerotinia sclerotiorum transcriptome during infection of Brassica napus. *BMC genomics*, *18*(1), 266.

Sexton, A. C., Minic, Z., Cozijnsen, A. J., Pedras, M. S. C., & Howlett, B. J. (2009). Cloning, purification and characterisation of brassinin glucosyltransferase, a phytoalexin-detoxifying enzyme from the plant pathogen Sclerotinia sclerotiorum. *Fungal Genetics and Biology*, *46*(2), 201-209.

Snowdon, A. L. (1990). *A colour atlas of post-harvest diseases and disorders of fruits and vegetables. Volume 1: General introduction and fruits*: Wolfe Scientific Ltd.

Stefanucci, A., Zengin, G., Llorent-Martinez, E. J., Dimmito, M. P., Della Valle, A., Pieretti, S., . . . Mollica, A. (2020). Chemical characterization, antioxidant properties and enzyme inhibition of Rutabaga root's pulp and peel (Brassica napus L.). *Arabian Journal of Chemistry*.

Sugar, D., & Powers, K. (1986). Interactions among fungi causing postharvest decay of pear. *Plant disease*, *70*(12), 1132-1134.

Sugar, D., & Spotts, R. A. (1999). Control of postharvest decay in pear by four laboratory-grown yeasts and two registered biocontrol products. *Plant disease*, *83*(2), 155-158.

Sutton, T. B., Aldwinckle, H. S., Agnello, A. M., & Walgenbach, J. F. (2014). *Compendium of apple and pear diseases and pests*: Am Phytopath Society.

Tomás-Barberán, F. A., & Espín, J. C. (2001). Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. *Journal of the Science of Food and Agriculture*, *81*(9), 853-876.

Tripathi, P., & Dubey, N. (2004). Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruit and vegetables. *Postharvest Biology and Technology*, *32*(3), 235-245.

Tripathi, P., Dubey, N., Banerji, R., & Chansouria, J. (2004). Evaluation of some essential oils as botanical fungitoxicants in management of post-harvest rotting of citrus fruits. *World Journal of Microbiology and Biotechnology*, *20*(3), 317-321.

Vico, I., Duduk, N., Vasić, M., & Nikolić, M. (2014). Identification of Penicillium expansum causing postharvest blue mold decay of apple fruit. *Pesticidi i fitomedicina*, *29*(4), 257-266.

Watanabe, T. (2010). *Pictorial atlas of soil and seed fungi: morphologies of cultured fungi and key to species*: CRC press.

Yourman, L., & Jeffers, S. (1999). Resistance to benzimidazole and dicarboximide fungicides in greenhouse isolates of Botrytis cinerea. *Plant disease*, *83*(6), 569-575.

Zhu, S. (2006). Non-chemical approaches to decay control in postharvest fruit. *Advances in postharvest technologies for horticultural crops. Research Signpost, Trivandrum, India*, 297-313.