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Evaluation of The Effectiveness of Ultraviolet Radiation and Reishi Mushroom Extract in Preserving Locally Produced Fruits From Fungal Contamination

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Abstract: Fungal contamination is considered one of the most critical factors limiting the quality and shelf life of fresh fruits during storage and marketing. The present study aimed to evaluate the effectiveness of ultraviolet-C radiation (UV-C) and the extract of the medicinal mushroom *Ganoderma lucidum* (Reishi) in suppressing pathogenic fungal isolates associated with Iraqi white apple (*Malus domestica*), orange (*Citrus sinensis*), and peach (*Prunus persica*), as well as in maintaining their postharvest quality attributes. Fruits were collected, and the associated fungi were isolated and identified under laboratory conditions. The samples were subsequently exposed to different treatments: UV-C (5, 10, and 15 min), Reishi extract (25, 50, and 100 mg/ml), and a combined treatment (UV-C10 + Reishi 50). Evaluations included the incubation period until the appearance of first visible symptoms, infection incidence at 7 and 14 days, and several quality indicators such as weight loss, firmness, color parameters (L^* , a^* , b^*), chlorophyll or anthocyanin content, total soluble solids (TSS), and titratable acidity (TA). Isolation and identification results revealed that *Penicillium expansum* was the most frequent isolate in Iraqi white apple, *Penicillium digitatum* predominated in orange, whereas *Monilinia fructicola* was dominant in peach. The combined treatment (UV-C10 + Reishi 50) proved to be the most effective, extending the incubation period to 15 days compared with only 3 days in the untreated control, and reducing infection incidence to as low as 3% after 14 days. Moreover, this treatment minimized weight loss (4.8% in orange and 8.0% in peach), enhanced firmness (36.0 N in orange and 26.0 N in peach), improved color stability, and increased pigment retention, while maintaining TSS and TA within desirable levels. These findings demonstrate that the integration of UV-C radiation with natural fungal extracts provides a sustainable and eco-friendly approach for managing postharvest fungal contamination, extending fruit shelf life, reducing reliance on synthetic fungicides, and supporting the goals of sustainable agriculture.

Keywords: UV-C Radiation, *Ganoderma lucidum*, Reishi Mushroom, Fruit Preservation, Qualitative Quality, Fungal Spoilage, Agricultural Sustainability

Introduction

Fresh fruits such as Iraqi white apples, oranges, and peaches are among the most important local agricultural products, distinguished by their high nutritional value and consumer demand [1], [2].

However, these fruits are perishable shortly after harvest, as they are susceptible to pathogenic fungi such as *Penicillium expansum*, which causes blue mold in apples, and *Aspergillus niger* and *Alternaria alternata*, which lead to the spoilage of oranges and peaches. This fungal contamination not only causes significant economic losses but also threatens consumer safety due to the production of mycotoxins [3], [4].

Traditional methods have been used to reduce pollution, such as refrigeration and chemical pesticide treatment, but these methods face several challenges, including high costs and incomplete effectiveness, in addition to health and environmental concerns arising from pesticide residues [5], [6]. Therefore, there was a need for natural and safe alternatives with high efficacy against fungal pathogens [7]. One of these alternatives is UV-C treatment, which inhibits fungal growth by causing damage to the fungal cell DNA and reducing the initial microbial load on the fruit surface [8]. Another method to reduce microbial contamination is the use of medicinal mushroom extracts, including the Reishi mushroom (*Ganoderma lucidum*), which has been known in traditional Chinese and Japanese medicine for over two thousand years as the mushroom of immortality [9]. This mushroom belongs to the Basidiomycota phylum and is characterized by its shiny reddish-brown woody fruiting bodies [10]. The Reishi mushroom contains a wide range of bioactive compounds, the most important of which are triterpenoids, known for their antimicrobial and antifungal properties, polysaccharides, especially β -glucans, which enhance the immune response and act as antioxidants, and phenolic compounds that play an important role in inhibiting fungal growth by affecting the cell wall and plasma membrane [11], [12].

Recent studies have shown that reishi mushroom extracts possess activity against many plant pathogenic fungi, making them a promising option in the field of agricultural product preservation [13], [14].

This study aims to test the effectiveness of ultraviolet radiation and reishi mushroom extract in reducing fungal contamination and extending the shelf life of three types of local fruits (Iraqi white apple, orange, and peach), while also evaluating the synergistic effect of the two methods when used together.

Materials and Methods

Local fruit samples: Iraqi white apple (*Malus domestica*), orange (*Citrus sinensis*), and peach (*Prunus persica*) were collected at the marketing maturity stage during May 2025 from local orchards in Balad District, Salah al-Din, Iraq. The fruits were hand-picked in the early morning hours to reduce exposure to heat stress and were transported directly to the laboratory in clean, ventilated boxes [15].

Isolation and diagnosis of fungi: Fungi were isolated from Iraqi white apples, oranges, and peaches showing signs of fungal decay such as the appearance of brown spots, white or green growths, and tissue softening. The infected parts were cut into small pieces (0.5–1 cm²), then washed with sterile distilled water and subjected to surface sterilization using a 1% sodium hypochlorite solution for one minute, after which they were rinsed three times with sterile distilled water. After that, the pieces were planted on plates containing Potato Dextrose Agar (PDA) medium supplemented with an antibiotic (chloramphenicol 250 mg/liter) to reduce bacterial contamination. The plates were incubated in an incubator at a temperature of $25 \pm 2^\circ\text{C}$ for 5–7 days, then the growing fungal colonies were isolated and purified using the hyphal tip technique or the single spore isolation technique [16], [17], [18].

The identification of the genera was based on the morphological characteristics of the colonies (color, texture, nature of the edges) and microscopic examinations of the spores and conidiophores using a light microscope [19], [20]. Standard taxonomic keys were used [21], [22].

UV Treatment : The Iraqi white apple, orange, and peach fruits, which were intact and superficially sterilized, were exposed to UV-C radiation with a wavelength of 254 nanometers using a German-made UV chamber. The fruits were placed 20 cm away from the radiation source and treated for different durations (5, 10, 15 minutes) with the aim of determining the optimal duration capable of inhibiting the growth of pathogenic fungi. During the treatment period, the fruits were rotated to ensure that the radiation reached the entire surface. After the treatment period, the fruits were stored at room conditions ($25 \pm 2^\circ\text{C}$) and a relative humidity of 70–80%. The appearance of fungal decay

symptoms was monitored daily for 14 days. Pieces of the treated fruits were also planted on PDA medium to verify the efficiency of ultraviolet radiation compared to untreated fruits [23], [24].

Preparation of Reishi mushroom extract and treatment of fruit: Dried *Ganoderma lucidum* (Reishi mushroom) was obtained from DXN Company, Malaysia, and ground using an electric grinder to obtain a fine powder. The methanolic extract was prepared by adding 50 grams of the powder to 500 ml of methanol at a ratio of (1:10 w/v), then the samples were shaken on an electric shaker at a speed of 150 rpm for 72 hours in the dark. After that, the samples were filtered using filter paper and followed by solvent evaporation under low pressure in a rotary evaporator at a temperature of 40°C to obtain the crude extract. The extract was stored at a temperature of 4°C until use, and it was dissolved in different concentrations (25, 50, 100 mg/ml) using a 1% DMSO solution as a co-solvent. These concentrations were used to treat Iraqi white apples, oranges, and peaches by immersion for 5 minutes, then they were dried with sterile air before storage.

After the treatment period, the fruits were stored at room conditions (25 ± 2°C) and a relative humidity of 70–80%. The appearance of fungal decay symptoms was monitored daily for 14 days. Pieces of the treated fruits were also planted on PDA medium to verify the efficacy of the extract compared to the untreated fruits [25], [26].

Experimental design: The treatments were designed with three replicates for each treatment and ten fruits per replicate:

1. Control (-): Untreated fruits (washed only with sterile distilled water).
2. Control (+): Fruits infected with pathogenic fungi without any subsequent treatment.
3. UV-C treatment: Exposing the fruits to UV-C rays (254 nm) for (5, 10, 15 minutes).
4. Reishi mushroom extract treatment: Soaking the fruits in different concentrations of the extract (25, 50, 100 mg/ml) for 5 minutes.
5. UV-C + extract treatment: Exposing the fruits to ultraviolet rays (10 minutes) and then immersing them in a 50 mg/ml reishi mushroom extract.

After applying the treatments, the fruits were stored at room temperature (25 ± 2°C, humidity 70–80%), and the appearance of fungal infections was monitored daily for 14 days. The following variables were measured:

Infection Incidence (%): The infection incidence for the stored fruits was calculated by recording the number of fruits showing visible fungal contamination on their surface to the total number of fruits used in each treatment, according to the equation:

$$\text{Infection incidence (\%)} = \frac{\text{Total number of infected fruits in all replicates}}{\text{Total number of fruits}} \times 100 \quad [27].$$

Incubation period: It was determined by recording the number of days from the beginning of storage until the first visible symptoms of fungal contamination appeared on any fruit in each treatment [28].

Weight loss (%): Each fruit was weighed at the beginning of the experiment (initial weight W_0) and then reweighed after each storage period (W_t) [29].

Firmness (N): Measured using a penetrometer in Newtons (N), with readings taken from two opposite sides of each fruit after peeling [30].

Color measurement: The color was measured according to the Hunter Lab system using a colorimeter, and the values were recorded: L^* (lightness), a^* (green-red), b^* (blue-yellow) [31].

Pigments content: The total chlorophyll content in apples and oranges was estimated by extracting it in 80% acetone and measuring the absorbance at 645 and 663 nanometers. The total anthocyanin content in peaches was estimated using the pH differential method and measuring the absorbance at 520 and 700 nanometers [32].

Chemical quality indicators: Total acidity (Titratable acidity, TA) was measured, expressed as an equivalent percentage of citric acid, using a 0.1N NaOH titration. Total soluble solids (TSS) were measured using a refractometer at 20°C and expressed in degrees Brix (°Brix) [33].

Statistical analysis: The data were collected and statistically analyzed using a completely randomized design (CRD) with three replications for each treatment, and Duncan's multiple range test was used to compare significant differences between the means at a probability level ($P \leq 0.05$) [34].

Results

The results of table (1) showed the fungal isolation from stored fruits (apples, oranges, peaches) revealed a group of fungi causing post-harvest diseases. *Penicillium expansum* was the most isolated fungus from apple fruits, accounting for 45%, and it is the main cause of blue mold, which is one of the most significant post-harvest diseases of stored apples worldwide, as it spreads rapidly under conditions of high humidity and suitable temperatures. *Alternaria alternata* fungus was also isolated at a rate of 25%, which causes the appearance of black spots on the fruits and is commonly found in warm environments. As for the fungi *Aspergillus niger* and *Fusarium spp.* They appeared in lower percentages 15% each as secondary pathogens or contaminants accompanying storage and transportation processes [4], [35].

Table 1. Isolated Fungi from local Fruits

Fruit type	Isolated fungi	Frequency of isolation (%)
Iraqi white Apple (<i>Malus domestica</i>)	<i>Penicillium expansum</i>	45
	<i>Alternaria alternata</i>	25
	<i>Aspergillus niger</i>	15
	<i>Fusarium spp.</i>	15
	<i>Penicillium digitatum</i>	50
Orange (Citrus <i>sinensis</i>)	<i>Penicillium italicum</i>	30
	<i>Aspergillus flavus</i>	10
	<i>Alternaria citri</i>	10
	<i>Monilinia fructicola</i>	40
Peach (<i>Prunus persica</i>)	<i>Rhizopus stolonifer</i>	30
	<i>Botrytis cinerea</i>	20
	<i>Alternaria alternata</i>	10

As for orange fruits, it was found that the dominant isolates belong to the genera *Penicillium digitatum* and *Penicillium italicum* at rates of 50% and 30% respectively, which are considered the main causes of green mold and blue mold in citrus fruits. This aligns with what many researchers have reported, that they constitute more than 80% of the post-harvest disease agents in citrus fruits. *Aspergillus flavus* was also recorded at a rate of 10%, which poses an additional danger due to its ability to produce aflatoxins, in addition to *Alternaria citri* at 10%, which causes black rot [36], [37]

While peaches, the results were somewhat different, with *Monilinia fructicola* being the most frequently occurring fungus at 40%, responsible for brown rot, which is one of the most dangerous diseases affecting peach and nectarine fruits. *Rhizopus stolonifer* fungus was also isolated at a rate of 30%, causing soft rot, which spreads rapidly when there are wounds on the fruits. *Botrytis cinerea* also appeared at a rate of 20% as the cause of gray mold, a disease widely prevalent in many stored fruits. Finally, the presence of *Alternaria alternata* was recorded at a rate of 10%, which is a widely spread fungus that causes rotting spots on fruits [38], [39]. These results show that these differences reflect both the nature of the fruits and their chemical composition, as well as their growth and storage conditions, in addition to the specificity of the relationship between the host and the pathogen.

Figure (1) shows the effect of ultraviolet treatments and reishi mushroom extract, either individually or in combination, on the appearance of initial symptoms and the fungal infection rate in Iraqi white apple fruits during the storage period. The negative control treatment (Control-) showed that the first appearance of symptoms occurred after only 4.2 days, with a high infection rate of 80% on the seventh day and 95% on the fourteenth day. In contrast, the positive control treatment (Control+) exhibited a faster appearance of symptoms (3.5 days) with an infection rate reaching 100% on the fourteenth day, reflecting the high susceptibility of the apples to fungal contamination in the absence of any protective treatments [24], [40].

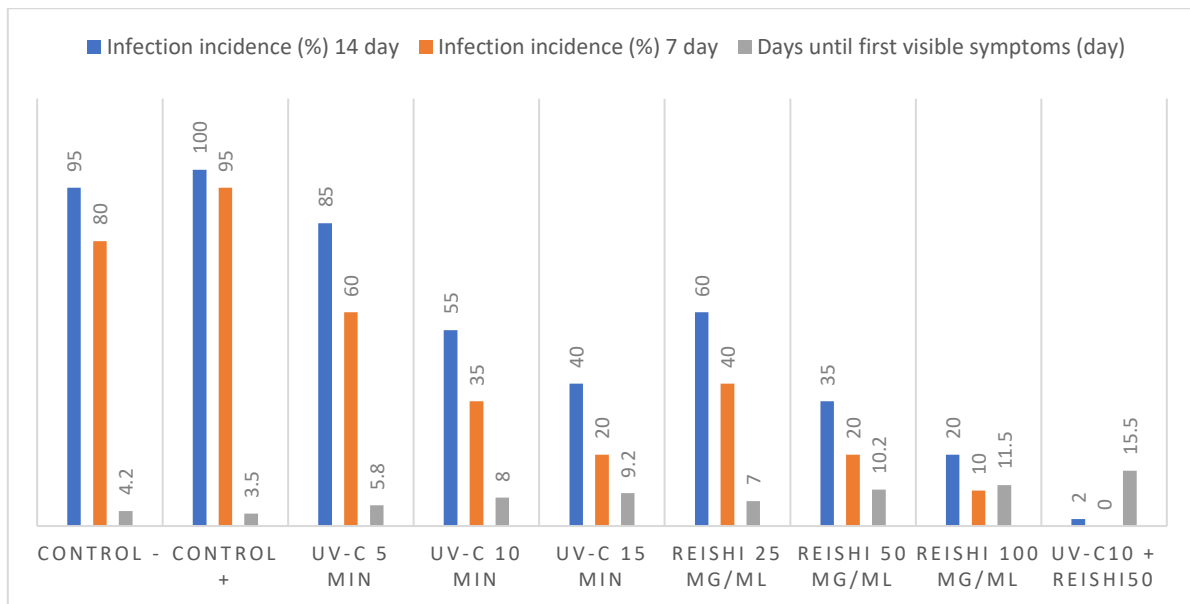


Figure 1. The effect of different UV-C treatments and Reishi extract on the time of appearance of the first symptoms and the rates of fungal infection in Iraqi white apple fruits during storage.

UV-C treatments showed remarkable effectiveness in prolonging the incubation period and delaying the onset of symptoms. The longer the exposure to UV radiation, the more days before the first symptoms appeared. The UV-C treatment for 15 minutes recorded 9.2 days before the appearance of symptoms, compared to 8.0 days for UV-C 10 minutes and 5.8 days for UV-C 5 minutes. The infection rates also gradually decreased with the length of exposure to the radiation, ranging between 20–60% on the seventh day, and dropping to 40–85% on the fourteenth day [41].

As for the Reishi mushroom extract, it showed a clear inhibitory effect that depended on the concentration used. The extract at a concentration of 25 mg/ml delayed the onset of symptoms to 7.0 days, with infection rates of 40% and 60% on the seventh and fourteenth days, respectively. The efficacy increased with the concentration raised to 50 mg/ml (10.2 days, 20% and 35% infection), then reached its maximum effect at 100 mg/ml where the symptoms were delayed to only 11.5 days with low infection rates (10% and 20%). These results are consistent with previous studies that indicated the phenolic compounds and triterpenoids in Reishi mushrooms possess antifungal properties [42], [43].

The most remarkable result appeared in the dual treatment (UV-C 10 minutes + Reishi 50 mg/ml), where the onset of symptoms was delayed until 15.5 days, with no infections recorded on the seventh day, while the infection rate on the fourteenth day did not exceed 2%. This illustrates the synergistic effect between ultraviolet radiation and the bio-extract, as the double treatment enhanced the fruits' resistance to fungal contamination to a degree surpassing any of the single treatments [9].

Figure (2) illustrates the effect of different treatments with UV-C radiation and reishi mushroom extract, in addition to their combined treatment, on delaying the appearance of fungal contamination symptoms and reducing infection rates on local orange fruits. The negative control treatment (Control -) showed the first symptoms after 6.0 ± 0.5 days, with the infection rate rising to 70% on the seventh day and 90% on the fourteenth day. As for the positive control treatment (Control +), it recorded a shorter incubation period (5.0 ± 0.4 days) with the infection rate reaching 100% on the fourteenth day, reflecting the high susceptibility of the fruits to infection in the absence of any preventive treatments.

UV-C treatments showed good effectiveness, as exposure for 10 minutes delayed the appearance of symptoms to 8.5 ± 0.7 days with infection rates reduced to 40% and 60% on days 7 and 14, respectively. Exposure for 15 minutes yielded even better results, with the incubation period reaching 10.0 ± 0.8 days and lower infection rates of 25% and 45%.

As for the treatments with reishi mushroom extract, they showed promising results depending on the concentration. A concentration of 25 mg/ml delayed the symptoms to 8.0 ± 0.7 days with infection rates of 45% and 65%. Increasing the concentration to 50 mg/ml achieved a longer incubation period

(11.0 ± 0.9 days) and lower infection rates (20% and 30%). As for the highest concentration (100 mg/ml), it recorded the best results individually, with an incubation period of 12.5 ± 1.0 days and very low infection rates (10% and 18%). This is attributed to the effectiveness of the bioactive compounds in reishi (polysaccharides and triterpenes) with antifungal activity [44], [45].

As for the combined treatment of UV-C (10 minutes) + reishi (50 mg/ml), it yielded the best results overall, recording the longest incubation period (16.0 ± 1.2 days) with complete absence of infection on the seventh day, and a very minimal infection rate (1%) only on the fourteenth day, indicating a strong synergistic effect between the two methods. These results indicate that combining ultraviolet radiation with reishi mushroom extract is an effective strategy for extending the storage life of local oranges and reducing fungal infection rates, which enhances the marketing potential and quality of the fruit post-harvest [46], [47].

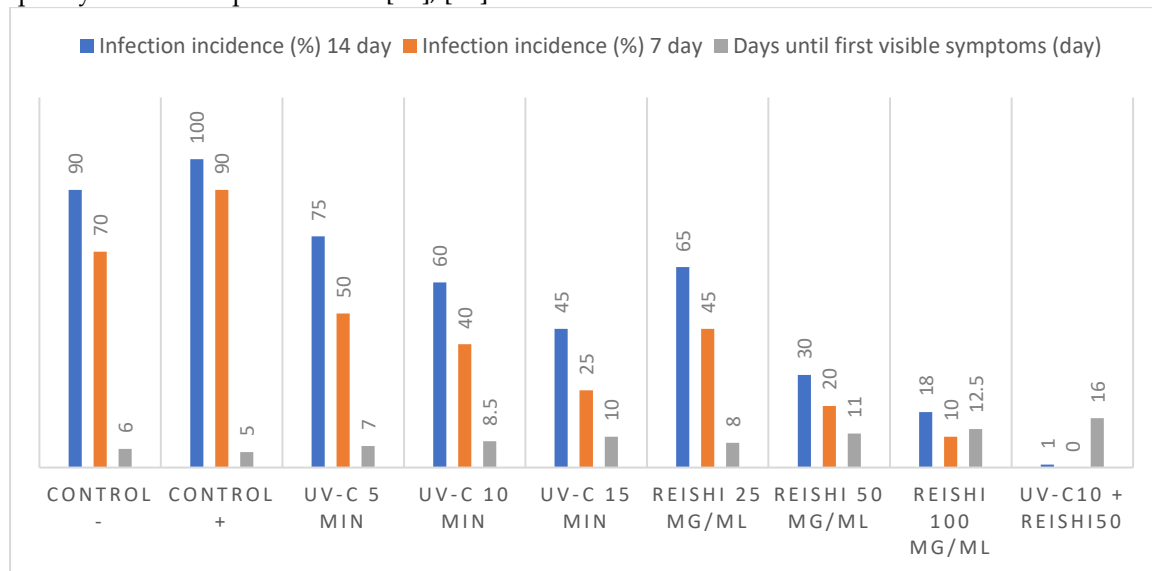


Figure 2. The effect of different UV-C treatments and Reishi extract on the time of appearance of the first symptoms and the rates of fungal infection in orange fruits during storage.

Figure (3) shows the effect of UV-C radiation and reishi mushroom extract, individually and in combination, on reducing fungal contamination in peach fruits.

The negative control treatment (Control -) showed the first symptoms of fungal contamination after only 3.8 ± 0.4 days, with high infection rates of 85% on the seventh day and 98% on the fourteenth day. As for the positive control treatment (Control +), it recorded a shorter incubation period (3.0 ± 0.4 days) with an infection rate reaching 100% on the fourteenth day, indicating the high susceptibility of peaches to fungal infection compared to apples and oranges. UV-C treatments showed an important role in reducing contamination, as exposure for 10 minutes delayed the appearance of symptoms to 6.5 ± 0.6 days with infection rates of 45% and 65%. Meanwhile, exposure for 15 minutes yielded better results (7.5 ± 0.7 days) with lower infection rates (30% and 50%).

As for the reishi mushroom extract, it showed concentration-dependent efficacy, with a concentration of 25 mg/ml recording an incubation period of 6.8 ± 0.6 days with infection rates of 50% and 70%. As for the concentration of 50 mg/ml, it delayed the symptoms to 8.5 ± 0.7 days with lower infection rates (30% and 45%). The highest concentration of 100 mg/ml achieved the best results when used individually, with an incubation period of only 9.8 ± 0.8 days and low infection rates (15% and 25%). As for the combined treatment of UV-C (10 minutes) + reishi extract (50 mg/ml), it yielded the best results, with an incubation period of 15.0 ± 1.0 days, no infections on the seventh day, and a very slight infection rate of only 3% on the fourteenth day. These results indicate that peaches are more sensitive to fungal contamination compared to apples and oranges. However, the use of biopreservation techniques (UV-C and reishi), whether individually or in combination, has clearly contributed to extending the incubation period and reducing infection rates, with the combined treatment excelling in maintaining the fruits for a longer period and reducing post-harvest losses [48], [49], [50].

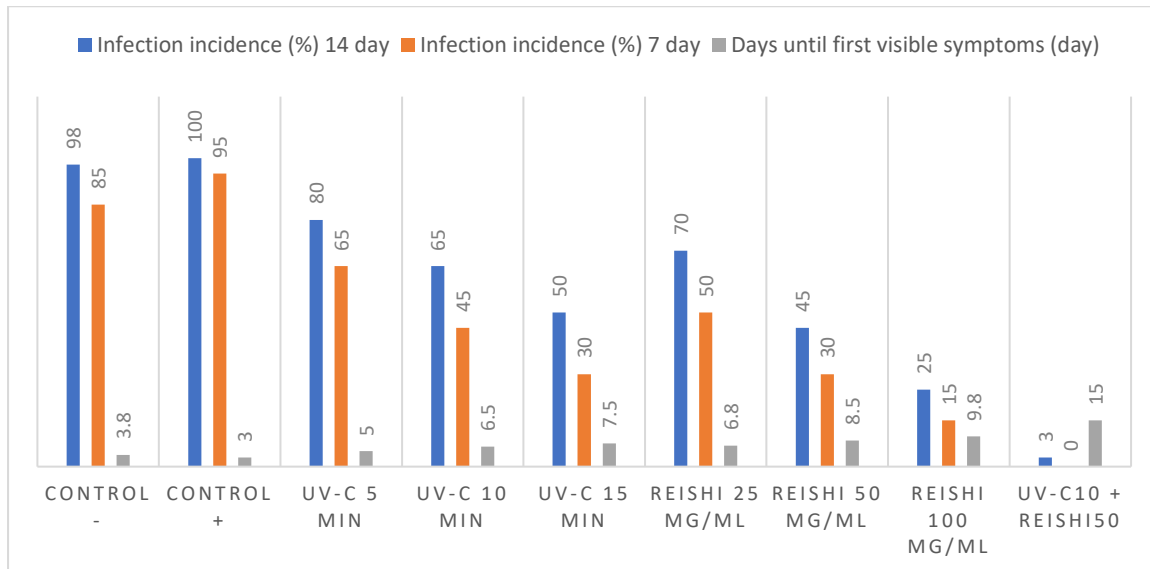


Figure 3. The effect of different UV-C treatments and Reishi extract on the time of appearance of the first symptoms and the rates of fungal infection in peach fruits during storage.

Table (2) shows the effect of different treatments (UV-C radiation, reishi mushroom extract, and the combined treatment) on the physical and chemical quality indicators of Iraqi white apple fruits after the storage period. The positive control treatment (Control +) recorded the highest weight loss (14.8%), followed by the negative control (12.5%), indicating the fruits weak ability to retain water in the absence of treatments. In contrast, the weight loss significantly decreased in the UV-C10 treatment (8.5%) and the Reishi treatment (7.8%), while the combined treatment of UV-C10 + Reishi50 recorded the least weight loss (5.5%), indicating the role of the treatment in reducing respiration and moisture loss during storage. The positive control treatment showed a significant decrease in firmness (26.5 N), compared to the negative control (28.0 N). As for the UV-C10 (32.0 N) and feather treatments (33.5 N), they significantly improved the fruit firmness, while the combined treatment recorded the highest value (35.0 N), confirming its role in delaying the physiological processes associated with texture softening.

The positive control recorded low L^* values (58.0) with an increase in a^* value (3.5), reflecting a color change toward redness due to deterioration. While the improved treatments (UV-C and feather) showed an increase in L^* value (62.5–63.0) and a decrease in a^* (1.2–1.5), indicating that the fruits retained their natural color for a longer period. The combined treatment showed the best values ($L^* = 64.0$, $a^* = 1.0$, $b^* = 16.0$). The chlorophyll content decreased in the positive control (0.40) compared to the negative control (0.45). While the UV-C10 (0.52) and the control (0.55) treatments recorded higher levels, the combined treatment achieved the highest value (0.60 mg/g), reflecting its role in slowing down pigment degradation. The positive control recorded a decrease in total soluble solids (10.8 °Brix) and total acidity (0.40%). While the other treatments showed a significant increase in both indicators, the combined treatment recorded the best values (TSS = 11.8 °Brix, TA = 0.50%), indicating its ability to maintain a balance between taste and flavor. The results indicate that UV-C treatments and reishi extract, especially when combined, not only limited fungal contamination but also contributed to maintaining the physical and chemical quality indicators of Iraqi white apples during storage, thereby enhancing the market value of the fruits and extending their storage life [24], [51], [52].

Table 2. The effect of different treatments (UV-C10 and Reishi extract) on the quality indicators of Iraqi white apple fruits during storage.

Treatment	Weight loss (%)	Firmness (N)	L^*	a^*	b^*	Chlorophyll		TSS (°Brix)	TA (%)
						/ Anthocyanin (mg/g Chl)			
Control -	12.5 ± 0.6	28.0 ± 1.5	60.2	2.1	18.5	0.45		11.2	0.45

	b	c	b	b	b	c	a	b
Control +	14.8 ± 0.7	26.5 ± 1.4	58.0	3.5	20.0	0.40	10.8	0.40
	a	d	c	a	a	d	b	c
UV-C10	8.5 ± 0.5	32.0 ± 1.6	62.5	1.5	17.0	0.52	11.5	0.47
	c	b	ab	c	bc	b	a	ab
Reishi 50 mg/ml	7.8 ± 0.4	33.5 ± 1.5	63.0	1.2	16.5	0.55	11.6	0.48
	c	b	a	c	c	b	a	a
UV-C10 + Reishi50	5.5 ± 0.3	35.0 ± 1.8	64.0	1.0	16.0	0.60	11.8	0.50
	d	a	a	cd	c	a	a	a

*Different letters in the same column mean significant differences at the 5% probability level.

Table (3) shows the effect of UV-C treatments and reishi mushroom extract, individually and in combination, on the physical and chemical quality indicators of local orange fruits during storage. The positive control treatment (Control +) recorded the highest weight loss percentage (12.2%), followed by the negative control (10.0%), reflecting faster moisture loss in the absence of treatments. While the improved treatments led to a reduction in loss, reaching 7.0% in the UV-C10 treatment and 6.5% in the Rishi treatment, the combined treatment recorded the lowest value (4.8%), confirming its role in reducing respiration and evaporation. The firmness decreased in the positive control (28.0 N) compared to the negative control (30.0 N). While the other treatments showed a significant increase in firmness, with UV-C10 recording a value of 33.0 N and the control recording 34.0 N, the combined treatment achieved the highest firmness (36.0 N), indicating a delay in tissue softening and the preservation of fruit quality. The L* value in the positive control decreased (63.5) while the a* value increased (4.0), indicating a color change toward redness associated with deterioration. While the UV-C and feather treatments achieved higher L* values (66.2–66.8) and lower a* values (2.2–2.5), reflecting the fruits' retention of their natural color. The combined treatment recorded the best results (L* = 67.5, a* = 2.0, b* = 23.0). The chlorophyll content decreased in the positive control (0.28) compared to the negative control (0.30), while the treatments gradually increased the content, reaching 0.35 in UV-C10 and 0.38 in the control, while the combined treatment recorded the highest value (0.40), indicating its role in slowing down the degradation of pigments.

The total soluble solids (TSS) decreased in the positive control (11.5 °Brix) compared to the negative control (12.0 °Brix). While the UV-C and Rishi treatments recorded higher values (12.2–12.3 °Brix), the highest value was observed in the combined treatment (12.5 °Brix). As for the total acidity (TA), it was lowest in the positive control (0.85%) and gradually increased with the treatments, recording 0.92% for UV-C10, 0.95% for reishi, and the highest value in the combined treatment (0.98%). The results indicate that the UV-C treatment and reishi mushroom extract, especially when used together, not only reduced fungal contamination but also contributed to improving and maintaining quality indicators by reducing weight loss, increasing firmness, enhancing color, and preserving the chemical balance of the fruits [53], [54], [55].

Table 3. The effect of different treatments (UV-C10 and Reishi extract) on the quality indicators of orange fruits during storage.

Treatment	Weight loss (%)	Firmness (N)	L*	a*	b*	Chlorophyll / Anthocyanin (mg/g Chl)		TSS (°Brix)	TA (%)
Control -	10.0 ± 0.5	30.0 ± 1.4	65.0	3.2	25.0	0.30	12.0	0.90	
	b	c	a	b	a	c	b	b	
Control +	12.2 ± 0.6	28.0 ± 1.3	63.5	4.0	26.0	0.28	11.5	0.85	
	a	c	b	a	a	c	bc	c	
UV-C10	7.0 ± 0.4	33.0 ± 1.6	66.2	2.5	24.0	0.35	12.2	0.92	
	c	b	a	c	b	b	ab	b	

Reishi 50	6.5 ± 0.3	34.0 ± 1.5	66.8	2.2	23.5	0.38	12.3	0.95
mg/ml	c	b	a	c	bc	a	a	ab
UV-C10 +	4.8 ± 0.2	36.0 ± 1.7	67.5	2.0	23.0	0.40	12.5	0.98
Reishi50	d	a	a	c	c	a	a	a

*Different letters in the same column mean significant differences at the 5% probability level.

Table (4) shows that UV-C treatments and Reishi mushroom extract, whether applied individually or in combination, had a significant impact on the quality indicators of peaches during storage, compared to the two controls (Control - and Control +).

In terms of weight loss, the positive control recorded the highest percentage (16.8%), while the loss decreased significantly in the combined treatment (UV-C10 + Reishi50) to reach (8.0%), reflecting the efficiency of these treatments in reducing water loss and delaying respiration processes. As for firmness, it significantly decreased in the control samples (18.5–20.0 N), while the UV-C and Reishi treatments showed a noticeable improvement, reaching the highest value in the combined treatment (26.0 N), indicating the role of these treatments in maintaining the texture of the fruits and delaying cellular breakdown. As for the color parameters (L*, a*, b*), brightness (L*) gradually increased from (54.0) in the control to (58.0) in the combined treatment, with a* and b* values decreasing, indicating a slowdown in color changes associated with increased redness and yellowness, thereby maintaining the market appearance of the fruits.

The results also showed an increase in chlorophyll/anthocyanin content, reaching (60.0 mg/100g Antho) in the combined treatment compared to (48.0 mg/100g Antho) in the positive control, reflecting a delay in chlorophyll degradation and an increase in the accumulation of anthocyanins with high nutritional and esthetic value.

Regarding total soluble solids (TSS), they ranged between (10.2–11.2 °Brix), with the highest value recorded in the combined treatment, while the titratable acidity (TA) showed a relatively stable range between (0.65–0.75%), providing a balance between sweet and sour taste, and enhancing consumer acceptance of the fruits.

The results indicate that the UV-C10 + Reishi50 treatment was the most effective in improving the quality of peaches during storage, by reducing weight loss, maintaining firmness, enhancing color attributes, and increasing anthocyanin and total soluble solids content. This highlights the potential of adopting this technique as a safe and effective means to extend the market shelf life of peaches while preserving their nutritional value [54], [56], [57], [58], [59], [60].

Table 4. The effect of different treatments (UV-C10 and Reishi extract) on the quality indicators of peach fruits during storage.

Treatment	Weight loss (%)	Firmness (N)	L*	a*	b*	Chlorophyll / Anthocyanin (mg/100g Antho)	TSS (°Brix)	TA (%)
Control -	15.0	20.0	55.0	12.0	22.0	50.0	10.5	0.70
	b	d	c	b	b	c	b	ab
Control +	16.8	18.5	54.0	13.5	23.0	48.0	10.2	0.65
	a	e	d	a	a	d	b	b
UV-C10	11.5	23.0	56.5	11.0	21.5	55.0	10.8	0.72
	c	c	bc	c	bc	b	ab	ab
Reishi 50	10.8	24.5	57.0	10.5	21.0	57.0	11.0	0.73
mg/ml	c	b	b	cd	c	b	a	a
UV-C10 +	8.0	26.0	58.0	10.0	20.5	60.0	11.2	0.75
Reishi50	d	a	a	d	c	a	a	a

*Different letters in the same column mean significant differences at the 5% probability level.

Conclusion

The results of this study showed that both ultraviolet (UV-C) radiation and Reishi mushroom extract had a significant effect in reducing fungal contamination and improving quality indicators in the studied fruits (Iraqi white apple, orange, peach) during storage. The combined treatment (UV-C10 + Reishi50) clearly outperformed the other treatments, as it contributed to delaying the first signs of fungal infection, reducing the incidence and severity of infection, minimizing weight loss, maintaining fruit firmness, improving color attributes, limiting undesirable changes in appearance, increasing chlorophyll and anthocyanin content, thereby enhancing nutritional and esthetic value, maintaining the balance between soluble solids and total acidity, and consequently improving taste and flavor. Therefore, the technique of UV treatment combined with fungal extracts (Reishi) can be adopted as an effective, safe, and environmentally friendly option to extend the market shelf life of local fruits while maintaining their nutritional and physical value.

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