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The Effect of Microwave Electromagnetic Radiation on Microorganisms and Stored Grain Pests in Iraqi Local Wheat

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ABSTRACT

Contamination of stored grain with microorganisms and insects is a significant problem in the grain industry, particularly with Iraqi local wheat. This study examined the effect of microwave radiation on various bacteria and fungus strains, specifically Escherichia coli, Salmonella, and Aspergillus spp. The results concluded that microwaving at 500 W for 60 seconds is an effective and rapid method to reduce microbial contamination in Iraqi local wheat. In this experiment, all biological indicators were eliminated. Additionally, microwave radiation can effectively control insects such as Trogoderma granarium, Tribolium castaneum, and Oryzaephilus surinamensis found in Iraqi local wheat. Grain samples, each weighing 50 grams and containing 14% moisture, were infested with stored grain insects. These samples were then exposed to microwave energy at 500 W for 60 seconds. A complete (100%) mortality rate was achieved for adult Trogoderma granarium insects under these conditions.The average moisture loss in the wheat was recorded at 1.9 percentage points, with no significant differences observed in the quality characteristics of the microwave-heated wheat. Microwave disinfection can offer a continuous process, allowing for the treatment of large volumes of product in less time. It is considered a safe and competitive alternative to traditional methods, as it prevents environmental contamination and leaves no undesirable residues. Therefore, using microwaves can be an effective strategy for controlling insect infestations and microbial contamination in stored grains compared to other available methods.

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INTRODUCTION

Grains are a vital and essential part of our nutrition, providing necessary vitamins, minerals, proteins, and carbohydrates that support the survival, health, and growth of the human body. Staples like rice, wheat, maize, and other cereals are commonly consumed around the world to meet food needs. As population growth continues and the demand for grain increases, concerns about food production and preservation have also risen. Consequently, more grain is being cultivated than ever before.

To ensure that grain remains available for consumption after the growing season, effective storage and transportation have become critical. However, grain storage can create environmental conditions that foster the growth of microorganisms and lead to the reproduction and spread of insects and pests. A primary factor contributing to these infestations is the moisture content in the grain, which makes it more susceptible to damage. This can result in losses in weight, color, and nutritional value, and the grain may even become harmful if consumed.

Figure 1. Life cycle of the insect *Trogoderma granarium*. A) adult insect. B) caterpillar (larva)

The increasing contamination of cereals and grains is exacerbating the global food crisis. To prevent food, grain, and seed contamination, it is essential to implement sterilization and disinfection measures that exceed the standard recommendations before storage and transportation begin. One effective method for achieving this is heat treatment using microwave irradiation (Olimov and Kalandarov, 2024).

There are many different studies in the field of microwave application for sterilization and disinfection processes, and microwave irradiation has achieved a better result to reduce the water content and killing all the microbes and insects in a short time. Due to the property of generating source heat for grain in the microwave, grains or seeds being processed achieve the same level of processing. Microwave application was technically advanced and environmentally friendly and the technical process for sterilization and disinfection suitable for all grains and seeds, especially Iraqi local wheat (Sirohi et al., 2021).

For wheat, microwave irradiation not only sterilizes the material but also keeps the material low in moisture content to extend the shelf life. There is a tunnel conveyor furnace that can sterilize tons of wheat per day. On the other hand, the microwave is an inexpensive machine compared to other types of sterilization. The purpose of this study is to investigate how microwave treatment will benefit growers and grain processors who wish to use non-chemical methods to prevent and control insect infestation, and bacterial and fungal growth during storage (Srivastava and Mishra., 2021).

MATERIAL and METHOD

Wheat samples of the winter wheat variety used in the study were collected in 2021 and 2022 from different fields in Iraq from different provinces. Each sample weighed approximately 3 kilos. The samples were taken to Baghdad, where the Quality Control Department (QCD) analyzed the microorganisms and the life cycle of the insects and their species present. Sterilized tools and gloves were used during sampling to prevent contamination by microorganisms.

Analytical Methods

In this study, the colony forming unit is used to determine the results by plate counting methods in bacteria and fungi and this including; The pour plate method: A liquid culture medium in bacteria (Violet Red Bile Agar (VRBA) and fungi (Sabouraud Dextrose agar (SDA) are inoculated into a Petri dish using molten agar that is cooled to about 40-45 °C (just above the solidification point and to reduce high-temperature-induced cell death). After the agar has solidified, the dishes are incubated under the appropriate condition (37°C to 24 h) to bacteria and (25 °C to 72 h) to fungi According to the Iraqi standard specification. Also, check for insects, larvae and their adult According to AACC. On the other hand, wheat grain moisture was determined using the moisture apparatus according to AACC methods (Dziki and Laskowski, 2005).

Microwave

Microwave irradiation is electromagnetic spectrum. In the microwave irradiation process, the microwave irradiation was performed in an LG Electronics RE1100 microwave oven. The device operated with alternating current of 220 V, 50 Hz and emitted radiation with a frequency of 2450 MHz. Before irradiation, the microwave oven was calibrated according to the ASTM standard (2019). 3000 g portions of wheat grain were placed in petri dishes (20 cm diameter) and irradiated for 60 s at the high power of 500 W and the rotation of the dish. The grain depth in the center of the panel did not exceed 2-3 cm. After the microwaving process, the grain samples were allowed to cool and then stored in airtight containers at room temperature for future analysis

(Soni et al., 2020). It was analyzed after exposure to microwave radiation, after three months, and after six months.

Principle of Microwave

Microwave heating is based on the conversion of alternating electromagnetic field energy into thermal energy by influencing the polar molecules of a material. The principle behind microwave elimination of microorganisms and insects is dielectric heating, which depends on their electrical properties. When an electric field is applied, bipolar molecules behave like microscopic magnets and tend to align with the field. Since the electric field changes millions of times per second, these molecular magnets cannot withstand the forces slowing them down. The resistance to rapid movement of the bipolar molecules creates friction and results in heat dissipation in materials exposed to microwave radiation (Mishra et al., 2024). Biological material exposed to such radiation absorbs an amount of energy that depends on the dielectric properties of the material.

The most important feature of microwave heating is volumetric heating, which allows materials to absorb microwave energy directly and internally and convert it to heat. The conversion of microwave energy to heat is given by the following equation (Das et al., 2013).

$$P = 2\pi E^2 f \varepsilon_o \varepsilon'' V \quad (1)$$

where P = power, W; E = the electric field strength, V/m; f = the frequency, Hz; ε_o = the permittivity of free space, F/m; ε''= the dielectric loss factor; V = volume of the material, m^3

Microwave Disinfestation

Microbial Mortality

Microwave ovens have immense application for inactivation of microorganisms such as fungal spores, bacteria (Maftoonazad and Ramaswamy, 2024). Microwaves (microwave oven MS3047GB; LG Electronics, Inc., Changwon, Korea) have been used to generate heat to destroy mold, yeast and bacteria in Iraqi wheat according Iraqi standard specification such as *Aspergillus spp*., *E. coli, Salmonella* and others. Microorganism cells are destroyed by heat generated by conduction in the substrate rather than direct impingement of microwaves on the cells causing destruction. The experiments were carried out on Iraqi local wheat. Temperature was the most important factor affecting microbial control and for optimal Destruction of microorganisms and insect. Increasing the moisture content and microwave heating killed most microorganisms after an exposure time of 60s (Sharma, et al., 2024).

Insect Mortality

Microwave irradiation was used to control insects. Sterilizing wheat through microwaves that support a high-frequency electric field is an inexpensive and effective way to control insects and larvae. Microwave radiation not only kills insects through the resulting heat but also affects survivors' reproduction (Das et al., 2013; Abed et al., 2023). Microwave radiation with good penetrability can kill pests inside and outside the grain.

Microwave radiation does not affect wheat qualities, and no changes have been observed. When compared to insect control methods where the operation and cost of a dielectric and microwave heating system to control moisture and insect invasion of grains, it concluded that microwave sterilization systems are very effective and have a great advantage over other methods such as conventional hot air dryers (Sirohi et al., 2021).

Statistical Analysis

One-way ANOVA was followed by Dunnett's multiple comparisons test. Data represents the mean ± SD of three independently repeated experiments (Kathum et al., 2015).

RESULTS and DISCUSSION

This study has demonstrated that microwave heating can effectively eliminate harmful microorganisms in wheat, including *E. coli* and *Salmonella*, as long as the wheat reaches a safe minimum temperature of at least 70˚C. The results indicate that *E. coli* bacteria can considered indicator bacteria for microwave sterilization. The findings showed that the bacteria were killed immediately after microwave treatment, and they remained nonviable even three months and six months later, as indicated in Table 1. Previous research has reported the effectiveness of microwave irradiation in killing various microorganisms. For instance, Chang et al. (2024) studied the microwave's impact on bacterial strains like *E. coli* and *Salmonella* and concluded that it is a fast and convenient method for reducing microbial contamination. Another study demonstrated the rapid sterilization of metal materials contaminated with *Enterobacteria* such as *E. coli* and *Salmonella typhi*, further confirming the reliability of microwave sterilization on biological indicators.

Table 1. Effect of microwave treatment on bacteria in local wheat during the storage

Samples	Control	Total bacteria count, CFU/g		
		After Treatment	After three months Treatment	After Six months Treatment
S1	1×10^2	1×10^1	1×10^1	0
S2	3×10^2	1×10^1	0	0
S3	6×10^2	0	0	0
S4	4×10^2	1×10^1	1×10^1	0
S5	5×10^2	0	0	0
S6	4×10^2	0	0	0

The results are presented as means ± standard deviations. Local wheat values were not significantly different ($p<0.05$), n=3.

The results presented in Table 2 indicate that fungi, such as *Aspergillus* spp., can be used as indicator organisms for microwave sterilization due to their role as a source of aflatoxin. The study examines the direct effects of microwave treatment on these fungi. Samples were analyzed immediately after treatment, as well as three and six months later, and all yeast and mold were eliminated in accordance with Iraqi standards for local wheat. Wang et al. (2024) reported similar findings regarding this organism. Additionally, it was shown that microwaves are effective in reducing the residual growth rate of *Aspergillus parasiticus*. The LT_{50} (52 ± 2 °C) and LT_{100} (70 ± 2 °C) of *Aspergillus parasiticus*. Microwave irradiation resulted in increased leakage of electrolytes, Ca^{+2}, proteins, and DNA. The mycelial surface exhibited a rough and swollen appearance along with distinct genomic DNA bands.

Table 2. Effect of microwave treatment on fungi in local wheat during the storage.

Samples	Control	Total fungi count, CFU/g		
		After Treatment	After three months Treatment	After Six months Treatment
S1	1×10^4	1×10^1	1×10^1	0
S2	3×10^4	1×10^1	0	0
S3	6×10^3	0	0	0
S4	4×10^4	1×10^1	0	0
S5	5×10^3	0	0	0
S6	4×10^4	0	0	0

The results are expressed as arithmetic means ± standard deviations (CFU/g). Values for the local wheat showed no significant difference ($p<0.05$, n=3).

Table 3 displays the effects of microwave radiation on the control of *Trogoderma granarium* and other insect species. Exposure to microwave radiation effectively destroys these insects. As shown in Figure 2, microwave treatment has proven effective in controlling insects in wheat. When insects are subjected to high-power microwave energy, heat builds up within their bodies, ultimately causing their death. This method can penetrate deep into wheat kernels, eliminating insect pests that may be hiding inside.

In their study, Abed et al. (2023) experimented with three insect species: *Sitophilus oryzae*, *Sitophilus granarius*, and *Rhyzopertha dominica*. These insects were placed in 100g samples of wheat seeds in glass dishes, each measuring (11 cm) in diameter. They were then treated in a microwave oven at maximum power (700 W) for various time intervals to determine the exposure duration required to eradicate the insects in the infested seeds. The researchers calculated the energy and time necessary to sterilize a specific amount of seeds. They found that a 30-second exposure resulted in a 100% kill rate for all types of insects tested.

Table 3. Mortality rates of pests stored at low temperature (4±1 ºC) after varying durations of microwave exposure

Treatment Sample	Insect life stage	Control	Mortality of pests		
			After Treatment	After three months Treatment	After Six months Treatment
S1	larvae	8	0	0	0
	adult	17	0	0	0
S2	larvae	15	0	0	0
	adult	21	0	0	0
S3	larvae	18	0	0	0
	adult	24	0	0	0
S4	larvae	18	0	0	0
	adult	22	0	0	0
S5	larvae	18	0	0	0
	adult	23	0	0	0
S6	larvae	17	0	0	0
	adult	23	0	0	0

Values in the same column that have different superscripts are significantly different ($p \leq 0.05$); n = 3.

Figure 2. Mortality of *Trogoderma granarium* insects treated in a microwave oven at maximum power

In this experiment, all biological indicators were eliminated. Our data indicated that the thickness of the grain is a critical factor influencing the effectiveness of microwave radiation in killing insects. Similar observations were noted for bacteria, as the time required for effective killing varies. Therefore, we conclude that disinfection using microwaves is an important, reliable, and rapid method (Ouma et al., 2024).

CONCLUSION and RECOMMENDATIONS

This study concludes that Microwave radiation has harmful effects on microorganisms and insects. Microorganisms such as bacteria and fungi can be destroyed by exposure to microwave radiation, making it a useful tool for sterilizing and disinfecting Iraqi wheat.

Certain insect species, such as *Trogoderma granarium*, can be effectively controlled using microwave radiation. Additionally, microwave radiation has harmful effects on other insect species found in local Iraqi wheat, including *Tribolium castaneum* and *Oryzaephilus surinamensis*. Results after six months demonstrated a negative impact on all of these species

Conflict of Interest Statement

The author has declared there are no competing interests.

Authors Contribution

SH conceived the study, developed the theoretical framework, performed experiments, collected and analyzed data, interpreted the results, and drafted and revised the manuscript.

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