Food Materials Research

ARTICLE

Open Access

https://doi.org/10.48130/FMR-2023-0020

Food Materials Research **2023**, 3:20

Consumption of irradiated foods: strawberries case study

Salma Barkaoui[1,2,3], Joana Madureira[2], Sandra Cabo Verde[2] and Nourhène Boudhrioua[3*]

[1] *Higher School of Food Industries of Tunis (ESIAT), University of Carthage, 58 Avenue Alain Savary, 1003 Tunis El Khadra, Tunisia*
[2] *Centro de Ciências e Tecnologias Nucleares (C2TN), Instituto Superior Técnico, Universidade de Lisboa, E.N. 10 ao km 139.7, 2695-066 Bobadela LRS, Portugal*
[3] *Laboratory of Physiopathology, Food and Biomolecules, Institut Supérieur de Biotechnologie de Sidi Thabet, Université de la Manouba, LR17ES03 BP-66, 2020 Ariana-Tunis, Tunisia*
* Corresponding author, E-mail: nourhene.boudhrioua@isbst.uma.tn

Abstract

Faced with the various technologies used today to preserve food, consumers are becoming more demanding on information relating to both the quality and the processing of food. One of the technologies that has proven its effectiveness in food safety is irradiation, however people remain cautious or even refuse this technology which is not yet very popular and popularized thinking that it is a toxic treatment. This paper identifies the basic knowledge of two populations (Tunisian and Portuguese) about ionizing treatment and their intention to purchase irradiated foods, focusing on strawberry fruits. An online survey was conducted for research purposes and 1,000 people, living in Tunisia and Portugal were involved. The findings showed that there is still a dearth of knowledge on food irradiation, which demonstrates mistrust, misunderstandings, and reluctance to purchase irradiated products. In contrast to 56.3% of Tunisians, the data indicated that 60.7% of Portuguese do not know what food irradiation is. The two populations think that irradiating food and consuming it are harmful, despite the fact that their knowledge of the process is spread out differently. The Portuguese, who were more interested about food irradiation, were also more inclined to purchase and consume irradiated strawberries than the Tunisians. In fact, 62.7% of Portuguese people indicated they would be convinced to buy irradiated strawberries, in contrast to 33.5% of Tunisians who stated they would certainly not buy it and insisted on the harmful effects of the treatment if they had more knowledge and evidence if the treatment had been shown to be successful.

Citation: Barkaoui S, Madureira J, Verde SC, Boudhrioua N. 2023. Consumption of irradiated foods: strawberries case study. *Food Materials Research* 3:20 https://doi.org/10.48130/FMR-2023-0020

Introduction

Consumers are growing increasingly demanding of information about food quality and manufacturing as a result of the many methods utilized to preserve food. The growing demand for nutritious, fresh, safe, and 'minimally-processed' foods has inspired innovative research in non-thermal food processing technology[1]. Consumers worry about potential risks related with consuming foods processed by new technologies. Typically, the customer is unaware of the procedures used and the ingredients used in food production[2,3]. Irradiating food is a reliable method of food preservation that has been approved for use in more than 60 countries[4]. Irradiation is a non-thermal decontamination method that is substantially more flexible than other techniques[5]. It is the most advanced minimum processing technique that has been extensively researched and examined, although it is not widely used in Europe and North Africa. The term 'food irradiation' refers to a process in which food is exposed to ionizing energy, such as gamma photons produced by radioisotopes such as ^{60}Co or, less frequently, ^{137}Cs, machine-generated X-rays ('Bremsstrahlung') with a maximum energy of 5 MeV, or accelerated electrons with a maximum energy of 10 MeV[6]. The irradiation technology was approved by the Food and Agriculture Organization, International Atomic Energy Agency, and World Health Organization (FAO/IAEA/WHO) joint committee on the wholesomeness of irradiated food in 1981[7]. The irradiation of food at levels up to 10 kGy (the total average dose) was indicated to be safe and not to cause any particular nutritional issues. According to the Joint FAO/IAEA/WHO Study Group on High-Level Irradiation's conclusions, food that has been exposed to radiation at any dose that is necessary to meet the desired technical goal is both fine to consume and nutrient-sufficient[8]. Using gamma, e-beam, and X-rays, several scientific research papers have examined the effects of ionizing radiation on a variety of foods, including fruits[9–11], vegetables[12], dairy products[13,14], meat products[15,16], seafood[17], spices and aromatic plants[18,19] and cereals and pulses[20,21]. Irradiation treatment can improve the antioxidant and sensory properties and the microbiological quality while extending the shelf life of products. Despite scientific data demonstrating that irradiation is not harmful or carcinogenic, consumers are nevertheless skeptical about this technique. According to each country's experience with nuclear technology, different anxieties exist, and their levels of severity also vary. For example, because of the Chernobyl-4 accident, many Ukrainians are wary of using nuclear technology for any purpose[22].

The fundamental understandings of two population groups (one from North Africa: Tunisia and one from Europe: Portugal) concerning ionizing radiation, as well as their intent to acquire these items, are examined in this survey article. This is part of a project carried out in collaboration between the two countries 2019–2021 to better understand

consumers and the marketing of irradiated products. The study was conducted with a sample size of 1,000 respondents, consisting of 394 Tunisians and 608 Portuguese. This research examined the data collected from both countries to gain insights and draw conclusions on various aspects of the study. This article is the first to address a variety of issues with the aim of better understanding consumer knowledge and reluctance to purchase irradiated products in order to provide solutions for a marketing and commercialization strategy. To our knowledge, this study is the first to explore both the perception of two populations of consumers (Portuguese and Tunisian) with the aim of evaluating the level of knowledge, their opinion, and their decision to purchase irradiated strawberries. A decision tree to was used to understand the purchase decision.

Materials and methods

The study looked at consumers' knowledge and perceptions of irradiated products in general and irradiated strawberries in particular. This work can help to better identify and understand consumer knowledge and reluctance about irradiated products in order to create a marketing plan. The data was collected *via* an online survey using Google forms and concerns 400 people living in Tunisia and 600 in Portugal. Compared to traditional offline methods, online surveys are considered superior in both internal consistency and predictive (face) validity[23]. Links to the questionnaire were distributed on Facebook and LinkedIn social networks and sent by email. In order to obtain a more heterogeneous sampling, students, friends, and other acquaintances living in different regions of the two countries were encouraged to respond. Similar methodology was adopted by Lensvelt & Steenbekkers[24]. A specific sampling strategy was not used for this study because of the way the questionnaire was administered, but the sample size and the sociodemographic of the respondents did represent how the two populations were distributed across the regions of each country.

The questionnaire was written in two languages, in French for the Tunisians and in Portuguese for the Portuguese, the same headings, questions and presentation were kept. The online questionnaire, designed after an in-depth review of the literature, has been organized into three different sections with a preamble explaining that food irradiation is a preservation technique used and recognized around the world and that their answers will be kept anonymous. A prologue has been included to introduce the study's framework and briefly describe the radiation treatment. In the first section, respondents indicated their level of knowledge associated with the use of irradiation. In addition, the level of knowledge of the respondents regarding irradiated food, the health effects during consumption, the attention of the consumer following the explanation and the attention to buy irradiated food products on the market was evaluated. In the second section respondents indicated their consumption of irradiated strawberries and the attention paid to purchase and consumption. The third section contains the various data of the respondents (gender, age, geographical area, and profession). In both surveys (Tunisian and Portuguese), a likert scale ranging from 1 to 5 was used (where 1 meant no/not at all and 5 were highly relevant). The answers offered were multiple choice questions, checkboxes and some questions were short answers to express themselves. Additionally, respondents were questioned about their level of familiarity with food safety and how it affects consumer decision-making using dichotomous variables.

The statistical analyses of the questionnaire data considering the coding, cross table, descriptive analyses, and Chi-square test and the decision tree were carried out by International Business Machines Statistical Package for the Social Sciences 22 (IBM SPSS Statistics version 22), New York Produced in the USA.

Results and discussion

Profile of the responders

There were 394 Tunisians in the survey and 608 Portuguese. Table 1 provides a thorough analysis of the participants' many characteristics, including gender, age, location, and socio-professional classification. Regardless of their socioeconomic standing, age, or area of residence, women made up more than half of all respondents. In fact, 63.5% and 68.8% of responders from Tunisia and Portugal, respectively, provided a response. More than half of our respondents (54.1% Tunisians and 67.2% Portuguese) fit the characteristics of a government servant. The Tunisian respondents reflect a younger demographic than the Portuguese respondents in terms of age. The resulting profile was as follows: 80% of Tunisians and 40% of Portuguese respondents are between the ages of 20 and 39. Younger people, in particular, tend to be more accepting of food treated with novel technologies like irradiation[25], and they generally exhibit the highest need for extra food safety education[26]. Furthermore, Tunisia had a higher representation in the student group (30.5%) compared to Portugal (4.8%), 70.8% were from Tunis, and 65.6% were from Lisbon, making the capital their main site of residence. The findings demonstrate the diversity of those who clicked on the link and agreed to participate in the survey, with a propensity for women to participate at a higher rate than males in both countries. Young people, residents of the country's capital, and workers make up a sizable portion of the respondents in the studied countries.

Consumer knowledge of irradiation technology and irradiated products

Knowledge about irradiation

According to the knowledge-based tool question (Table 2), 56.3% of Tunisians are aware of food irradiation technology, with 71.4% and 34.5% having heard of it through courses or training or on TV or the internet, respectively (Table 3). This finding may be related to the age group of Tunisian respondents (30.5% university students). In contrast, 60.7% of Portuguese people had never heard of irradiation or any of its sources (gamma, e-beam, or X-rays). Portuguese people who are knowledgeable about irradiation obtain 41% of their information through the Internet and 44% of it from reading in print media (newspapers and magazines). Other studies carried out on different populations in Europe and South America have reported that the populations questioned did

Table 1. Respondents' characteristics.

		Tunisia		Portugal	
		Workforce	Percentage (%)	Workforce	Percentage (%)
Gender	Female	250	63.5	417	68.6
	Man	144	36.5	191	31.4
Age (years old)	<20	11	2.8	3	0.5
	20–29	203	51.5	73	12
	30–39	119	30.2	161	26.5
	40–49	43	10.9	140	23
	50–60	12	3	101	16.6
	>60	6	1.5	130	21.4
Profession	Secondary student	3	0.8	1	0.2
	University student	120	30.5	30	4.8
	PhD/Postdoctoral researcher	12	3	22	3.6
	Unemployed graduate	29	7.4	14	2.3
	Domestic	4	1	8	1.3
	Retired	8	2	88	14.5
	Merchant/Trader/Self-employed	5	1.3	37	6.1
	Civil servant/employee (public or private)	213	54.1	408	67.2
Geographical area	Capital	279	70.8	398	65.6
	North	53	13.5	60	9.9
	South	28	7.1	28	4.6
	Center	17	4.3	72	11.8
	Living abroad	17	4.3	26	4.3
	Azores archipelago	–	–	20	3.3
	Madeira archipelago	–	–	4	0.7

Table 2. Number of answers to whether or not irradiated foods are known.

	Tunisia		Portugal	
	Workforce	Percentage (%)	Workforce	Percentage (%)
Yes	222	56.3	369	39.3
No	172	43.7	239	60.7

Table 3. Sources of information on food irradiation.

Sources	Tunisia	Portugal
	Percentage of observations (%)	Percentage of observations (%)
Special event: exhibitions, fairs, scientific seminars	8.2	24.1
Internet or TV	71.4	41.4
Scientific papers or magazines	21.4	44.3
Places, points of sale: hypermarket, supermarket	6.4	1.7
In a course or training	34.5	28.3

not know about food irradiation. Indeed, Galati et al.[27] reported that 84.2% of Italian respondents do not know about the food irradiation treatment process. Also, a study by Deliza et al.[28] who found that approximately 60% of participating Brazilians have never heard of food irradiation. According to a study by Resurreccion et al.[29], 87.5% of customers in the USA understood very little about the food irradiation process, despite the fact that 72% of them had heard of it. The rate of fear of populations towards irradiation is different, in fact according to a survey by Resurreccion et al., Chilean consumers are far less aware of food irradiation (23.5%) than Americans (72%), Turkish consumers had a similar value (29%)[3]. Irradiated food and radioactive food are the same things, according to 45.9% of respondents. The latter impression is proof that people don't know enough about food irradiation and don't understand it. A survey in Istanbul conducted by Gunes & Deniz Tekin[3] showed that the majority of respondents (80%) had doubts regarding the safety of radioactively contaminated food. The number of respondents who said that food irradiation is safe was just 11%. Indeed, according to this present study, 43.7% and 60.7% of Tunisian and Portuguese respondents have never heard of this type of treatment, representing a fairly high rate, despite the various studies carried out on food irradiation worldwide. This underlines that the public needs more knowledge about this method of preservation, that more dissemination is needed by bringing the scientific results closer to the consumer. Therefore, it is obvious that potential consumers of irradiated foods would only decide whether or not to consume such products if they had sufficient knowledge and information on the issue[30].

Food irradiation data is rarely covered in papers that take an investigative approach. Indeed, as demonstrated in Table 4, which contains some consumer survey studies to try to understand the perception, acceptability, concerns, and temptation to buy irradiation goods. The impact of food irradiation has been the subject of several scientific articles, although consumer research has been few and inadequate globally.

Consumption of irradiated food and taste appreciation

A question based on whether or not you had already consumed an irradiated food was asked, as presented in Table 5. Among all respondents, 8.2% of Portuguese and 13.1% of Tunisians said that they had already consumed an irradiated product. For those who answered 'Yes, I have

Table 4. Published surveys on food irradiation in the period year 1992–2022.

Country	Published survey on scientific journals with impact factor		
	Population investigated (n)	Percentage of people who do not know about irradiation (%)	References
North Africa			
Tunisia	This work (394)	43.7	This work
European Union			
France	–		
Portugal	This work (608)	60.7	This work
Italy	392	84.2	[27]
Other Countries			
Korea	700	18	[31]
Chili	497	76.5	[30]
Brazil	168	58	[28]
	119	17	[32]
Canada	36	–	[33]
USA	160	32	[34]

Table 5. Question concerning the population of Tunisia and Portugal's consumption of irradiated food.

	Tunisia		Portugal	
	Workforce	Percentage (%)	Workforce	Percentage (%)
Yes	57	13.1	50	8.2
No	100	23	72	11.8
I don't know (maybe without noticing)	277	63.8	486	79.9

already eaten', the most commonly consumed foods were fruits and vegetables, with 85.1% of Tunisians and 83.3% of Portuguese participants reporting their intake. Following that, dishes containing one or more irradiated ingredients (e.g., spices) were consumed by 24.3% of Tunisians and 33.3% of Portuguese respondents.

When asked to rate the irradiated tested products out of five, 45.8% of Tunisians responded with a rating of three out of five, compared to Portuguese 35.1% with a rating of moderate appreciation (three out of five), and 33.3% with a rating of five out of five, which corresponds to their level of appreciation for the irradiated products. Based on the same question (consumption already of irradiated food), 63.7% of Tunisians and 79.9% of Portuguese answered that they do not know, perhaps without being informed. This reveals that consumers do not have knowledge about irradiation, which can be related to the labeling regulation that impose the signaling of the irradiated products with the 'Radura' symbol on the packaging or indicating the mention of 'treated by ionizing radiation' on the packaging. The word 'Radura' is derived from radurization, a term composed of the initial letter of the word 'radiation' and the term 'durus', which is the Latin word for 'hard' or 'durable'. This symbol was used for foods processed by ionizing radiation. The 'Radura' is usually green in color and looks like a plant in a circle. The upper half of the circle is dotted. The symbol can be interpreted as follows: the central point represents the radiation source and the two segments ('leaves') represent the biological shield intended to protect workers and the environment[35]. In Tunisia, according to article 8 set out in the order of the ministers of trade and crafts, public health and industry, energy and small and medium-sized enterprises of September 3, 2008 relating to the labeling and presentation of foodstuffs: the labeling of any foodstuff which has been treated with ionizing radiation must bear one of the following words: 'treated by ionizing radiation' or 'treated by irradiation' written for this purpose in the immediate vicinity of the product name. The use of the international food irradiation symbol 'Radura' is optional, but when used it must appear in close proximity to the product name. Additionally, the US FDA has required, since 1986, that irradiated foods include labeling with either the statement 'radiation treated' or 'radiation treated', accompanied by the 'Raduran' symbol[30].

Risk-trust of irradiated food

One of the most crucial questions to ask in order to learn further about consumers and what they believe about the link between irradiated products and health is: 'Do you think that the consumption of irradiated food presents a health risk?' Fifty three percent of the Portuguese answered that they did not know compared to the Tunisians were mixed 45% are sure that the consumption of irradiated products poses a danger to health while 40% answered that they do not know. A low rate of both communities answered that no health risk is linked to the consumption of irradiated products. These results show that there is a problem of trust and an already constructed prejudice with regard to these products. Research has proven no toxicity or health risk. Given that respondents had little awareness of this technique and the need to restore public confidence in safe technologies, our findings show that consumers have a problem with disinformation regarding food irradiation treatment. It is important to be honest and transparent, sharing both what is known and what is unknown in terms of risks and benefits, in order to keep the public's trust[36]. Galati et al.[27] reported that irradiation risk perception depends on how the customer views the technology in light of the information obtained.

The effect of the 'health risk' item on willingness to purchase irradiated foods

From the two questions of the survey on the health risk reflection and the desire to test/consume irradiated foods, a cross table (Table 6) was produced. The results were as follows: 74.9% of Tunisians and 62.8% of Portuguese who do not want to become consumers believe that this technology represents an immediate threat to their health, while more than half of those interested in irradiated foods have no idea whether it is a safe or risk-free method of preservation (51% of Tunisians vs 65% of Portuguese). The most frequent comments from respondents were that irradiation causes cancer, is harmful to health, and that irradiated products are radioactive.

They lack sufficient understanding necessary to comprehend the treatment's effects because irradiation is a very uncommon food preservation treatment. Respondents from both populations made these remarks. These results obtained from the Tunisians and the Portuguese corroborate those of Galati et al.[27], who reported that 80% of the inhabitants of Istanbul were concerned about the safety of irradiated foods. Moreover, according to Junqueira-Gonçalves et al.[30], 57.1%

Table 6. Cross table: Desire to consume irradiated food considering health risk.

		Do you think that the consumption of irradiated products presents a health risk?					
		Tunisia			Portugal		
		Yes	No	I do not know	Yes	No	I do not know
Workforce and percentage included in: Does it make you want to consume irradiated food?	Yes	26	43	73	10	140	67
		18.3%	30.3%	51.4%	4.6%	64.5%	30.9%
	No	125	2	40	76	3	42
		74.9%	1.2%	24.0%	62.8%	2.5%	34.7%
	I do not know	28	15	42	33	24	213
		32.9%	17.6%	49.4%	12.2%	8.9%	78.9%

of Chileans surveyed were unaware that food irradiation could harm their health. Despite the numerous scientific studies on irradiated foods that have demonstrated an improvement of the microbiological, sensory, and bioactive properties, the consumer's misconceptions about irradiation keep them skeptical. Consumers frequently amplify the risk associated with unfamiliar foods or technologies while minimizing the risk associated with well-known foods or home preparation[37]. In order to better understand what consumers think about food preservation methods, a question about the effect comparison between irradiation and food additives was asked in this context. Seventy percent of the two populations Portuguese and Tunisians, answered that they did not know which treatment was more harmful than the other. This result may also explain why consumers do not have a clear idea between the fundamental difference in the treatments applied to food (physical or chemical), which leaves them skeptical when buying. Kaptan & Kayısoglu[38] noted that the majority of consumers are aware of additives on food labels, which has a negative impact on their decision to buy the food. Moreover, the majority of consumers considered control programs for additives to be insufficient, and some respondents lacked knowledge of these initiatives. Data demonstrated the need for consumer education on the benefits, safety issues, label declarations, and control programs of food additives[39]. Studies have revealed that participants' mistrust in government-approved food additives stemmed from a lack of knowledge and comprehension of food additives as well as from unclear risk communications between stakeholders like the government, industry, and consumers[40]. Scaling data methods were applied to questionnaire responses in 2008 Canadian research of consumers' acceptance of food technology, including irradiation, in order to identify the key determinants of consumer acceptability (as well as those that are not). The aim of the study was to forecast responses to potential food product and process technologies in the future[33]. Food irradiation has been rated negatively on the risk-benefit continuum (e.g., harmful, dangerous, risky), whereas traditional foods, nutrient fortification, and vacuum packaging were positioned at the positive end of the graph. They represented this information in a graphical display of how consumers perceive traditional and new technologies (eg, useful, safe, trustworthy). The majority of food technology, including pesticides, food irradiation, and genetic engineering used on both plants and animals, are on the negative end of the continuum from known and controllable to unknown and uninformed (e.g., unknown, unsure). The responses 'clearly understood' (positive) and 'unknown/uncertain' (negative) carried the majority of the variance between samples (19.5%) in their favor[33].

The effect of gamma irradiation on strawberries were investigated by Barkaoui et al.[9]. The results showed that the irradiated fruits had no effect on the viability of human cell lines (293T non-tumor cells and A549 tumor cells), suggesting the absence of cytotoxic effects. Another study on the effect of e-beam on raspberries by Elias et al.[41] reported no cytotoxic effects against tumor and non-tumor cell lines of the extracts from irradiated raspberry at doses below 3 kGy and stored for up to 7 d. In order to disseminate their research, make their findings more intelligible to the general public, and assist people in overcoming their fear of radiation, scientists must simplify their findings. Food irradiation worries are false and readily dispelled if the public is aware of the technology and how to utilize it properly. To do this, scientists must make their findings more comprehensible to the general public, promote their discoveries, and assist people in overcoming their fear of radiation by bringing it closer to them. Information and communication channels that are accessible to the largest audience could be used. By ensuring that children receive an early education, prejudice can also be avoided from influencing young customers. It is feasible to introduce educational modules on cutting-edge, environmentally friendly, and sustainable technology in classrooms. The chance to reach a larger audience is provided by presenting research findings on irradiated foods at conferences and professional associations. Through seminars and short courses, extension and outreach workers with expertise in food irradiation provide their communities a range of extremely beneficial services[42]. Bring these new technologies closer to the customer with the use of posters, media, and seminars for the public distribution of scientific findings. As an illustration, the C^2TN - Centro de Ciências e Tecnologias Nucleares actively participates each year in the Science Fair, where researchers present parts of their research projects and scientific work to the general public (all age groups) through readings of product tastings, showcasing their machines, etc.

Case study of irradiated strawberries

According to the responses collected from the two surveys, 97% and 92.9% of respondents from Tunisia and Portugal, respectively, consume strawberries, with a weekly frequency during their availability in the market.

Effect of irradiation on strawberries

Regarding the question about the impact (positive or negative) of irradiation on the quality of strawberries, such changes in color, flavor, aroma, and nutritional value, etc.

Irradiation has an impact on the quality of strawberries, as referred to by 77.9% of Tunisians vs 50.8% of Portuguese respondents. However, 28% of Tunisians believe that the quality of strawberries will be degraded by irradiation, while 64% of Portuguese respondents said they do not know whether the effect is positive or negative. Irradiated strawberries have been the subject of much scientific research. According to the different findings, the strawberries' taste was unaffected by the irradiation. Indeed, Barkaoui et al.[11] observed similar results when they compared that the use of gamma radiation with 2 kGy against the control and reported that this dose contributed to the sensory acceptability of strawberries after 14 d of cold storage. Electron-beam also was tested on strawberries by Barkaoui et al.[10] and Yoon et al.[43], the two studies reported that e-beam irradiation reduced deterioration in sensory quality compared to the control (non-irradiated). Yoon et al.[43] reported that X-rays improved strawberry flavor after 3, 6, and 9 d of storage. All cited references used low doses of irradiation that did not exceed 3 kGy and highlighted improvements in quality, microbiological, physicochemical and antioxidant properties. This proves that irradiation has a positive effect on the quality of strawberries while increasing the shelf life.

Attention to purchase irradiated strawberries in the trade

The question, 'Do you accept a price difference between irradiated strawberries and non-irradiated strawberries?' was asked in the survey. The data gathered revealed that, while 74.5% of Portuguese will accept a price difference, 59% of Tunisians oppose it because they think the price of strawberries is already too high. Tauxe[44] reported that surveys conducted by the Food Marketing Institute suggest that about 50% of the population will buy irradiated food. Acceptance would increase if the cost was similar to a non-irradiated product. Surveys suggest that if the public understands that irradiation minimizes harmful bacteria, then the acceptance rate would increase from 50% to 80%–90%. However, there is still a misunderstanding regarding the distinctions between the effects of the irradiation process and contamination by radioactive materials, and the ionizing radiation industry is unable to effectively communicate the risks and advantages of food irradiation technology[45]. Another question was asked about the temptation to buy irradiated products on the market, 62.7% of Portuguese respondents said they might, compared to 33.5% who said no. Table 7 represents the cross-results of these two questions the temptation to buy irradiated strawberries and the price difference. The results reported that 92.1% of Portuguese and 70.5% of Tunisians are willing to pay the difference in treatment costs. More than half of people in both countries, 58.2% in Tunisia and 55.4% in Portugal, are hesitant to buy irradiated strawberries. However, 78.8% of Tunisians refuse to buy irradiated strawberries because of the cost differential, compared to only 23.4% of Portuguese people. These findings suggest that the higher price of irradiated strawberries relative to untreated strawberries is a factor restricting purchase decisions, especially when combined with a lack of information and misconceptions. Deliza et al.[28] reported that the difference in price of irradiated and untreated papayas was insufficient to be a key factor influencing buying decision for Brazilians. Indeed, the price effect can influence purchase behavior if price levels approach 30% compared to the non-treated option. The participants' views of the technique changed as a result of learning about the advantages and regulations of food irradiation in Brazil. However, in addition to ongoing concerns about potential long-term consequences of consuming irradiated food, the notion of a greater cost to consumers emerged as a major worry among the groups. People from lower socioeconomic classes, where money is more limited, showed this anxiety more clearly. Gunes & Deniz Tekin[3] observed that customers expected to pay a higher price and intended to only pay a 5% premium for irradiated foods in a study of Turkish consumers. US research has produced a variety of results, but one of it is that some customers are prepared to spend up to 10% extra for irradiated meats, fish, and chicken as long as the process increases the safety of the products[46,47]. Compared to fruits and vegetables, muscle food and seafood appear to respond to irradiation more favorably[29]. Based on economic theory, Wilcock et al.[48] stated that consumer willingness to pay for extra safety would decide the demand for food safety. Therefore, the demand for food safety rises not just as consumers become more aware of the hazards connected with food illness or contamination, but also when the gross domestic product and the spending power of the ordinary consumer rise. This justification is consistent with some observations made here, particularly with regard to people of lower socioeconomic status' perceptions: a higher price could have a negative effect when factored into individual decision-making, lessening the importance of the advantages of irradiation to food safety.

Decision tree

The factors age, sex, place of residence, and profession were considered in the development of the decision tree to explore their effect on purchasing behavior and to classify the decisions taken to determine the profile of persons likely to purchase irradiated strawberries. Figure 1 depicts the outcome. Gender/sex is the only factor that influences the purchase choice. Irradiated strawberries have attracted more attention from Portuguese than Tunisians. Indeed, 20% of Tunisian women who responded positively to the purchase of irradiated strawberries, with an interested percentage of 50.8% remaining undecided on the purchase. While, for men, 40% refuse to buy irradiated strawberries. Tunisian men remain even more skeptical than women about buying attention. Concerning Portuguese, regardless of their gender, female, or male, are both interested in buying irradiated strawberries, with 61.3% of men and 63.3% of women

Table 7. Cross table: Desire to buy irradiated strawberries offered on the market considering different prices.

		Price difference			
		Tunisia		Portugal	
		Yes	No	Yes	No
Would you be tempted to buy irradiated strawberries offered on the market	Yes	55 70.5%	23 29.5%	116 92.1%	10 7.90%
	Maybe	77 41.8%	107 58.2%	45 44.6%	56 55.4%
	No	28 21.2%	104 78.8%	292 76.6%	89 23.4%

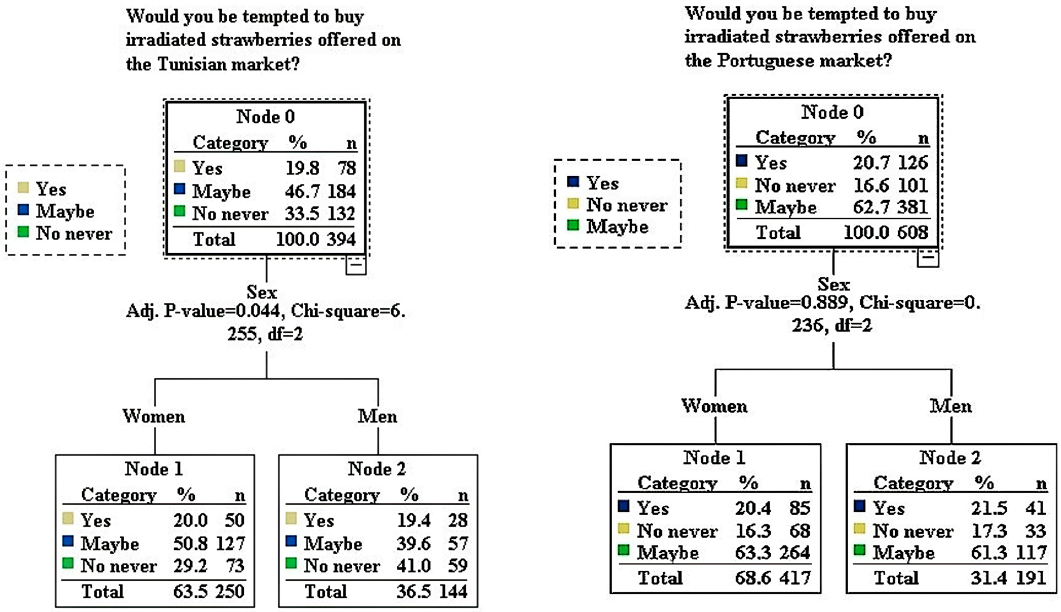

Fig. 1 Tunisian and Portuguese decision tree for purchase of irradiated strawberries.

respectively, against an average of 16% who still hesitate. It is crucial to emphasize the fact that there is a significant chunk of skeptics because they may still be convinced to buy irradiated strawberries with strong finance and business investments for the straightforward presentation and explanation of the irradiation process. In contrast to the Tunisians, who showed more skepticism toward the irradiation, the Portuguese expressed greater enthusiasm in the purchase and consumption of irradiated strawberries. From our data, we can conclude that the decision to buy irradiated strawberries is shaped by a multitude of variables, including lack of trust in government, manufacturers, and labeling requirements, as well as the status of the economy. Consumers' attitudes toward this treatment are unaffected by nationality or the population sampled. The latter have a common concern: the process, in their opinion, inevitably could causes radioactivity in the food. In contrast, consumers, initially, tend to exhibit resistance to new technologies. For example, people have previously expressed reservations about canning milk due to a lack of understanding of the benefits of the preservation method[44].

Conclusions

The findings of this study showed that there is still a dearth of knowledge on food irradiation, leading to mistrust and reluctance to purchase irradiated foods. It is vital to establish an international strategy including the scientists research dissemination to the general public in order to promote the benefits of ionizing radiation technologies, aid in better understanding, and persuade the consumer that the items are safe for his health. The survey's findings indicate that 60.7% of Portuguese and 43.7% of Tunisians don't know what food irradiation is, and 45.4% of Tunisians are confident that irradiation is harmful. By looking at several factors including age, sex, occupation, and place of residence, it has been discovered that gender is the only variable impacting customers' purchase decisions. In Tunisia, women replied more favorably than men to the purchase of irradiation strawberries, but in Portugal, more than 60% of respondents are favorable and support the action. In conclusion, Portuguese were more eager to purchase and consume irradiated strawberries than the Tunisians, who had a higher level of skepticism about food irradiation.

Acknowledgments

The authors are grateful to the Foundation for Science and Technology (FCT, Portugal) and Ministry of Higher Education and Scientific Research, Tunisia for financial support to the Bilateral Portugal-Tunisian research project (Conventional and non-conventional strawberries processing: effects on product quality, safety, antioxidants, and anti-diabetic potential, 2019–2021), to FCT for financial support through national funds FCT/MCTES to C2TN (UID/Multi/04349/2020), and for PhD studentship granted to Joana Madureira (SFRH/BD/136506/2018). The work was also developed in the scope of the Coordinated Research Project D61024 'Development of New Applications of Machine Generated Food Irradiation Technologies' financed by the International Atomic Energy Agency (IAEA). The authors are also grateful to University of Carthage Tunisia for the national funding to S. Barkaoui (2018-PFE-194), (2019-BALT-887), (2020-BALT-576) and (2021-BALT-1272).

Conflict of interest

The authors declare that they have no conflict of interest.

Dates

Received 15 April 2023; Accepted 9 July 2023; Published online 4 September 2023

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