The Effect of X-ray on Food

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Abstract

Food irradiation is one of the most important techniques used in food sterilization and examination, by exposing food to a specific and precisely defined amount of radiation. These rays work to kill germs, bacteria, and any organisms that harm human health. In this research, we will demonstrate the use of X-rays in food irradiation by conducting three experiments on three types of food: milk, fish preserve, and Wheatflour.

The experience with milk samples showed that when the dose of X-ray was increased, the number of bacteria decreased greatly, and the dose value of 6.0 kGy reduced the number of Chronobacter bacteria. (1.0 logml^{-1})

As for fish preserves, it was observed that at a dose of 3KGy the QMAFAM value decreased by more than 100 logs. When the dose is increased to 6 kGy, the majority of microorganisms are completely inactivated.

As for the Wheatflour samples, it was found that the starch digestibility of wheatflour increased by irradiation dose at 2.5 kGy.

Key Words: Irradiation, X-ray, Irradiation Dose, Milk, Fish Preserves, Wheatflour.

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Introduction

Irradiation is a safe and effective technique used to sterilize many things such as medical devices, medicines, pharmaceuticals, and foodstuffs. Radiation is a method of transferring electromagnetic energy through space in the form of waves or photons, and the equivalent heat transfer for this energy is the energy emitted by the sun.

Ionizing radiation can destroy harmful organisms such as germs and bacteria...etc., by partially or completely disrupting the genetic material of these organisms. (Mahmoud, 2009).

Food is irradiated under strictly defined environmental conditions, where the food must be exposed to a certain amount of radiation that is sufficient to achieve the desired result, and at the same time, it doesn't lead to food deterioration. (Ahmed H Radhi et. al, 2020).

In the field of food irradiation, there are three types of processing that are dealt with:

1. Radappertization: It is the process of sterilization of food, which is processed with a sufficient dose of ionizing energy to prevent its spoilage or infection with bacterial poisoning, in this case, it does not matter the duration and conditions in which the food is stored after the processing process provided that it is not exposed to contamination after was. The dose required in this process is in the range of 25-45 KGy. (Tauxe, 2001).
2. Radiation radiation: It is the process of treating food with a dose of ionizing energy sufficient to reduce pathogenic organisms such as bacteria and germs in addition to parasites transmitted through food to a degree that none of them is detected in the processed food when it is examined by any recognized bacteriological test method. (Tauxe, 2001).

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3. Radiation: It is an uncommon term in the food irradiation process. (Fatma A Khazaal et.al, 2020) In this type, the food is processed with a dose of ionizing energy sufficient to enhance the quality of its preservation by causing a significant reduction in the number of organisms that cause its spoilage. (Tauxe, 2001).

There are three sources of radiation to produce the exact amount of ionizing energy needed to achieve a proper exposure: gamma rays emitted by cobalt 60 orcesiumm 137, electron beam, and X-ray generators. (Moreira, 2020).

the X-rays and gamma rays give high energy so they are used in food irradiation processes, as shown in detail in Table (1).

Table 1. Shows the values of frequency, wavelength, and energy level of types of electromagnetic radiation

Type of Electromagnetic Radiation	**Frequency, f (Hz)**	**Energy, E (eV)**	**Wavelength, λ (cm)**
Gamma rays	1020	4.140×10^5	3.0×10^{-10}
X-rays	1018	4.140×10^2	3.0×10^{-8}

The most commonly used in food processing applications by WHO worldwide is X-ray because the energy from it doesn't induce radioactivity in the food product. (WHO, 1981)

X-rays have many advantages such as the source being easily available and does not need to be renewed, high productivity rate, and long period, On the other hand, it has disadvantages such as the machine used is complicated to install, it needs regular maintenance and requires large amounts of energy. (WHO, 1981).

These are some of the forms of X-ray machines used in irradiation:

Figure 1. X-ray machine used in food irradiation

Figure 2. X-ray machine used for food examination

One of the most important parameters that must be determined in the process of irradiating materials is the radiation dose or the absorbed dose which is the amount of ionizing radiation that is transferred to a unit mass of the material. Their purpose is to control the irradiation process to ensure that the material is not exposed to excessive or underexposed radiation energy (Ajibola et. al, 2020).

The SI unit for the absorbed dose is gray (Gy), where 1 Gy equals the absorption of 1 J per kilogram of the substance.

The following table shows the applications of irradiation to foods according to the dose (Haff Natsuko Toyofuku et. al, 2008):

Table 2. Classification of food irradiation applications according to radiation dose (HaffNatsukoToyofuku, 2008)

	Application	**Gy**
Low dose (up to 1 kGy)	Inhibit sprouting (potatoes, onions, yams, garlic)	0.06-0.2
	Delay in ripening (strawberries, potatoes)	0.5-1.0
	Prevent insect infestation (grains, cereals, coffee beans, spices, dried nuts, dried fruits, dried fish, mangoes, and papayas)	0.15-1.0
	Parasite control and inactivation (Tapeworm, Trichina)	0.3-1.0
Medium dose (1 kGy to 10 kGy)	Extend shelf-life (raw and fresh fish, seafood, fresh produce, refrigerated and frozen meat products)	1.0 - 7.0
	Reduce the risk of pathogenic and spoilage microbes (meat, seafood, spices, and poultry)	1.0 - 7.0
	Increased juice yield, reduction in cooking time of dried vegetables	3.0 - 7.0
High dose (above 10 kg)	Enzymes (dehydrated)	10.0
	Sterilization of spices, dry vegetable seasonings	30.0 max
	Sterilization of packaging material	10.0 - 25.0
	Sterilization of foods (National Aeronautics and Space Administration, NASA, and hospitals)	44.0

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In this research, we will demonstrate the use of X-rays in food irradiation by conducting three experiments on three types of food: milk, fish preserves, and Wheatflour (Pashkova et. al, 2018). Each experiment differs from other experiments in many respects. The main purpose of this research is to demonstrate the methods of using X-rays in sterilization processes and the eradication of pests in the field of nutrition.

First Experiment

1. This experiment aims to determine the ability of x-rays to destroy bacteria in milk samples. (Zakiyeh et.al, 2020).

Materials and Method

1. Malik Samples

Purchasing Fresh milk samples from a local market in AL-Rifai and keeping them at 4°C until use (Toyofuku, 2008).

2. Bacteria Mixture Preparation

Six strains of Cronobacter bacteria in equal volumes (10 ml each) were placed in an empty sterile 100 ml package and then incubated at 37°C for 24 h. (Mahmoud et.al, 2009)

The Irradiator Used in the Experiment

We used the RS 2400 industrial cabinet X-ray irradiator with Specific irradiation doses (0.1, 0.5, 1.0, 2.0, 4.0, and 6.0 kGy). (Moreira, 2020).

Treatment of the Milk Samples with X-ray

Sixteen sets of GLA containing 10 ml of milk inoculated with the Cronobacter were prepared. (EFSA, 2011).
then it was treated with x-ray irradiation with the following doses (0.1, 0.5, 1.0, 2.0, 4.0, and 6.0 kGy). (EFSA, 2011).

Second Experiment

The purpose of the experiment was to determine the ability of X-rays to disinfect fish preserves from bacteria. (EFSA, 2011).

Materials and Method

1. Fish Preserves Samples

Samples were prepared one day before irradiation and placed in a round polypropylene package with geometrical dimensions of d = 15 cm, h= 5 cm. then it Stored at a temperature of 4±2 ºC.

*2. Bacteria Mixtures (15*100mm) ss tube preparation:*

Incubator media was created from agar to establish colonies of different types of bacteria (salmonella, coliform bacteria, listeria...etc.) under certain conditions and then placed in the incubation for 48 hours at a temperature of 30 ± 1 °C. (Manzoor, 2014).

The Irradiator Used in the Experiment

An ILU-10 accelerator for X-ray irradiation was used (gamma objective - 1 cm tantalum, mm water, an aluminum filter) (Cecchi et.al, 1996).

3. Treatment the Fish Preserves Samples with X-ray

The sanitary criterion for determining the purity of a food product is the quantity of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAM). (Sanzharova, 2021).

The experiment was carried out using x-ray doses (1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 kGy).

The germination of colonies of microorganisms is delayed after irradiation, so the number of colonies is calculated over four days.

The unit for expressing the results is in colony-forming units per gram (CFU/g).

Third Experience

The purpose of this experience was to study the effects of X-ray irradiation on the wheatflours (Ashie et. al, 1996).

1. Flour Samples

Wheat flour (moisture content 150 g kg-1, granule size <500 μm) was purchased from theapple market of the AL-Rifai and then stored at -20°C inside air-and moisture-proof polyethylene bags (500 g each) (Zandr´e et. al, 2021).

The flour is dried in an oven at a temperature of 50 °C.

2. The Irradiator Used in the Experiment

We used 60Co γ -ray irradiator with Specific irradiation doses 0, 5, 10,15, and 20 kGy (dose rate 0.5 kGy$\boldsymbol{h}^{-1}$) (Shafia, et al., 2019).

Treatment Wheatflour Samples with X-ray

The Wheatflour was dried in an oven at a temperature of 50◦C. (1 g) of Wheatflour was hydrolyzed with 200 units of endo-(1-3)(1-4)-β-Dglucanase (Saha, 2013).
The wheat flours irradiated at 0, 5, 10, 15, and 20 kGy were dried to 10 g Kg^{-1} in a vacuum oven at 50°C and then placed in sealed moisture-proof polythene bags. (Wisconsin, 2019) the sample was rescanned after cooling to 25 ◦C. we use the Setaram Micro-DSC III micrometer in this experiment. (Mahmoud et. al, 2010).

The Results

1. The First Experience

The results showed the effect of X-ray doses on milk samples as the Cronobacter population was slightly decreased at 0.1 kGy X-ray dose.
Then a greater decrease in the number of bacteria was observed when the dose of X-ray was increased. The number of chronic bacteria was significantly reduced at a dose (P < 0.5KGy).
The X-ray exposure at the largest dose value of 6.0 kGy reduced the number of Chronobacter bacteria (1.0 logml^{-1}).

The Second Experiment

After the completion of the experiment, the graphic relationship linking the irradiation dose with QMAFAM was drawn, as shown in the following figure:

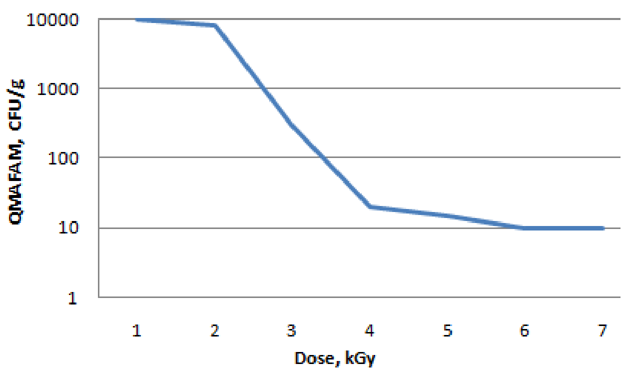

Figure 3. The effect on QMAFAM values during X-ray irradiation

The following chart shows that when the dose is increased to 1KGy the QMAFAM will decrease at a small rate.
QMAFAM value decreased by more than 100 logarithms at anirradiation dose of 3 Gy.
Irradiation at a dose of 6 kGY, microorganisms were almost completely inhibited.

The Third Experience

During the first scanning of Wheatflour, the first enthalpy of endothermic gelatin showed that irradiation caused the gelatin to start temperature (T01) to increase with increasing dose.
In addition, irradiation increased the maximum gelatinization temperature (T02) but decreased the gelatinization temperature range (T02 - T01).
And the results are as shown in the following table:

Table 3. Thermal properties determined by DSC for starch in irradiated Wheatflour

Irradiation dose (Gy)	T0 1 (◦C)	T02 (◦C)	T02-T01 (◦C)	ΔHc (J g−1)	PHI (J ◦C−1)
0	63.1	71.2	8.2	10.25	1.25
5	63.5	72.2	8.8	10.24	1.19
10	63.3	72.3	8.9	9.4	1.06
15	62.8	72.6	9.8	10.6	1.12
20	63.8	73.1	9.5	9.4	0.99

It was found that the starch digestibility of wheat flour was increased by irradiation dose at 2.5 kGy.
At doses above 2.5 ,Gy there was a reduction in starch digestibility because the increased radiation dose caused an increase in the proportion of β-linked starch.
An increase in the radiation dose leads to a possible increase in the crystallization of amylopectin molecules in Wheatflour.

Conclusions

The most important conclusions obtained through the experiments conducted and the data obtained within the scope of this study are:
The results showed the effect of X-ray doses on milk samples that the number of chronic bacteria was significantly reduced at a dose (P < 0.5KGy) and X-ray exposure at the largest dose value of 6.0 kGy reduced the number of Chronobacter bacteria (1.0 logml^{-1}).
In the second experience, the QMAFAM value decreased by more than 100 logarithms at an irradiation dose of 3 Gy.
Irradiation at a dose of 6 kGY, microorganisms were almost completely inhibited
in the third experience, the starch digestibility of wheatflour increased by irradiation dose at 2.5 kGy.

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