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A COMPREHENSIVE HISTORICAL OVERVIEW OF THE DEVELOPMENT AND ACCEPTANCE THE FOOD IRRADIATION TECHNIQUE

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Abstract

Food irradiation as a food preservation method has gained increasing prominence in recent decades. No other food processing method has been studied so thoroughly and for so many years as treating food with ionizing radiation. Moreover, when compared with different approaches developed in the past, none have had such high expectations, or such a high level of criticism as the food irradiation method. Although accepted in many countries and supported by a huge amount of scientific research from all domains of human health, there is still a great reluctance towards irradiated food. Since this method uses a special form of electromagnetic energy, consumers' opinion is often burdened with the wrong perception that irradiated food is radioactive, has toxicological, genetic, mutagenic, or carcinogenic effects, and has reduced and deteriorated nutritional quality. Therefore, this paper aims to present a comprehensive historical overview of the development and acceptance of irradiation procedures by leading international institutions: FAO, IAEA, and WHO. Starting from the first concrete interest in food irradiation in 1896, it has taken many years for these institutions to reach a consensus on this issue, influencing strongly the attitude of national health authorities in different countries posed with numerous dilemmas and ambiguities. It can be concluded that although it was confirmed that any food treated with ionizing radiation with a maximum dose of 10 kGy is considered safe and beneficial, there are still significant gaps in terms of legislation, harmonization of regulations, and equivalence of standards, doses, and labeling of such foods. However, the World Health Organization's Food Safety Unit has described food irradiation as possibly the most significant contribution to public health made by food science and technology since the pasteurization of milk.

Keywords: food irradiation, historical overview, legislation, FAO, IAEA, WHO

INTRODUCTION

Food, as a fundamental need for human life, is a main factor in transmitting and causing many diseases that represent a global health problem. Food spoilage can be noted as one of the biggest problems facing humanity since its microbial contamination can cause numerous poisonings and lethal incomes. Despite modern hygiene measures during food production, a large percentage of raw food (especially of animal origin) is already contaminated by the time it reaches consumers (WHO, 1988). Numerous factors increase this risk, and most often they are today's mass production, the possibility of long-term food storage, the manufacturer's desire to extend food shelf life as much as possible, andthe

increasingly frequent need for ready meals (Loaharanu, 2003; Erkmen & Bozoglu, 2016; Roberts, 2001).Therefore, the new food safety standards emphasize the approach "Safe from field to table," indicating the possibility of hazards being integrated into any segment of the production, packaging, transportation, and food consumption(Gould, 1996).

Humanity's constant struggle with the factors that contaminate and spoil food is also aimed at preventing enormous food losses, especially when it comes to food stored for a certain period and intended for later usage(WHO, 1988; Erkmen & Bozoglu, 2016). This can be confirmed by the fact that in many countries, losses in stored cereals are estimated at at least 10%, while in other types of food, they reach over 25% (WHO, 1988; Elmadfa *et al*., 1999).For these reasons, food processing technology has developed numerous procedures for food preservation, each of them applied in a specific wayand each with certain advantages and disadvantages.

It is undeniable that in recent decades, significant progress has been made in terms of keeping food safe, especially regarding microbial contamination, contamination with pesticides and their residues, and the increased use of additives, chemical pollutants, and biological toxins (Elmi, 2008). But at the same time, it is clear that the success of mankind in protecting itself from diseases transmitted through food also depends on the development of ever-better methods and technologies for its processing (Pillai, 2004).

Food irradiation as a food preservation method has gained increasing prominence in recent decades. No other food processing method has been studied so thoroughly and for so many years as treating food with ionizing radiation. Moreover, when compared with different approaches developed in the past, none have had such high expectations or such a high level of criticism as the food irradiation method (Pillai, 2004). This is mostly because the food irradiation technique uses a special form of electromagnetic energy (ionizing energy) that is used to reduce the population of undesirable biological organisms in food or to prevent their development (WHO, 1988; Miller, 2005).

Following the numerous literature data and from experiences worldwide, treating food with ionizing radiation with doses up to 10 kGy is safe from both nutritional and toxicological aspects. At the same time, with the correct application of ionizing energy, several beneficial effects can be achieved:(1) extending the food shelf life;(2) reducing the need for preservative usage;(3) achieving microbiological safety;(4) delaying the ripening and spoilage of fruit and vegetables; and (5) preventing germination in many types of plants (WHO, 1988; Loaharanu, 2003; www.iaea.org).However, although accepted in many countries and supported by enormous scientific research from all domains of human health, there is still a great reluctance towards irradiated food (Loaharanu, 2003). Since this method uses a special form of electromagnetic energy, consumers' opinion is often burdened with the wrong perception that irradiated food is radioactive, has toxicological, genetic, mutagenic, or carcinogenic effects, and has reduced and deteriorated nutritional quality. Therefore, this paper aims to provide an overview of the development and acceptance of irradiation procedures by leading international institutions, as well as the introduction of this procedure into food processing processes.

1. Development of food irradiation technique

The beginnings of treating food with ionizing radiation are associated with the discovery of X-rays by Roentgen (1895) and radioactive materials by Becquerel (1896). These discoveries opened the field for large-scale scientific studies that analyzed the possible effects of this type of radiation on biological organisms. Thus, in the early decades of the 20th century, it became clear that ionizing radiation could have beneficial uses in food processing and safety. As a result of extensive research since then, a globally accepted

technology for food treatment has been created, with numerous advantages and low costs (Goresline, 1982;Miller, 2005).

The first concrete interest in this method was noted in Germany in 1896 (Stewart, 2004; Miller, 2005). However, the idea that food could be preserved by exposure to X-rays was proposed by Professor Samuel C. Prescott, in 1904 in the US Institute of Technology, (CAST, 1989). In 1916, this method was also proposed by the US Department of Agriculture as an effective way to destroy the destructive tobacco pest *Lasioderma serricorne* (Diehl, 1995).Although it was clear that ionizing radiation kills bacteria, despite the great hopes raised by this new methodfrom the first experiments, there was no available technology to develop a permanent, reliable, and economical source of ionizing radiation in quantities needed for industrial use (WHO, 1988).Therefore, more significant achievements in this field were made after the end of World War II (Diehl, 1995).

In 1940, progress in two areas opened the way for the development of an affordable source of ionizing radiation for industrial use: (1) electron accelerators were designed and (2) atomic fission was discovered. These discoveries renewed interest in the use of ionizing radiation in the food industry, followed by numerous studies that confirmed the potential to become a powerful weapon for preventing food losses and food-borne diseases.Therefore, further researches were directed toward developing a new, commercial process for preserving food safety (Miller, 2005; WHO, 1988).

It is believed that the greatest impetus for using ionizing radiation in food preservation came from the US Army, which began such activities in 1953. During that period, the US Army Natick Soldier Center experimented with irradiating military rations as a possible alternative to the canning or freezing of meat (Diehl, 1995). Between 1953 and 1961, the US Army continued to study the safety of 21 irradiated foods. This was followed by the first official approvals by the US Food and Drug Administration (FDA) and US Department of Agriculture(USDA)for irradiating: bacon, wheat,wheat products (in 1963),and potatoes (in 1964) (CAST, 1989). At the same time, theUS Atomic Energy Commission began to install irradiation facilities at several universities, at the National Fisheries Service, and at the Entomological Research Center of the US Department of Agriculture (Diehl, 1995).

Such activities were not limited to the United States only. In 1950, similar activities began in Cambridge (England), and later in Belgium, Canada, France, Germany, the Netherlands, Poland, and the Soviet Union (WHO, 1994). According to data cited by Goresline (1982), in 1966, 33 countries were involved in examining the effects of ionizing radiation on food, while by 1972, their number had increased to 55. In 1973, Japan was the first country to begin commercially treating about 10,000 tons of potatoes per month to prevent their germination during storage. However, the largest operation of this kind was carried out at the port of Odesa (former Soviet Union), where, starting from 1959, about 400,000 tons of imported grain were irradiated each yearfor disinfection (CAST, 1989).

Particularly significant progress in this field was achieved after 1970 when meals of various types of meat supplied to astronauts began to be sterilized with ionizing radiation. This was followed by a large number of scientific studies, development programs, critical analysis, and numerous experiments in various institutions, all with the same goal: to decide whether the treatment of food with ionizing radiation is safe for human health (CAST, 1989).

1.1.Development of regulations for food irradiations

Although food irradiation has been studied more than any other technology in the food industry, the attitude of national health authorities has been strongly influenced by the

opinions and statements of leading international institutions: the Food and Agriculture Organization (FAO), the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) (Diehl, 1995; Pillai, 2004; WHO, 1994;Diehl, 1979). It took a long time for these institutions to reach a consensus on this issue, which posed numerous dilemmas and ambiguities.

The regulation development began with the "First International Conference on the Peaceful Uses of Atomic Energy" in 1955 in Geneva, held under the auspices of the United Nations. The following year, FAO established an Atomic Energy Branch in Rome, which aimed to assist countries that were using ionizing radiation to reduce food losses (CAST, 1989).The first international meeting devoted exclusively to the scientific data related to the safety of foods treated with ionizing radiation was held in Brussels in 1961, under the sponsorship of FAO, IAEA, and WHO. With 28 countries attending, it was concluded that it was still too early to approve food irradiation for industrial purposes, although the results of numerous studies presented by several countries were positive. It was recommended anFAO/IAEA/WHO Expert Committeeto be formed, which would provide advice and recommendations on this issue (WHO, 1988). Thus, in 1964in Vienna, a Joint FAO/IAEADivision of Atomic Energy in Food and Agriculture Committee was established, aimed to work on topics related to the safety of irradiated foods(CAST, 1989).

After reviewing numerous studies on the effects of the use of treated foods on animals and human volunteers, FAO/IAEA/WHO Joint Committee in 1964 concluded that: "The irradiation of foods in accordance with the procedures to be followed in practice has not given any indication of adverse effects of any kind and there is no evidence that the nutritional value of the irradiated foods is affected in any way". According to this, the FAO/IAEA/WHO Expert Committee approved regulatory control of foods treated with ionizing radiation, as well as a lists of products on which such treatment is permitted. Tests for assessing the safety of consuming irradiated foods, similar to those used to assess conventional food additives, were also proposed (WHO, 1988).

In 1969, the Expert Committee granted "provisional acceptance" of potatoes, wheat, and wheat products treated with ionizing radiation. The "provisional" nature of the acceptances meant that the data available at the time were still insufficient to fully establish their safety and that further evidence was needed. Later, in 1976, irradiated wheat and potatoes were granted "unconditional acceptance", while other products were granted "provisional acceptance". In the following years, the number of products for which ionizing radiation treatment was permitted increased (WHO, 1988).

This positive attitude of the Expert Committee (JECFI) towards irradiated foods and the subsequent guidelines given for further assessments of their safety had a decisive influence on international developments in this field. Thus introduction of this method in many countries of the worldstarted (Diehl, 1979; WHO, 1988). All this has intensified scientific research on this field, so based on a large number of scientific studies, FAO, IAEA, and WHO in their 1981 report emphasized that: "Any food treated with ionizing radiation with/up to a maximum dose of 10 kGy is considered safe and beneficial."As a result of this report, in 1983 the Codex Alimentarius Commission (CAC) accepted the Expert Committee (JECFI) recommendations, which resulted in the adoption of the General Standard for Irradiated Foods. In 1984, the Recommended International Code for the Operation of Radiation Facilities was adopted.Finally, in 1998, the Scientific Committee on Food (SCF) issued a favorable opinion on the irradiation of a large number of foodstuffs, but with a specific warning that "The treatment of food with ionizing radiation must not be used to conceal negligence in the handling of foodstuffs, nor to disguise their unsuitability for use as food" (European Commission, 2003).

In the period that followed, the need to increase the permitted dose for the treatment of certain products arose, following the newly acquired knowledge that spices are so heavily contaminated with microorganisms that an increase in the permitted dose is necessary. Therefore, it was concluded that the treatment of food with ionizing radiation can be carried out at all doses, as long as it is necessary, safe, and meets nutritional requirements. Based on this, in 2000the General Standard for Irradiated Foods was revised, and the Expert Committee (JECFI) concluded that "Food may be irradiated to any dose provided, that it is adequate to achieve the intended technological purpose, and the food is safe for consumption and nutritionally adequate."This conclusion was based on extensive scientific evidence indicating that it can be used to effectively eliminate spores of proteolytic strains of *Clostridium botulinum*, as well as other food spoilage microorganisms. Thus, it was determined that no upper limit for the radiation dose should be imposed, and accordingly, irradiated food is considered good in the entire range of technologically useful doses, from below 10 kGy to above 10 kGy (FAO, 2003).

So far, the United States has been the leader in food irradiation and this method in their regulations is treated as a food additive. According to these regulations, food irradiation is approved by the Food and Drug Administration (FDA), but the treatment of each new type of food is approved separately, with a specific and separate level for dose value determination. The reasons for irradiating many food products in the USA are the numerous and frequent outbreaks of pathogenic bacteria, especially of *Escherichia coliO157:H7* and *Listeria monocytogenes* (Roberts, 2001).

However, despite such long-term activity in this area, there are still significant gaps in terms of legal legislation and the need to develop "generic treatments" against different categories of pests between different countries that allow food irradiation (www.iaea.org). This can be confirmed by the differences in permitted doses and types of food that are irradiated worldwide as presented in Table 1.

Table 1. Comparison of permitted dose-applications in various regions. (Source: GHI, 2018)

Country:	USA	Canada	EU	China	India	AU&NZ
Spices, dry herbs, seasonings						
Maximum permitted dose, kGy	30	10	10*	10	6 - 14	2 - 30
Fruits, vegetables, leafy produce for shelf-life extension						
Maximum permitted dose, kGy	4.0	-	1.0 - 2.0**	1.5	1- 2.5	0.15 - 1.0
Meat products						
Maximum permitted dose, kGy	4.5 (un)refrigerated uncooked products	1.0 - 4.5 Fresh raw ground beef	-	8 Poultry livestock, cooked meats	-	-

*EU maximum overall average absorbed dose. **in UK

As seen from Table 1, spices, dry herbs, and seasonings are the only food categories for which irradiation treatment is permitted anywhere in the world, making them the most commonly irradiated food in international trade. Moreover, Table 1 shows that the United

States allows significantly higher doses for irradiation of spices, fruits, and vegetables, compared to other countries. Accordingly, a general conclusion is that one of the biggest challenges facing the global food sector in ionizing radiation is the harmonization of regulations and the equivalence of standards, doses, and labeling of such foods (GHI, 2018).

CONCLUSION

Food irradiation as a food preservation method improves food safety and extends food shelf life. Many years of extensive research have proved that this method is safe from nutritional and toxicological aspects. That has resulted in many regulatory approvals for its technological use from leading international institutions responsible for food safety at the global level. However, there are numerous differences between countries regarding the type of food that can be irradiated, the permitted doses, and how such food is labeled and traded. This indicates that for the full implementation of this technique as an innovative food safety method, harmonization of standards and regulations at the global level is necessary.

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