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EVALUATION OF TEXTURE AND COLOR OF READY-TO-EAT FOOD PROCESSING BY IONIZING RADIATION

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ABSTRACT

Development of ready-to-eat food need effective conservation technologies to ensure that product will be free from bacterial, viral, and pathogens contamination. Beyond that, it is important to maintain satisfying consumers' requirements about taste, practicality advantages and nutrition. In this context irradiation process is a treatment that reaches to reduce the microbial load making food safer. For this purpose, different radiation doses may be applied, which may or may not interfere negatively on other parameters of food quality. The objective of this work is to evaluate the effects of ionizing radiation on the instrumental characteristics of an elaborated ready-toeat product. The samples were irradiated at the Radiation Technology Center (CTR) of the Nuclear and Energy Research Institute (IPEN / CNEN-SP), with doses of 0 (control), 4.5 kGy and 7,5 kGy. After irradiation processing the Texture analysis were performed in a Texturometer TA-XT2, Color measurements in a Minolta Chroma Meter and Water Activity (aw). Hardness results increased proportionally with the increase in the applied dose. It was not found significant difference between the doses in relation to the results for aw. In conclusion, both doses can be used to this kind of product.

1. INTRODUCTION

Several people search for practicality when cooking and sometimes choose the consumption of food ready-to-eat. One of the aims for the food industry is to meet the needs of this public with tasty and safe products. The concept is based on having food with color and texture that looks and feels the same as a food prepared just hours before consumption. Thus, the meals can be individual, to be frozen and have a wider choice of dishes each day.

Ready-to-eat food is gaining popularity in retail markets and in home-delivery businesses. But without proper thermal processing and chemical preservatives, chilled meals have very limited shelf-life and present great concern for food safety. Commercial production of readyto-eat meals does not have a final kill step for foodborne pathogens after the meals are packaged and before shipment [1] In spite of they give a consumer the convenience of use without any further preparation. Ready-to-eat food may also contain microorganisms that could be generated during the processed or storage, such as mycotoxins [2] resulting in both acute toxicity and chronic health problems. Besides, there are decaying microorganisms, which may or may not be pathogenic, that are usually the cause of chemical changes in food [3].

One alternative conservation processing to aim of increasing safety and quality microbiological of food is irradiation. The main objectives of the use of ionizing radiation in foods are to make them safe by reducing the population of pathogenic/spoilage microorganisms to undetectable levels increasing shelf life of the product. However, as well as other conservation methods, some chemical changes may be induced by radiation in the composition of ingredients/feedstock [4,5].

In this context, the objective of this study was to irradiate a ready-to-eat developed with gamma irradiation doses aiming a preservation process. The focus is on the evaluation of the effects of ionizing radiation on intrinsic and extrinsic characteristics such as water activity (important parameter related to bacterial growth), texture, and color, since these attributes considerably interfere with the acceptance of choice by the consumers.

2. MATERIALS AND METHODS

2.1. Sample

A ready-to-eat was prepared in order to analyze the effects of ionizing radiation with different doses. Meat (47.8 %), Kabocha squash (9.6 %), potatoes (14.2 %), Arborio rice (14.2 %), and green beans (14.2 %) were used. All ingredients were cooked for 100 minutes at 80 °C, cooled to room temperature and the analyzes were performed the next day. 300 g of the samples were packaged into polyethylene bags.

2.2. Sample Irradiation

The process of irradiation of the samples by gamma rays was performed at the Radiations Technology Center (CETER) of the Nuclear and Energy Research Institute (IPEN-CNEN/SP) using a Cobalt 60, type Gammacell-220 irradiator at doses 4.5 and 7.5 with a dose rate 0.648 kGy/h (September, 2018).

Non-irradiated samples were used as control. Analyses were performed after irradiation to evaluate the effects of radiation on colorimetric, textures and amount of free water (a_w) characteristics.

2.3. Instrumental analysis

2.3.1. Colorimetric Analysis

The instrumental analysis of the color was performed using the Minolta Chroma Meter color model CR-400 digital, according to Standard by *Commission Internationale de L'Eclairage*, (S 014-4/E:2007) [6] by the ISO 11664-4:2008 [7].

It was calibrated on white porcelain surface. Twenty random readings of the samples were performed for each dose of gamma irradiation. The results were expressed in CIELAB and CIE L*C*h color space which are the most used systems for the evaluation of color in foods. It was obtained the parameters L* (brightness), a* (intensity of red / green) and b * (yellow / blue intensity) [6].

Chroma C* (saturation or color intensity), and Hue angle (amount of color in which red-purplish = 0 °, yellow = 90 °, green = 180 °, blue = 270 °, and black = 360º) are obtained through the CIELAB model with the following formulas [8].

$$C* = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

$$h = \tan^{-1}\left\{\frac{b^{*}}{a^{*}}\right\} \quad (2)$$

2.3.2. Texture analysis

The hardness samples were determined using Stable Micro Systems TA-XT2i texture analysis with a compression capacity of 50 kg and 100 kg load cell. The analysis was carried out in Measure Force in Compression mode. The pre-test, test and post-test speed were respectively 2.0 mm/s, 2.0 mm/s and 10.0 mm/s with a 5 mm sample compression distance and Trigger force of 100 g using an acrylic probe cylindrical P/36R. It was carefully weighed 10g sample at room temperature [9, 10]. For each dose 10 readings were taken.

2.3.3. Water activity (a_w)

Water activity was measured in triplicate at a temperature of (25 ° C ± 1) on the Aqualab, 4TE Duo digital apparatus [11,12]

2.3.4. Statistical analysis

The results were analysed using the program GraphPad Prism (version 8.0), which was also used for the elaboration of tables and graphs. The comparisons among the data were performed using two-way ANOVA, with a statistical significance limit of by Tukey test ($p < 0.05$).

3. RESULTS AND DISCUSSION

3.1. Colorimetric measures

The visual impact generated by the color of a product interferes with consumer acceptance and purchase decision, which is why it is one of the most important sensory characteristics in the food industry. Table 1 and Fig. 1 show the results obtained from the colorimetric analysis.

CIE L*a*b* color space provide a standard, approximately uniform color scale which could be used by everyone so that color values could be easily compared. In a uniform color scale, the differences between points plotted in the color space correspond to visual differences between the colors plotted [6]

The L* axis runs from top to bottom. L* indicated the brightness (0 - dark / opaque and 100 - white). Therefore, the irradiated samples presented higher opacity in relation to the control. There is statistically significant difference among samples.

Table 1: Means and standard deviation of colorimetric analysis ready-to-eat irradiated with 4.5 and 7.5 kGy.

Dose	L*	a*	b*	C*	h
Control	64.85 ± 2.55[a]	-2.91 ± 0.75[a]	24.06 ± 3.87[a]	24.24 ± 3.89[a]	96.96 ± 1.67[a]
4.5 kGy	54.47 ± 2.81[b]	1.54 ± 2.04[b]	15.16 ± 4.08[b]	15.36 ± 4.11[b]	83.71 ± 7.33[b]
7.5 kGy	50.85 ± 3.77[c]	2.48 ± 1.23[b]	12.44 ± 2.69[c]	12.75 ± 2.64[c]	78.18 ± 6.17[c]

[1]Means followed by the same letter in the columns do not differ statistically from each other by the Tukey test (p> 0.05).

The a* (Positive a* is red. Negative a* is green) and b* (Positive b* is yellow. Negative b* is blue) axes have no specific numerical limits [8]. Thus, the control sample is redder differently from the irradiated samples. All samples have yellowish tendency and 4.5 kGy and 7.5 kGy samples did statistical difference between them.

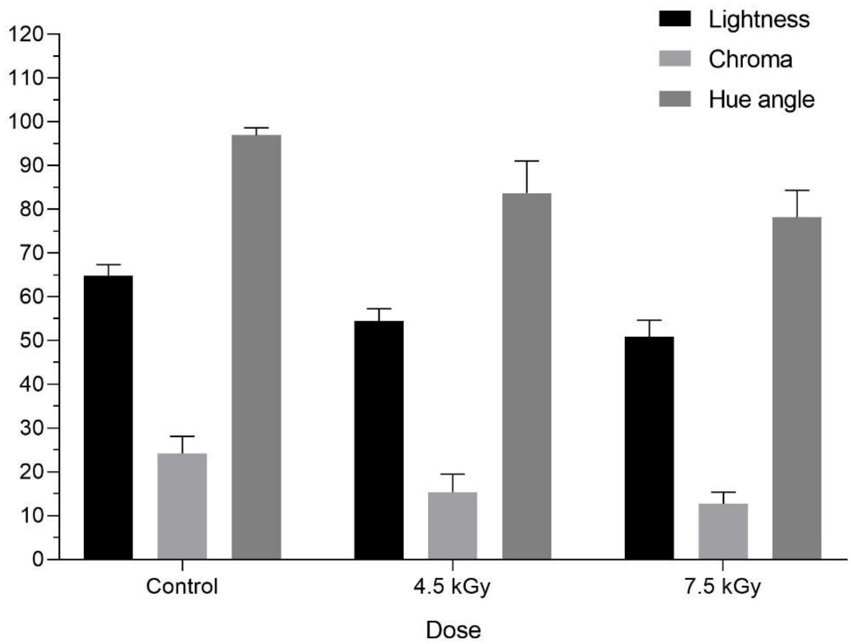

Figure 1: CIEL*C* h color measurement results.

CIE L*C*h color scale is an approximately uniform scale with a polar color space. The CIELCh scale values are calculated from the CIELAB scale values. The L*, brightness, value is the same in each scale.

Chroma indicates Saturation or color intensity (0 - impure color and 60 - color pure) [8]. The results presented in the Fig. 2 show that the samples saturated after processing by ionizing radiation. Hue angle, which indicates the actual color, presented significant difference between the samples irradiated as well showed values between 96.96 ± 1.67 to 78.18 ± 6.17 indicating that the color of the samples is yellowish.

3.2. Hardness

At compression tests in texture analysis, the sample is deformed and the extent of the deformation and/or the resistance offered by the sample is noted and used as an index of the texture of the food. Simple compression tests are often termed uniaxial compression which means that the sample is compressed in one direction and is unrestrained in the other two dimensions [10].

Fig. 2 show the hardness values of the ready-to-eat irradiated.

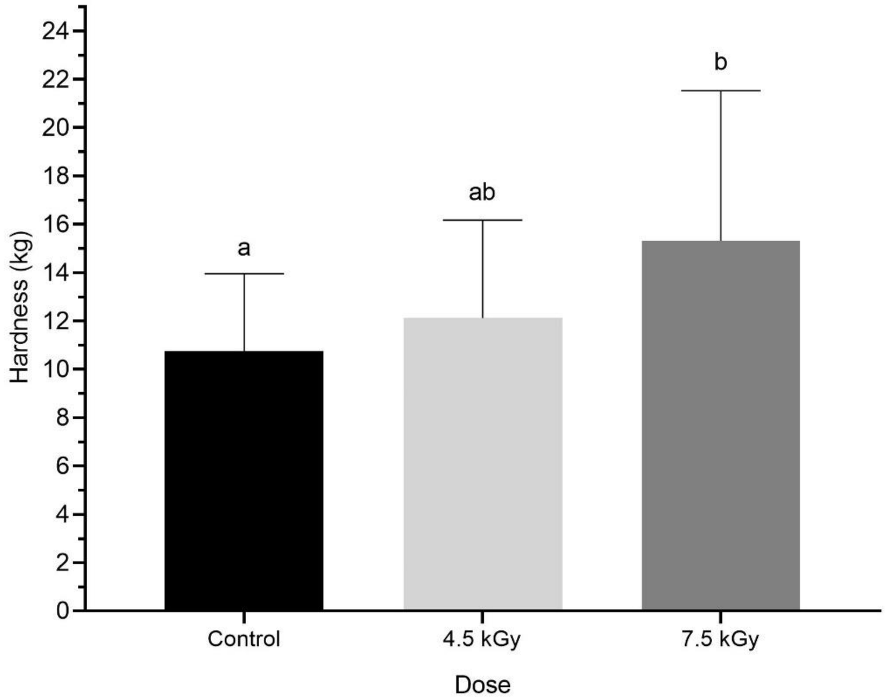

Figure 2: Hardness results of ready-to-eat irradiated with 4,5 kGy and 7,5 kGy.

As expected, the hardness had raised with increasing irradiation doses. The product analysed by the present study there are three entire main ingredients that correspond to protein, carbohydrates, and fibers with different textures. Proteins in foods exposed to ionizing radiation may exhibit coagulation, unfolding, molecular uncoiling, molecular cleavage, and splitting of amino acids. Such changes have been linked to altered functional properties of food proteins. Once the hardness is directly associated not only with the composition and structure as well as maintaining their integrity [13].

In this study the changes caused by the breakage of molecules by ionizing radiation made the product more resistant to compression test, requiring greater maximum strength with increasing dose. There was statistically significant difference ($p<0,05$) among non-irradiated (Control) and irradiated (4.5 kGy and 7.5 kGy) samples. Results among 12 kg and 15 kg were observed.

2.3. Water activity (a_w)

Due to the high inclusion of animal ingredients in a feed, these raw materials made extremely critical microbiologically [14]. It is important to research the properties and stability of water activity in foods. Water activity analysis provides values that allow greater control of microorganisms in the raw material and processed products of animal origin [15].

The amount of water present in a food can be in the form of bound and unbound water, that ratio between the unbound or available water content is termed water activity. a_w is a parameter very important in food industry because the parameter can (1) control undesirable chemical reactions, (2) prolong the activity of enzymes, (3) understand the caking and clumping of powders, and (4) optimize the physical properties of foods such as texture and moisture migration [15].

The speed of desirable and unwanted chemical and biochemical reactions that occur during food storage depends mainly on water activity. The growth rate of microorganisms decreases with water activity and may even be completely paralyzed in water activity less than 0.6, varying the minimum value with the type of microorganism [14].

Radiation interacts with the material causing two types of effects, the direct effect and the indirect effect. In the direct effect the radiation interacts with the DNA molecule, causing the breakdown of this molecule. In the indirect effect, which represents 70 % of the interaction, the radiation breaks down the water molecule present in the medium, in a process called radiolysis, creating a series of free radicals that will interact with the cellular components [16,17].

From the results found, there was no significant difference between the samples. However, the water activity values were not within the minimum limits of fungal growth and aflatoxin production, as shown in Fig. 3.

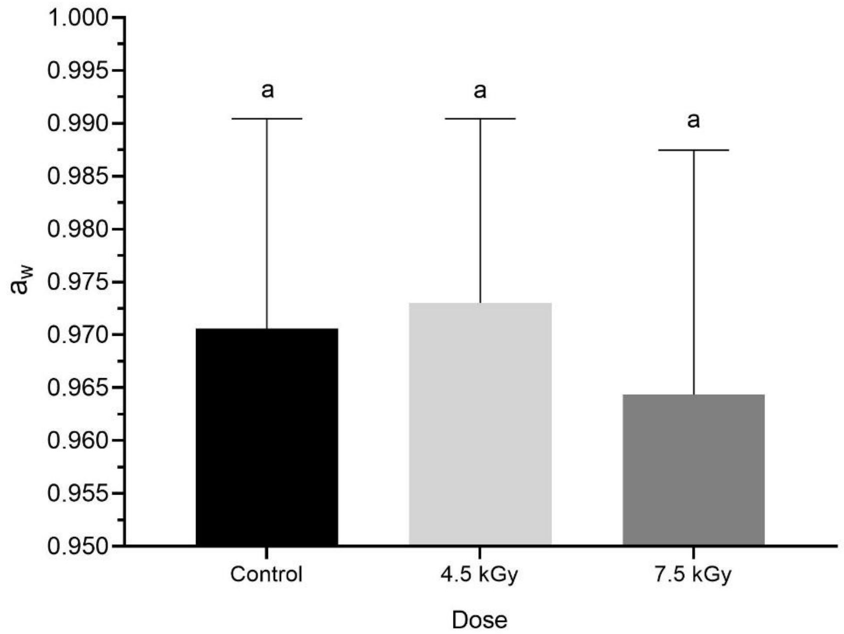

Figure 3: Water activity results of ready-to-eat irradiated.

The level of water activity found in the non-irradiated and irradiated sample is above 0.97 and according to the literature is more prone to the development and proliferation of microorganisms. However, it is already known that from the standpoint of microbiological quality irradiation of food serves a number of objectives [17].

According to Peter Roberts [18] a dose range can achieve different types of outcome. For example: 1) destruction of spoilage microorganisms; 2) extend shelf life fruit and vegetables meat, poultry, fish, and ready meals (0.5–3.0 kGy); 3) inactivation/destruction of parasites; 4) improve food safety of pork and fish (0.3–6.0 kGy); 5) reduce numbers of non-spore-forming pathogenic bacteria in fresh and frozen meats, poultry, fish, and ready meals (3.0–7.0 kGy; 6) reduce numbers of non-spore-forming pathogenic bacteria; 7) improve food safety dry ingredients such as spices, herbs, other condiments (range of 5.0–10.0 kGy) [18,19].

It is important to analyse the effect of water activity of this product with microbiological analyses relating radio sensitivity of microorganisms and bacteria.

CONCLUSIONS

In conclusion, the results color and hardness of the ready-to-eat samples showed significant difference ($p < 0.05$) between the irradiated and non-irradiated samples. One the other hand, water activity analysis did not differ statistically. In spite of the 7,5 kGy dose presented the highest value of the hardness the results in this study already indicate that the 4.5 kGy and 7.5 kGy doses can be applied in new shelf life studies and food analysis for this type of product and trade. Positively, this study emphasizes the versatility and possibility of using ionizing radiation as an effective conservation process for the specific product that was studied and also for food industry in general without causing major changes in the raw material while still ensuring quality and safety.

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