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Research Article

Consumers' knowledge, awareness and acceptability of fresh irradiated tomatoes in Arusha, Tanzania

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Abstract

Food irradiation is an emerging technology with many advantages for consumers. Among the benefits of food irradiation that inhibits the growth of pathogenic microorganisms. This study aimed to evaluate consumer awareness, acceptance, and understanding of food irradiation technology. Questionnaires and focus group discussions were used to collect data. A 7-point hedonic test was also used to compare the acceptability of irradiated and non-irradiated fresh tomatoes among 70 panelists from Morogoro, where the irradiated sample was stored at room temperature (25 ± 2 ^{o}C). Moreover, a total of 50 respondents from Arusha, Tanzania, participated in this study. The results indicated that the majority of participants were males (58%), n=29. This study revealed a moderate level of consumer awareness of food irradiation technology. Among the interviewed people, 52% were aware that irradiation could be used as a food preservation method. Moreover, 99% of the interviewed persons were not familiar with the ''RADURA'' symbol. On the another hand, consumer acceptability panelists ranked irradiated and non-irradiated tomatoes for colour, appearance, texture and smell. In terms of texture significance ($p < 0.05$), a difference between irradiated and non-irradiated tomatoes was observed, with a score of 6.64 higher than 5.47, respectively. In conclusion, most consumers were unsure about food irradiation but accepted the irradiated tomatoes. Thus, more knowledge and awareness about food irradiation technology are needed in Tanzanian.

1. Introduction

Food irradiation is a more effective method in the treatment of food as compared to other methods, including pasteurization, freezing, chemical, refrigeration, or canning processes [1]. Food irradiation is also referred to as "cold pasteurization" since the results are similar to those achieved by heat-based pasteurization, but without using heat or increasing the temperature [2]. The process inactivates microorganisms, viruses, bacteria, or insects, as well as prevents the germination and sprouting of potatoes, onions, and garlic [3]. It also slows the ripening and ageing of fruits and vegetables, reduces pathogens in food, extends shelf life, and protects consumer health [4].

New food technologies uniquely affect consumers' lives because they are concerned about what is consumed and fear the unknown, which tends to resist change [2]. Lack of Information on the perceived risks and benefits of such technologies contributes to the doubt or delay of the public in accepting new technologies [5]. Despite more studies being conducted on ionizing radiation as an effective means of food preservation than any other food preservation technique, the implementation and acceptance of the technology are still very slow [6, 7]. In addition, limited information and knowledge, may lead to most consumers rejecting technologies are not well known and not commonly used, such as the genetic modification of crops (GMOs) and irradiation [8]. The reason behind, this is because that consumers perceive the risks of new technologies differently from producers, processors, and other experts. Consumers make decisions about food based on their feelings, rather than facts [9].

Food irradiation is an effective tool for eliminating foodborne, pathogens and spoilage microorganisms from food [10]. It has gained significant attention due to its potential to improve microbial quality, ensure safety, and extend the shelf-life of fresh produce [11]. The safety and efficiency of food irradiation have been approved by several authorities, including, International Atomic Energy Agency (IAEA) in Vienna, The Food and Agriculture Organization (FAO) and World Health Organization (WHO) [1]. The elimination of pests on agricultural commodities can also be achieved through this technology, reducing post-harvest losses and the use of chemical fumigants and additives [12]. Food irradiation up to an overall dose of 10 kGy has been considered safe to reduce microbial loads to 65 - 80 % and extend the shelf-life of the products [11, 12].

Despite the multiple benefits and recognition by International bodies such as the International Atomic Energy Agency (IAEA), the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the general principles of food hygiene in the Codex Alimentarius for the past 100 years [13], food irradiation technology is still slowly implemented, mainly due to social and political factors, and lack of proper knowledge among consumers. Furthermore, health effects from the 1986 Chernobyl nuclear power plant accident and the 2011 Fukushima nuclear power plant accident in Japan [14] led to low implantation of the technology due to contaminated food products.

Moreover, the large scale adoption of this technology for the decontamination of products has not been taken up by the fresh produce industry. This could be due to the need for further research on food irradiation to evaluate the effects on fruits and vegetables of the radiation doses required for controlling several pathogenic organisms [15]. According to the International Atomic Energy Agency (IAEA), food irradiation is unfamiliar to most consumers, and it was concluded that education about food irradiation should be implemented [12]. Many innovations, even those with that have advantages, require time before they are accepted or used. Technologies such as pasteurization, immunization, and chlorination are now considered safe for public health, however, each of these experienced suspicions and resistance when they were first introduced [16].

Although, Nkuba and Mohammed (2014) [17] conducted a study on the determination of radioactivity in maize and mung beans grown near to the Minjingu phosphate mine in Tanzania, no study has been done on consumer attitudes toward food irradiation technology [18]. The objective of this study aimed to identify consumers' knowledge, acceptance, and awareness of food irradiation technology.

2. Materials and methods

2.1. Study area

The study was conducted in Arusha city to understand the awareness of tomato consumers on irradiated fresh tomatoes (Fig 1). Arusha city was selected based on the availability of key respondents above 18 years who were producers and some were consumers of potatoes. The urban district of Arusha is located between 3° 23′ and 12.93° North latitude and 36° 40′ and 58.77° East longitude. Another reason for choosing this area is that it is located near the head office of the Tanzania Atomic Energy Commission which is the Regulatory Authority for controlling the peaceful use of radiation, enabling the researcher to access some information from the Authority.

2.2. Study design and statistical analysis

A descriptive cross-sectional design using a quantitative and qualitative approach was applied to a self-administered questionnaire [19]. The questionnaires were used to investigate consumers' knowledge and awareness of fresh tomato irradiation.

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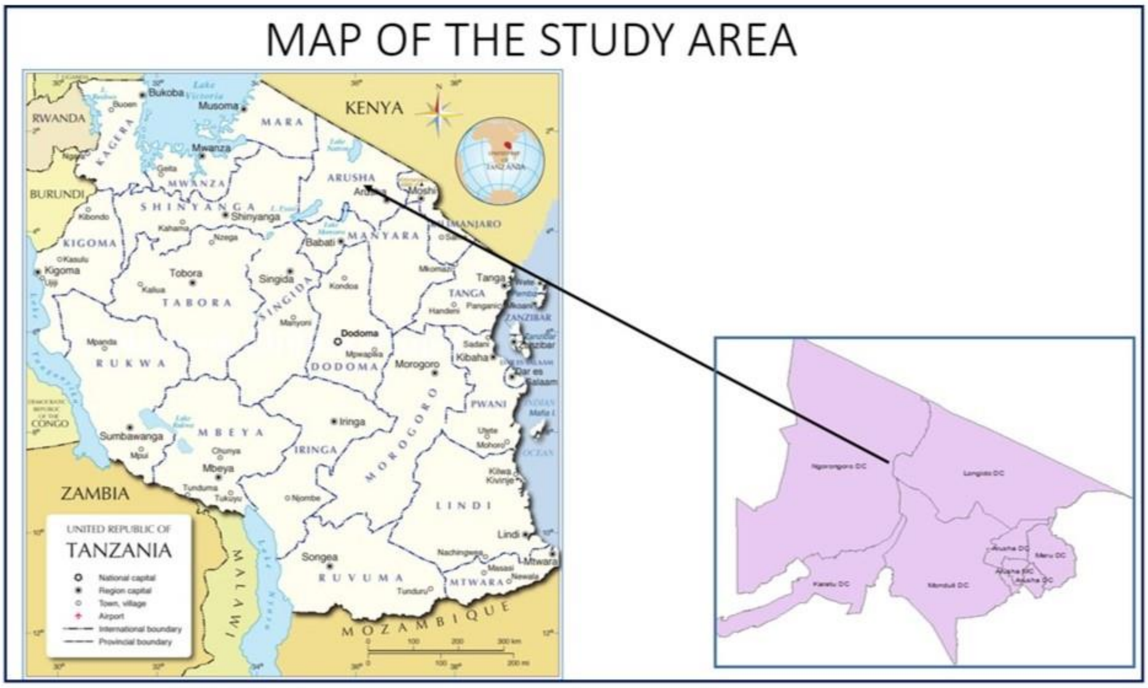

Figure 1. Map of the study area.

For assessment of consumer acceptance of irradiated tomatoes, questionnaires were used. The panelists were from Morogoro, where the irradiated sample was kept at room temperature (25 ± 2^{0}C). In addition, a structured questionnaire was administered to farmers, and consumers, and descriptive information was generated from focus group discussions (FGD) and Key Informant Interview (KII) was done with the Tanzania Atomic Energy Commission (TAEC) in Arusha to get information on knowledge, awareness, and perceptions of irradiated food.

The collected data were summarized and analyzed using statistical software (IBM SPSS version 20). To determine frequency and percentage, descriptive statistics were used. The audio-recorded data from the Focus Group Discussion and Key Informant Interviews were transcribed and manually coded in Microsoft Word, guided by Joffe [19]. The coded data were extracted and grouped into clusters and themes to create similar patterns. Two sample the t-test was used for the sensory evaluation and GenStat software version 15th Edition was used for data analysis.

2.3. Sampling procedure

The participants involved in the study included farmers, traders, and consumers of tomatoes; 29 (male) and 21 (female) participated in the survey, which was administered through a questionnaire. A total of seventy-two sensory evaluation panelists were chosen at random and trained on the methods and procedures used in sensory evaluation.

2.4. Sensory evaluation

Irradiated and non-irradiated tomatoes were given to panelists after 28 days of storage for sensory evaluation. The procedure carried out for this evaluation was similar to that described by Lim *et al.* (2022) [20]. According to Lim *et al*. (2022) [20], the panelists tasted and evaluated their overall liking using a 7- point hedonic scale. The panelists were asked to rate their preferences for appearance, color, smell, texture, and overall acceptability on a hedonic scale from 1 to 7 [20]. Hedonic scale where 7= like extremely, 6= Moderately like 5= slight like, 4= neither like nor dislike, 3= slightly dislike 2= dislike moderate, 1= dislike most. The same procedure was used in this study, 100 panelists were selected randomly for sensory evaluation. A large number of panelists (i.e 100) was chosen in order to increase confidence in the interpretation of the results. Irradiated samples were taken at random from 1, 1.5, and 2 kGy to form one group of irradiated samples. Samples were coded with three digits randomly assigned to them to avoid bias. The acceptability threshold was set at a score

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above 4; therefore, scores of 4 and below were deemed unacceptable.

2.5. Awareness and knowledge of irradiated food products

A questionnaire was prepared for the consumers' participation. The purpose of the questionnaire was to determine the respondents' attitudes toward food irradiation. A total of 50 respondents were selected. Ten (10) questionnaires were distributed out of 50 to employees of the Tanzania Atomic Energy Commission, ten (10) to tomato grower households, ten (10) to people from Arusha supermarkets, ten (10) to students at the University of Agriculture in Sokoine, and ten (10) to tomato cultivators in Arusha. This proportion was not based on the size of each population group. Instead, a purposive sampling method was used to distribute an equal number of questionnaires (10 per group) to five key stakeholder categories relevant to the study. This ensured a balanced representation of perspectives from experts, producers, sellers, students, and consumers for comprehensive analysis. The level of awareness was assessed using a structured questionnaire with open ended question.

The questionnaire comprised of two parts. The first part, Part A solicited respondents' demographic information, including gender, age, education, income level, and occupation. Part B was assessed respondents' knowledge of food irradiation technology. Parts C and D were based on personal interviews. This includes; a focus group discussion containing six questions and key informant interviews containing three questions. Employees of the Tanzania Atomic Energy Commission, tomato households, people from Arusha supermarkets, and tomato cultivators in Arusha were chosen at random for FGDs, while the director of technology and technical services, as well as the leader of the tomato sellers, were involved in the KII. The discussion was organized and led by two assistants. The participants were seated facing each other to allow eye contact and a free flow of discussion and were informed that their voices would be recorded during the discussion. Participants were also encouraged to express themselves freely and there were no correct or incorrect answers.

The printed questions prepared by the researcher were distributed to the participants during discussions. At the end of the discussions, the participants were asked to provide any other alternatives to irradiation for food preservation that they were aware of. All comments and suggestions were noted and deliberated in the final draft of the survey instrument and data analysis.

3. Results and discussion

3.1. Demographic profile

A total of 50 respondents participated in the survey administered through a questionnaire, of which 62 % (n=31) were male and 38 % (n=19) were female. Their average age was 33years (minimum=17, maximum =58years) and the majority (54%) of them had a university education. Fig. 2 shows the sex-aggregated data on respondents' education level.

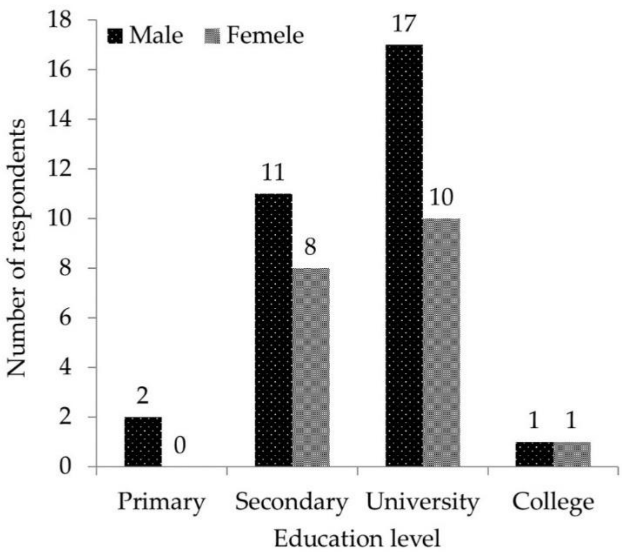

Figure 2. Respondent's education level.

3.2. Consumers' knowledge and awareness of food irradiation

The knowledge of food irradiation was assessed using seven questions, with a score of one (1) indicating knowledge and zero (0) indicating ignorance. The range of knowledge scores was 0 to 7 (average mean = 3.4, or 49%). Respondents were aware of the regulatory authority in charge of all aspects of radiation technology, including the safe use of radiation (62%), the use of radiation in industry and hygiene products (56%), and increasing shelf life (52%). Table 1. shows the total scores for each question.

Consumers were asked to provide their views on food

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Table 1. Consumer's knowledge and awareness of food irradiation in Arusha region.

Knowledge question	Total responses	N	Percentage
Ever seen an Irradiated food product	23	50	46%
Does food Irradiation delay fruit ripening	19	50	38%
Treated with irradiation can increase shelf life	26	50	52%
Irradiated food and food product will not become radioactive	20	50	40%
Irradiated food will still be nutritious the process	23	50	46%
Regulations that oversee the use of radiation	31	50	62%
Industrial and hygiene products	28	50	56%

N= Total number of respondents.

irradiation to determine their level of understanding. "*The irradiation process consists of exposing food to ionizing radiation*". "*It kills microorganisms and reduces the number of microorganisms responsible for deteriorating food.*"It also "*increases the shelf life of the food*".(FGD, Arusha, 19th April 2021).

In addition, the participants were also asked to differentiate between irradiated and radioactive food.

"*Yes, there is a difference between irradiated and radioactive food*"."*Radioactive is food contaminated with radioactive material.*""*Radioactive food is emits radiation*".(FGD, Arusha, April 19, 2021).

Limited knowledge of food irradiation has been documented in several studies. The results show that about forty-six percent (46%) of the respondents had never seen irradiated food products. This concurs with a study conducted in Chile, where 76.5% of participants had never eaten or seen irradiated food in grocery stores [21]. In addition, the study found that, 52% of the participants were aware that irradiation technology could be used as a method of food preservation and could increase the shelf life of some food products. Caputo (2020) [5] reported a similar finding, finding that 58.3 percent of consumers have never heard the term "irradiated food," and 31.7 percent of those who have heard of food irradiation do not know what it means. Moreover, the survey conducted in Canada by Maherani *et al.* (2016) [12] found that the majority of Canadian consumers were not well informed about food irradiation, and about 57% of Canadian consumers had never heard of food irradiation as a means of food preservation technique.

Furthermore, it was noted that, during the Focus Group Discussion, irradiated food requires special labeling to increase people's awareness and knowledge about food irradiation. This concurs with the findings of Komolprasert (2016) [22], who urged that, labels must bear a statement such as "treated with radiation" or "treated by irradiation" or the use of the RADURA symbol. In addition, the World Health Organization (WHO) recommends labels or international symbols for irradiation, known as "RADURA" on irradiated foods.

In developed countries like the United States of America (USA) and Canada, the use of the RADURA logo is compulsory, whereas it is optional in other countries. For example, countries like the European Union do not allow the use of the international logo "RADURA" in their names; instead they use the word "treated by irradiation" [23-24]. Labeling is an important step in assuring consumers who are deciding whether or not to purchase irradiated products.

3.3. Consumer's perception towards food irradiation

Most participants expressed concerns about the use of irradiation in foods. Consumers were unsure about the safety of irradiated food for human consumption. Although information on the safety of food irradiation was provided, it did not appear to be sufficient to persuade participants, as mentioned during focus group discussions.

"*I never consumed irradiated food," so I don't know if it is safe or not*". *It is not safe because residue remains after the process, as with other methods such as chemical methods.*" (FGD, Arusha, April 19, 2021).

The study conducted by Lima *et al.* (2017) [25] indicated that 52.8% of Brazilians interviewed were ready to consume irradiated products if they knew that irradiated food is safe for human consumption and does not cause short and/or long-term health

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Table 2. Acceptability of irradiated tomatoes stored at room temperature (25 ± 2 °C) for 28 days.

Sensory attributes	Radiated tomatoes	Non-irradiated tomatoes	p-Value
	Means ± SD	Means ± SD	
Colour	6.28±0.86	6.10±0.94	0.120
Texture	6.04± 0.82	5.47±0.83	<0.001
Smell	5.82±0.89	5.84±0.97	1.00
Appearance	6.24±0.84	6.02±0.81	0.818

Means in each rows were significantly different (p<0.05) where by SD = Standard Deviation of the means sensory parameter (n=2).

problems. A study conducted by Galati *et al.* (2019b) [26] showed that the acceptability of food products treated with ionizing radiation is mainly affected by the perceived risk of consumers associated with the long-term consumption of irradiated foods and their effects on human health.

In the current study, only 11 % of respondents were certain that food irradiation was safe.

"Yes, it is safe because the technology is approved bythe International Atomic Energy Agency (IAEA), Food and Agriculture Organization (FAO) and the World Health Organization (WHO)." Safe because the food is exposed to radiation in the same way that luggage is exposed to x-rays in airports, and nothing remains in the food." "The safety depends ondose; ata low dose, the food will be safe; ata high dose, the food will not be safe." (FGD, Arusha, April 19 2021).

Nutritional quality is an important factor to be maintained during irradiation. Participants were concerned about nutrition and believed that the nutritional content would be reduced during the process. Many consumers believe that important nutrients are lost during food irradiation process. However, several studies have shown that, nutrients are not lost after food irradiation. Woodside (2015) [27] reported that trace elements, minerals, and macronutrients such as protein, carbohydrates, and fats are not affected by irradiation at doses up to 50 kGy. Moreover, loss of nutrients is very common in many preservation techniques such as canning, drying, heat pasteurization and sterilization. Notably, the main advantage of food irradiation is that it can be used to treat packaged foods, which will remain safe and protected from microbial contamination after treatment.

"I read one of the published articles which indicates that the method leads to some nutrientloss". "I don't know…., I know nothing about the loss in nutrients". "I don't know, but some literature says there is no change". "It depends on the irradiation doses; there are no changes at low doses, but there are changes at high doses (FGD, Arusha, April 19, 2021).

Lastly, the participants were asked if they were familiar with the RADURA logo and word, which represents irradiated food. It was revealed that all the participants were not aware of this logo or word, some of them heard it for the first time during the discussion.

After getting familiar with this logo and word, most of the participants suggested that it is important to have this symbol on the product for a consumers' decision-making. This means that the lower the level of consumers' knowledge, the lower the likelihood of consumers accepting the technology. This finding was supported by Hussin (2018) [28], who urged that, labels must bear a statement such as "treated with radiation" or "treated by irradiation. Also, the participants suggested that, the logo and word "irradiated" be included so that consumers could choose between irradiated and non-irradiated foods.

"To be clear for both consumers who want to buy irradiated food and those who do not."This will help exporters meet standards and regulations.""Other countries don't use symbols, they use the words "treated with irradiation," but it is important to use those wordsrather than nothing."(FGD, Arusha, April, 19 2021).

3.4. Consumer acceptability

The sensory characteristics are presented in Table 2. There was a significant difference in texture between the treated and untreated tomatoes (P < 0.05). However, no significant differences were detected in the appearance, smell, and colour of irradiated and non-irradiated tomatoes (p > 0.05), as presented in Table 2. The results showed that irradiated tomatoes

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were more acceptable than non-irradiated tomatoes, with a score of 5.47. Both samples were moderately liked by consumers on a 7-point hedonic scale, but treated tomatoes were more liked than untreated tomatoes. Related findings reported that red pepper sampled irradiated with a small dose (control and 0.5 kGy) turned mushy and foamy after 10 days of storage [29]. According to similar findings in the study done by Rahman *et al.* (2021) [30], whereby after evaluation of the sensory properties of red chill, the results show that nosignificant difference in terms of colour, texture, and smell between irradiated tomatoes and non-irradiated red chill. For colour attributes, the mean scores (6.28 ± 0.97) of radiated tomatoes exceeded the mean scores (6.10 ± 0.95) for non-irradiated tomatoes. Munir *et al*. (2018) [31] reported that fresh tomatoes retained their red color after irradiation. Based on the 7-point hedonic scale, the color of the irradiated sample was liked more than the non-irradiated sample. The same results were obtained for the appearance attribute, the scores (6.2 ± 0.84) for non-irradiated tomatoes were lower compared to the scores (6.02 ± 0.94) of irradiated tomatoes.

The appearance, smell, and color of the irradiated tomatoes differed insignificantly ($p<0.05$). The color of the-irradiated tomatoes had the highest mean score of 6.28, while that of non-irradiated tomatoes was 6.10, and the mean score for appearance was 6.24 for irradiated and 6.02 for non-irradiated tomatoes. The study found that panelists couldn't distinguish between irradiated and non-irradiated tomatoes based on color, appearance, or smell. This indicates that irradiated tomatoes do not lose their sensory properties and do not produce any unpleasant odour. Uniform findings for the study conducted by Adam *et al.* (2014) [32] did not find any change in sensory attributes such as color and texture of irradiated, sliced, prepared tomatoes during the sensory evaluation. The treatment with gamma radiation used in this study had no effect on the color, appearance, or smell of tomatoes. According to Singh *et al.* (2016) [33], texture is an important quality parameter that determines the acceptability and shelf life of fresh horticultural produce.

4. Conclusions

From the study, the majority of the respondents had a negative perception of irradiated tomatoes; which was mainly associated with inadequate awareness and knowledge of food irradiation. This can be achieved by educating consumers about the benefits and uses of food irradiation. Also, when purchasing irradiated food, the buyer should check for the "RADURA" logo and word. To increase consumer acceptance, it is essential to educate the public with scientifically credible information about the benefits and safety of irradiation technology. The regulatory authority should aim to reduce negative perceptions and promote the use of irradiation technology by educating and communicating with consumers about the technology through schools, media, conferences, and universities. Furthermore, the study found that irradiating tomatoes increased their shelf life while having no effect on organoleptic properties; however, after more than 14 days of storage, the texture of irradiated tomatoes was preferred over that of non-irradiated tomatoes. These findings suggest that irradiated tomatoes, can be implemented without affecting consumer acceptability.

Authors' contributions

Writing the paper, collecting data and doing lab works, R.J.M.; reviewed and supervising, R.S.; supported in writing the paper, D.N.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflicts of interest.

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