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Awareness of irradiated food consumption between Brazil and Argentina

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Abstract

Although food irradiation has been commonly used to ensure food safety, most consumers are unaware of the basic concepts of irradiation, misinterpreting information and showing a negative attitude towards food treated with ionizing radiation. The present research aimed to compare the responses of Argentine and Brazilian subjects to the Awareness Scale on Consumption of Irradiated Foods (ASCIF) to assess the consumption awareness related to these foods between the two Latin American populations. The study was approved by the Research Ethics Committees of both Brazil and Argentina, following the adaptation methodologies recommended by the International Test Commission (ITC), complying with the guidelines for translations and retranslations, as well as for the application of this instrument in Argentina. The instrument included 31 items, encompassing four factors: irradiated foods' Safety (S), Concepts (C), Labeling (L) and Awareness (A), to assess the Argentine population's knowledge of irradiated foods. Statistical tests were performed to guide the data analysis, providing the results for the present research. The Paired t-Test was used to compare the scales applied in Brazil and Argentina. In conclusion, the results revealed that most Argentine and Brazilian consumers are unaware of the benefits of irradiated foods.

Keywords: Food irradiation; Consumer awareness; Psychometrics; Brazil; Argentina; Consumer knowledge.

Highlights

- Cross-cultural comparison of Argentine and Brazilian awareness of irradiated foods.
- Statistical analysis confirms differences in consumer awareness between Brazil and Argentina
- Argentine and Brazilian consumers were found to be unaware of the benefits of irradiated foods

1 Introduction

Food irradiation is a process used for various purposes, the main function of which is food safety. Although food irradiation has been applied to ensure food safety, most consumers are oblivious to the basic concepts of irradiation, misinterpreting information and showing prejudice towards food treated with ionizing radiation (Buczkowska et al., 2023; Galati et al., 2019).

According to International Atomic Energy Agency (IAEA) records from 2021, 68 countries authorized the sale of one or more types of irradiated foods (International Atomic Energy Agency, 2024). Based on Kume et al. (2009), the global number of foods treated by irradiation was 410,000 tons, consisting of: 46% dehydrated spices and vegetable products, 20% grains and fruit, 8% meat and fish, 22% garlic, cabbage and potatoes, and 4% others (mushrooms, honey, etc.). In the United States, Canada and Brazil, 101,400 tons of spices, 7,000 tons of fruit, and 8,000 tons of meat were irradiated, totaling 116,400 tons (29%). The global export of irradiated food products is close to half a million tons, 40% of which goes to China, 20% to the USA and 13% to Vietnam, followed by Mexico with 8%. Other countries together account for 19%, bearing in mind that the amount of irradiated food produced and marketed within each country is much greater. As reported by Vital et al. (2023), China, the world leader in food irradiation, had 2019 130 multipurpose facilities with cobalt-60 sources, three-quarters of which were exclusively for food. In addition to these, there were also 78 commercial units with electron accelerators, with 5 to 10 new sites expected to be built every year. China irradiated 600,000 tons and 1,000,000 tons of food for domestic consumption in 2015 and 2020, respectively.

In 2017, there was a lack of validated instruments to assess the consumption awareness of irradiated foods in Brazil. Thus, a study (Rusin et al., 2017) was carried out to elaborate a valid, robust instrument adapted to the Brazilian culture, to assess the collective awareness regarding the consumption of irradiated foods, called the "Awareness Scale on Consumption of Irradiated Foods (ASCIF)". As for the ASCIF (Rusin et al., 2017), it was observed that this instrument presented good evidence of validity. Four factors were found to represent the 31 items of this instrument: irradiated foods' Safety (S), Concepts (C), Labeling (L) and Awareness (A).

In 2023, a new experiment was conducted to validate the ASCIF instrument for the Argentine population, which showed similarities and differences concerning the awareness of consumers from both of the Latin American cultures studied.

Brazilian and Argentine cultures have a great synergy, being important trading partners. It is, therefore, necessary to understand the consumption habits and expectations of these two countries.

To evaluate consumer awareness and behavior, as well as to compare the knowledge and habits of Argentine and Brazilian consumers regarding irradiated foods, a questionnaire called the Awareness Scale on Consumption of Irradiated Foods (ASCIF) was applied. Implementing different statistical comparison methods, the present research sought to assess whether consumers in these two countries are aware of the benefits of irradiated foods.

The general objective of this work was to compare the responses of Argentine and Brazilian individuals to the Awareness Scale on Consumption of Irradiated Foods (ASCIF) to determine the consumption awareness of these foods among the two populations.

2 Methodology

2.1 Literature review

The initial stage consisted of updating the bibliography using databases such as Scopus, Science Direct, Web of Science, Google Scholar and classic publications in the studied area. To refine the research, the following keywords were used in the search engines: "food irradiation" AND (knowledge OR attitude OR perception OR awareness) AND consumer AND (survey OR questionnaire OR interview) AND (Argentine OR Argentinian), from the past five years, in Portuguese, English and/or Spanish.

2.2 Sample

The sample group comprised Argentine men and women from different social classes and levels of education, from the province of Buenos Aires, identified on the employee lists of the *Comisión Nacional de Energía Atómica* - CNEA (National Atomic Energy Commission), universities (professors and students),

companies from the food sector and the overall Argentine population, as the instrument aims to reach a lay audience regarding the subject of irradiated foods, therefore, the sample's social variability is desirable. Participants accepted the terms of the Informed Consent Form before starting the survey by clicking next/continue in the data collection system.

Respondents from all school levels (excluding the illiterate, given that the questionnaire requires reading and comprehension skills) were considered for the research, with ages ranging from 18 to 70 years old, of both sexes and different social classes, establishing the sample's social variability. The instrument was applied online to these groups between October 25, 2023 and December 7, 2023, with the total number of respondents at 500.

2.3 Data collect

The data were collected electronically through the site SurveyMonkey (2024). To evaluate the awareness and behavior of consumers as well as the knowledge and habits of consumers related to irradiated foods, a questionnaire with a Likert scale of agreement was applied. The scale offered five options of answer for each affirmative, ranging from strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), and strongly agree (5). This instrument consisted of items that identified the sample's sociodemographic characteristics, behavior measures and knowledge extent regarding the studied subject. To ensure that the collection was restricted to Argentina, the Internet Protocol (IP) range for accessing the instrument's data collection link was limited to residents of the Province of Buenos Aires.

2.4 Statistical treatment

Statistical treatments guided the data analysis, providing the results for the present research. The Paired t-Test was used to compare the scales of 2017 in Brazil (Rusin et al., 2017) and to 2023 in Argentina. These statistical analyses were carried out using IBM SPSS (version 21).

2.5 Research ethics committee approval

This research project was approved in Brazil by the Research Ethics Committee of the University of São Paulo on October 20, 2023 (Certificate of Presentation for Ethical Appreciation No. 74513223.3.0000.5494). The present work was equally approved in Argentina by the Central Ethics Committee of the Ministry of Health of the Province of Buenos Aires, on September 22, 2023 (Ethical Evaluation Report No. ACTA-2023-40111123-GDEBA-CECMSALGP).

3 Results and discussion

In the literature review, no recent psychometric instruments were found to be able to assess the Argentine consumers' awareness of irradiated foods. In this sense, the ASCIF psychometric instrument, which has been validated for Brazil (Rusin et al., 2017), was also used in the present adaptation study for Argentina. The ASCIF is considered to be a complex instrument, both because of its subject matter, which is unknown to a large part of the population, and because of its structure, consisting of four factors: irradiated foods' Safety (S); Concepts (C); Labeling (L); and Awareness (A), being distributed in 31 items (S = 15; C = 8; L = 5; A = 3).

A total of 500 Argentine consumers (51% women, 49% men) were involved in the study to validate this scale. Among the total sample, 28.4% of the participants were aged between 30 and 39, 47.8% declared to have a university degree and an average family income of 2 to 5 minimum wages, which is equivalent to 900 to 2,250 dollars a month (24%).

The statistical assumptions of normality, linearity and singularity were then analyzed. It was observed that the histograms, the skewness and kurtosis values as well as the significance tests (Shapiro-Wilk) indicated a normal distribution. According to Hair et al. (2009), deviations from the multivariate normality are innocuous when all the variables meet this condition. Hence, the model was assumed to satisfy the linearity hypothesis criteria. This

was achieved by analyzing the residuals and observing that the points were randomly distributed around zero. At the same time, the uniqueness assumption was evaluated by the variables that fit the variance inflation factor (VIF) criterion of less than 5 and tolerance greater than 0.1, as recommended by Hair et al. (2009).

Table 1 shows the item's detailed scores and standard error (s.e.) structured pursuant to the abovementioned four factors, as well as a brief comparison between the Argentine and Brazilian responses to the 31 items in the instrument. It was possible to observe that for both the Argentine and Brazilian populations, the highest score obtained was on question 16 (Q16. I think it is necessary to carry out educational campaigns to inform the population about food irradiation), registering 3.88 (0.04) and 4.59 (0.03) respectively, indicating score ranges between agree and strongly agree, as per the Likert scale.

The lowest score obtained was in question 8 (Q8. I deliberately consume irradiated foods) for the Argentine sample, with 2.40 (0.04) points, while for the Brazilian sample, the lowest score was observed in question 10 (Q10. I would be willing to pay more for irradiated foods) with a 2.38 (0.04) score, reflecting values closer to disagree, as specified by the Likert scale.

Table 1. ASCIF items for Argentina and Brazil, with means and standard error in parenthesis.

Items	Means (s.e.) (Argentina)	Means (s.e.) (Brazil)
		Results according to Rusin et al. (2017)
Q29. I think that irradiated foods are not harmful to health in the long-term. (S)	3.09 (0.05)	3.01 (0.04)
(Q29. Yo considero que los alimentos irradiados no hacen mal a la salud a largo plazo.)		
Q11. I would encourage the consumption of irradiated foods. (S)	3.02 (0.05)	2.84 (0.04)
(Q11. Yo incentivaría el consumo de alimentos irradiados.)		
Q28. I think that irradiated foods are not harmful to health in the medium-term. (S)	3.15 (0.05)	3.12 (0.04)
(Q28. Yo considero que los alimentos irradiados no hacen mal a la salud a medio plazo.)		
Q30. I think that irradiated foods are not harmful to the health of future generations. (S)	3.12 (0.05)	3.03 (0.05)
(Q30. Yo considero que los alimentos irradiados no hacen mal a la salud de las próximas generaciones.)		
Q13. I would consume irradiated foods because I know that they are safe for consumption. (S)	3.21 (0.05)	3.11 (0.05)
(Q13. Yo consumiría alimentos irradiados, porque sé que estos son seguros para el consumo.)		
Q12. I would consume irradiated foods, because I know they do not cause health issues. (S)	3.18 (0.05)	3.10 (0.05)
(Q12. Yo consumiría alimentos irradiados, porque sé que estos no causan daños a la salud.)		
Q27. I think that irradiated foods are not harmful to health in the short-term. (S)	3.20 (0.05)	3.24 (0.04)
(Q27. Yo considero que los alimentos irradiados no hacen mal a la salud a corto plazo.)		
Q15. I approve the consumption of irradiated foods. (S)	3.19 (0.05)	3.16 (0.05)
(Q15. Yo apruebo el consumo de alimentos irradiados.)		
Q26. I feel safe about the consumption of irradiated foods. (S)	3.09 (0.05)	3.01 (0.05)
(Q26. Yo me siento seguro cuanto al consumo de alimentos irradiados.)		

Table 1. Continued...

Items	Means (s.e.) (Argentina)	Means (s.e.) (Brazil)
		Results according to Rusin et al. (2017)
Q10. I would be willing to pay more for irradiated foods. (S) *(Q10. Yo estaría dispuesto a pagar más por alimentos irradiados.)*	2.41 (0.05)	2.38 (0.04)
Q9. I would consume irradiated foods. (S) *(Q9. Yo consumiría alimentos irradiados.)*	3.04 (0.05)	3.35 (0.05)
Q21. I am comfortable buying food when I read the following information on the label " Food Treated with Ionizing Radiation". (S) *(Q21. Yo tengo seguridad al comprar un alimento cuando leo en la etiqueta la siguiente información: "Alimento Tratado con Energía Ionizante".)*	3.14 (0.05)	3.07 (0.05)
Q23. I would buy irradiated foods, because I know this process does not make the food radioactive. (S) *(Q23. Yo compraría alimentos irradiados, porque sé que este proceso no convierte el alimento en radioactivo.)*	3.32 (0.05)	3.48 (0.05)
Q25. Irradiated foods are nutritionally safe. (S) *(Q25. Los alimentos irradiados son seguros bajo el aspecto nutricional.)*	3.16 (0.05)	3.30 (0.04)
Q31. The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO/ONU) recommend the irradiation of foods. (S) *(Q31. La Organización Mundial de la Salud (OMS) y la Organización de las Naciones Unidas (FAO/ONU) recomiendan la irradiación de alimentos.)*	3.04 (0.06)	3.11 (0.03)
Q2. Food irradiation can be used to reduce the microbial load on products. (C) *(Q2. La irradiación de alimentos se puede utilizar para reducir la carga microbiana en los alimentos.)*	3.30 (0.05)	4.07 (0.04)
Q7. Food irradiation can be used to increase shelf life of products. (C) *(Q7. La irradiación de alimentos se puede utilizar para aumentar el plazo de vida útil de los alimentos.)*	3.34 (0.05)	3.98 (0.04)
Q3. Food irradiation can be used to inhibit the budding of bulbs, roots and tubers on products. (C) *(Q3. La irradiación de alimentos se puede utilizar para inhibir el brote de bulbos, raíces y tubérculos.)*	3.26 (0.05)	3.58 (0.04)
Q5. For the irradiation of foods, the minimum absorbed dose should be sufficient to achieve the intended purpose. (C) *(Q5. La dosis mínima absorbida por el alimento irradiado debe ser suficiente para alcanzar la finalidad pretendida.)*	3.39 (0.05)	3.77 (0.04)
Q6. Argentina authorizes the use of food irradiation. (C) *(Q6. Argentina autoriza el uso de la irradiación de alimentos.)*	3.07 (0.05)	3.63 (0.03)
Q24. Irradiated food is microbiologically safe. (C) *(Q24. Los alimentos irradiados son seguros bajo el aspecto microbiológico.)*	3.28 (0.05)	3.50 (0.04)
Q4. Food irradiation can be used to delay the ripening of fruits. (C) *(Q4. La irradiación de alimentos se puede utilizar para atrasar, retardar la maduración de las frutas.)*	3.24 (0.04)	3.57 (0.04)
Q1. Irradiated food is different from radioactive food. (C) *(Q1. El alimento irradiado es diferente del alimento radioactivo.)*	3.30 (0.05)	3.99 (0.05)

Table 1. Continued…

Items	Means (s.e.) (Argentina)	Means (s.e.) (Brazil)
		Results according to Rusin et al. (2017)
Q18. All foods that undergo irradiation should have this information highlighted on the product label. [L] *(Q18. Todos los alimentos que pasan por proceso de irradiación deberían tener esa información destacada en la etiqueta del producto.)*	3.51 (0.05)	4.53 (0.03)
Q20. I think it is important that the Radura symbol is present in the labels of irradiated foods. [L] *(Q20. Yo considero importante el símbolo de la Radura en las etiquetas de los alimentos irradiados.)*	3.42 (0.05)	4.45 (0.03)
Q22. The product label should highlight the presence of irradiated food. [L] *(Q22. La etiqueta de los alimentos debería destacar la información de alimento irradiado.)*	3.38 (0.05)	4.40 (0.03)
Q19. I think that additional information in the labels of irradiated foods is important. [L] *(Q19. Yo considero que las informaciones adicionales contenidas en las etiquetas de los alimentos irradiados son importantes.)*	3.71 (0.04)	4.45 (0.03)
Q16. I think it is necessary to carry out educational campaigns to inform the population about food irradiation. [L] *(Q16. Yo considero que es necesario hacer campañas educativas para informar a la población sobre la irradiación de alimentos.)*	3.88 (0.04)	4.59 (0.03)
Q14. I am aware of at least one irradiated food. [A] *(Q14. Yo conozco algún alimento irradiado.)*	3.21 (0.05)	2.58 (0.06)
Q17. I know Radura, the symbol used to represent irradiated foods. [A] *(Q17. Yo conozco la Radura: es el símbolo internacional utilizado para representar un alimento irradiado.)*	3.25 (0.05)	2.45 (0.06)
Q8. I deliberately consume irradiated foods. [A] *(Q8. Yo consumo conscientemente alimentos irradiados.)*	2.40 (0.05)	2.40 (0.05)

Factors: Irradiated foods' Safety [S]. Concepts [C]. Labeling [L]. Awareness [A].

It should be noted that in Q6 of the Argentine survey, the word Brazil was changed to Argentina to account for the cultural adaptation of said country. Another observation about Table 1 is that, to compare the scales applied in Brazil and Argentina, it was decided that using the standard error (s.e.) was more appropriate in this context, rather than the standard deviation.

To compare the results obtained with the samples from Argentina and Brazil, the Paired t-Test analysis was performed. A t-test is a type of statistical test used to compare the means of two groups (Moore et al., 2009). The null hypothesis states that both means are statistically equal, whereas the alternative hypothesis states that both means are not statistically equal, that is, they are statistically different to each other (Sundaram et al., 2014). According to Altman (1990), the Paired t-Test, sometimes called the dependent samples t-test, is used to determine whether the difference in the means of two paired samples is statistically significant. In this test, the same subjects are measured at two time points or observed by two different methods.

Table 2 shows the results for the Paired t-Test. The responses to the ASCIF's 31 questions were compared for the Argentine and Brazilian populations. At the same time, the four factors (S, C, L and A) of the Argentine and Brazilian ASCIF were analyzed.

Table 2. Paired t-Test.

		Paired Differences					t	df	*p*-value
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 29	Q29(ARG) - BR	0.228	1.546	0.069	0.092	0.364	3.299	499	0.001
Pair 11	Q11(ARG) - BR	0.334	1.552	0.069	0.198	0.470	4.814	499	0.000
Pair 28	Q28(ARG) - BR	0.180	1.482	0.066	0.050	0.310	2.716	499	0.007
Pair 30	Q30(ARG) - BR	0.248	1.571	0.070	0.110	0.386	3.530	499	0.000
Pair 13	Q13(ARG) - BR	0.278	1.609	0.072	0.137	0.419	3.863	499	0.000
Pair 12	Q12(ARG) - BR	0.270	1.572	0.070	0.132	0.408	3.841	499	0.000
Pair 27	Q27(ARG) - BR	0.088	1.530	0.068	-0.046	0.222	1.286	499	0.199
Pair 15	Q15(ARG) - BR	0.222	1.589	0.071	0.082	0.362	3.123	499	0.002
Pair 26	Q26(ARG) - BR	0.286	1.693	0.076	0.137	0.435	3.778	499	0.000
Pair 10	Q10(ARG) - BR	0.086	1.615	0.072	-0.056	0.228	1.191	499	0.234
Pair 9	Q9(ARG) - BR	-0.104	1.674	0.075	-0.251	0.043	-1.389	499	0.165
Pair 21	Q21(ARG) - BR	0.284	1.647	0.074	0.139	0.429	3.856	499	0.000
Pair 23	Q23(ARG) - BR	0.068	1.657	0.074	-0.078	0.214	0.918	499	0.359
Pair 25	Q25(ARG) - BR	-0.022	1.468	0.066	-0.151	0.107	-0.335	499	0.738
Pair 31	Q31(ARG) - BR	0.018	1.541	0.069	-0.117	0.153	0.261	499	0.794
Pair S	S - factor1	0.164	1.378	0.062	0.043	0.285	2,.666	499	0.008
Pair 2	Q2(ARG) - BR	-0.626	1.392	0.062	-0.748	-0.504	-10.055	499	0.000
Pair 7	Q7(ARG) - BR	-0.506	1.379	0.062	-0.627	-0.385	-8.205	499	0.000
Pair 3	Q3(ARG) - BR	-0.150	1.438	0.064	-0.276	-0.024	-2.333	499	0.020
Pair 5	Q5(ARG) - BR	-0.292	1.511	0.068	-0.425	-0.159	-4.321	499	0.000
Pair 6	Q6(ARG) - BR	-0.428	1.484	0.066	-0.558	-0.298	-6.451	499	0.000
Pair 24	Q24(ARG) - BR	-0.120	1.422	0.064	-0.245	0.005	-1.887	499	0.060
Pair 4	Q4(ARG) - BR	-0.172	1.415	0.063	-0.296	-0.048	-2.718	499	0.007
Pair 1	Q1(ARG) - BR	-0.598	1.712	0.077	-0.748	-0.448	-7.811	499	0.000
Pair C	C - factor2	-0.362	1.206	0.054	-0.467	-0.256	-6.701	499	0.000
Pair 18	Q18(ARG) - BR	-1.032	1.343	0.060	-1.150	-0.914	-17.188	499	0.000
Pair 20	Q20(ARG) - BR	-1.024	1.427	0.064	-1.149	-0.899	-16.049	499	0.000
Pair 22	Q22(ARG) - BR	-1.034	1.420	0.064	-1.159	-0.909	-16.280	499	0.000
Pair 19	Q19(ARG) - BR	-0.738	1.300	0.058	-0.852	-0.624	-12.699	499	0.000
Pair 16	Q16(ARG) - BR	-0.704	1.252	0.056	-0.814	-0.594	-12.573	499	0.000
Pair L	L - factor3	-0.906	1.175	0.053	-1.010	-0.803	-17.246	499	0.000
Pair 14	Q14(ARG) - BR	0.890	1.829	0.082	0.729	1.051	10.882	499	0.000
Pair 17	Q17(ARG) - BR	1.072	1.843	0.082	0.910	1.234	13.004	499	0.000
Pair 8	Q8(ARG) - BR	0.196	1.702	0.076	0.046	0.346	2.576	499	0.010
Pair A	A - factor4	0.719	1.475	0.066	0.590	0.849	10.903	499	0.000

Six Questions from factor (S): Q9 (I would consume irradiated foods), Q10 (I would be willing to pay more for irradiated foods), Q23 (I would buy irradiated foods, because I know this process does not make the food radioactive), Q25 (Irradiated foods are nutritionally safe), Q27 (I think that irradiated foods are not harmful to health in the short-term), Q31 (The World Health Organization (WHO) and the and the Food and Agriculture Organization of the United Nations (FAO/ONU) recommend the irradiation of foods) and one from factor (C): Q24 (Irradiated food is microbiologically safe), showed a *p*-value > 0.05, which, according to the null hypothesis, indicate that the means are statistically equal.

The other questions presented a p-value < 0.05, so, as stated by the alternative hypothesis, both means are not statistically equal, in other words, the Argentine and Brazilian responses are statistically different from each other. When the factors S, C, L and A were tested, the p-value < 0.05 indicated that there is a statistically significant difference between the means of the Argentine and Brazilian groups.

4 Conclusions

The analysis of the consumer perceptions regarding irradiated foods in Argentina and Brazil reveals significant discrepancies. It should be noted that the present study focused on four factors: irradiated foods' Safety (S), Concepts (C), Labeling (L), and Awareness (A). Out of the 31 questions analyzed, only 7 demonstrated no significant differences between the two groups, indicating that 24 questions revealed statistically significant differences ($p < 0.05$). This finding highlights the importance of recognizing the distinct cultural perceptions and knowledge levels about irradiated foods in Argentina and Brazil, rather than assuming a uniform awareness across both populations.

Furthermore, the significant differences observed in the responses were mainly related to the safety of irradiated foods (S), accentuating the different cultural attitudes towards food irradiation in each country. The statistical analysis, with p-values consistently below 0.05 for the majority of questions, corroborates the conclusion that the Argentine and Brazilian populations have significantly different views on the safety and acceptability of irradiated foods. This highlights the importance of implementing tailored educational initiatives to enhance the understanding and acceptance of irradiated foods, as consumer perceptions are heavily influenced by their cultural contexts, as well as by the effectiveness of communication concerning food safety technologies.

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