BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
09-01A (2021) 01-20

Application of gamma radiation in pea (*Pisum sativum* L.) in nature to inhibit sprouting and increase shelf life

Albano[a] A.M.S., Arthur[b,a] V.

[a]*Instituto de Pesquisas Energéticas e Nucleares/Centro de Tecnologia das Radiaçôes, 05508-000, São Paulo, São Paulo, Brasil*

andressam@yahoo.com

[b]*Centro de Energia Nuclear na Agricultura/ Departamento de Radiobiologia e Ambiente, 13416-000, Piracicaba, São Paulo, Brasil*

arthur@cena.uso.br

ABSTRACT

The irradiation of fresh post-harvest foods has as main interests: inhibit sprouting, increase shelf life, reduce or delay damage caused by insects and diseases. This work is a preliminary study on the use of gamma radiation in fresh peas grains (*Pisum sativum* L.) in order to evaluate its effects on the inhibition of sprout and its increase in shelf life. The peas were submitted at irradiation process with four radiation doses: 0 (control), 0.15, 0.30 and 0.45 kGy, in a ^{60}Co research irradiator, with a dose rate of 0.323 kGy/h. After irradiation the samples were stored at 8 °C, being evaluated at 1, 7, 14 and 21 days by analyzes of: visual aspect, weight loss, color, hardness, pH, total soluble solids, total titratable acidity, ratio SST/TTA, water content and ash. By the results it was observed that in all parameters analyzes with gamma radiation doses used did not affect significantly in the shelf life of grains. The 0.30 kGy dose increased the germination of the peas and the 0.45 kGy dose was not sufficient to inhibit the sprouting of the peas.

Keywords: **gamma radiation, *Pisum sativum*, conservation.**

ISSN: 2319-0612
Accepted: 2020-12-08

1. INTRODUCTION

Pea, one of the most produced foods in the world, belongs to the *Fabaceae* family, *Viciae* sub-division and originating in the Middle East [1, 2, 3]. It is a vegetable of high nutritive value in it is centesimal composition, high levels of protein, C vitamins, B complex, minerals such as calcium, iron phosphorus and potassium, with ample alternatives of use in food. In the form of green grains, can be consumed in natura or can be canned or frozen immediately after harvesting [4, 5].

The consumption of peas in the form of freshly harvested green grains, as a minimally processed product, is growing and its worldwide production is around 28.7 million tons, of which 17.4 million are green pea. According to data from the United Nations Food and Agriculture Organization (FAO) the world's largest pea producers are China with 60% of world and India with 26% of green peas and in South America, the largest producers in 2017 were Peru with 131 mil ton, Chile with 15 mil ton and Argentina with 28 mil ton [6]. It was classified as the 79th most traded product in the "Companhia de Entrepostos e Armazéns Gerais de São Paulo – CEAGESP" in 2017, seasonality is from May to October [7]. In Brazil the production is not expressive as in other countries. In 2013 Rio Grande do Sul was the largest producer with 2.1 mil tons and 2017 was an inversion being the state largest of Minas Gerais the largest producers with 2 mil tons [8].

The purpose of minimally processed foods is to provide consumers with convenient, fresh-looking, fruit-and-vegetable products with a long shelf life [9]. In the United States, commercialization of these foods began in 1960 and in France since the eighties, but in Brazil, this type of product has become commercially available in major quantity only in the last two decades. Currently, minimally processed foods have become an important food market in Brazil. The interest of approximately 70% Brazilian supermarkets in increasing the sales of these products makes the potential of agroindustry growth high [10].

However, fruits and legumes that were benefited by this minimum processing, have a short shelf life of only a few days before being consumed, subsequently become unfit for consumption [11]. Because this processing may favor the survival of microorganisms because they constitute an excellent culture medium due to the presence of damaged tissues and high moisture content, increasing the availability of substrate for metabolization and its potential for deterioration [12].

In order to increase the shelf life of these foods, [13] studied some vegetable conservation techniques such as: blanching, refrigeration, freezing, drying and ionizing radiation, among others and in his conclusion pointed out that among the conservation methods studied, with respect to the conservation time, drying, fermentation, canning, freezing and ionizing radiation are the methods that allow plants to be conserved for longer periods, in some cases being longer than 12 months.

Due to this, there are several studies with the use of gamma radiation to irradiate fresh post-harvest foods, with the main interests of inhibiting sprouting, increasing shelf life, reducing or delaying damage caused by insects and diseases [14]. The use of gamma radiation to inhibit is widely used in China and Japan, and in 2005 more than 88,000 tons of food were irradiated for this purpose in both countries [15]. The use of low radiation dose inhibits high efficiency budding for onions, garlic, potatoes and yams. Soon after the harvest doses between 0.02 to 0.075 kGy and after this period doses between 0.1 to 0.2 kGy were used by Neves; Manzione and Vieites [16].

The aim of this study was to evaluate the effects of gamma radiation on fresh peas (*Pisum sativum* L.), in order to inhibit sprouting and increase its shelf life, by means of physical and physicochemical analyzes.

2. MATERIALS AND METHODS

2.1. Samples and Irradiation

These peas were purchased in Municipal Market in São Paulo city, in bags of nine kilo of green peas, harvested three days in the south of Minas Gerais. And this stages of preparation for irradiation were: selected the grains, sanitized in chlorine (15 mL/L) for 5 minutes, rinsed in running water, dried on absorbent paper, weighed (50 g) and packaged (Styrofoam tray measuring 11x11 cm and plastic film).

The samples were separated into 4 groups (n= 4 samples/ group) according to gamma radiation doses: control group (without irradiation), and with 0.15 kGy, 0.30 kGy 0.45kGy radiation doses. The samples were irradiated at room temperature in a Gammacell-220 irradiator at Radiation Technology Center – CETER of the Institute of Energy and Nuclear Research – IPEN-CNEN/SP. A 0.662 kGy/h dose rate and Harwell Amber 3042 dosimeters to certify the radiation doses were used. After the irradiation process, all packages were stored in a refrigerator at 8 ºC and analyzed on 1, 7, 14 and 21 days after irradiation.

2.2. Analyzes

The fresh pea samples were performed in the months of September and October 2018, by physical analysis (visual aspect, weight loss, color and hardness) and physicochemical (pH, total soluble solids, total titratable acidity, ratio, water content and ash) in the periods of: 1, 7, 14 and 21 days after irradiation, together with the control group. Each analysis was performed in triplicate, except for color that was performed in 4 samples and texture in 10 samples.

Physicochemical, physical (except texture) and statistical analyzes were performed at the Laboratory of Radiobiology and Environment, Piracicaba, São Paulo, Brazil and texture analysis was performed at the Irradiated Food Analysis Laboratory (LADAI), Center of Radiation Technology (CETER), São Paulo/SP, Brazil.

For physical analysis the peas were analyzed in grains and for physicochemical analysis the grains were grind in a blender.

2.2.1. Visual aspect

The visual aspect of the pea was evaluated by means of a subjective scale of values adapted from the methodology established by Santillo [17], based on the progress of ripening as well as on the occurrence of injuries, germinated seeds, insects and rot that may compromise the commercial quality of the product, being 0.4 – optimum (100%); 0.3 – good (80%); 0.2 – regular (60%); 0.1 – bad (40%). For the illustrative purposes, Figure 1 shows grain images for determining the scale used in the study. Each day of analysis 3 samples were evaluated per treatment.

Figure 1: Scale of values to determine the commercial quality of the product**.**

			
Intact grain (optimum)	Grain whit loss of color (good)	Yellowish grain, loss of texture (regular)	Rot, injury or germination (bad)

2.2.2. Weight loss

The packages with the peas were weighed on a semi-analytical balance model AS2000C. The results obtained from the difference between at the initial weight on the day of the experiment and the weight at the time of sampling and expressed as the percentage of fresh weight loss. It was used equation 1, according to the methodology established by Santillo [17].

$$\%\ \text{weight loss} = (\text{final weight} / \text{initial weight}) \times 100 \qquad (1)$$

2.2.3. Color

The color of the peas was evaluated using a Minolta colorimeter (Chroma Meter CR- 400) measuring L*, a*, b*, chroma and hue-angle, where L* represents the lightness. Hue-angle is the tone and chroma indicates the chromaticity or color purity. Measurement was performed directly on peas, considering four different positions per package according to the methodology established by Santillo [17].

For the determination of chroma value and hue-angle, equations 2 and 3 were used:

$$\text{Chroma Value } (C^*) = [(a^*2 + b^*\ 2)\ ½] \qquad (2)$$

$$\text{Hue-Angle } (h^*) = \tan{-1}\ (b^*/a^*) \qquad (3)$$

2.2.4. Hardness

Instrumental hardness was evaluated using a Stable Micro Systems texturometer model TA-TX2i, with a 2 mm cylindrical probe with the result of the resistance in relation to force applied by the device in Newtons per second (N/s). The test consists of attaching a support to the base of the equipment is to activate by software where the probe moves towards the base, with speed of 1.0 mm/s up to 10 mm after breaking stress. For this experiment was evaluated ten peas per package [18].

2.2.5. pH

The pH was evaluated using a Marconi model MA-522, being calibrated with acid and basic pH standard solutions and tested with buffer solution each day of analysis, following the methodology of the Association of Official Agricultural Chemists (AOAC), 2016 [19]. The evaluation was carried out in triplicate.

2.2.6. Total Soluble Solids (TSS)

The total soluble solids were quantified by direct reading in a digital refractometer, mark Rudolph Research model J57. The results were expressed in ºBrix according to the methodology established by the AOAC [19].

The measurements were carried out by dripping 3 samples of the ground peas directly into the prism of the refractometer equipment.

2.2.7. Total Titratable Acidity (TTA)

The total titratable acidity was determined using 5 grams of ground peas, homogenized and diluted to 50 mL of distilled water, using the standard solution of 0.1 N sodium hydroxide (NaOH) in the burette, determining the volume in milliliters of NaOH required to titrate the mixing until the pH was recorded at 8.1, according to the methodology established by the AOAC [19].

2.2.8. Ratio (TSS/TTA)

The TSS/TTA ratio was calculated from the ratio of the total soluble solids (TSS) to the total titratable acidity (TTA), were used equation 4, according to the methodology established by the AOAC [19].

$$\text{Ratio} = \text{TSS} / \text{TTA} \tag{4}$$

2.2.9. Water Content

Using the protocol of the Analytical Standards of the Instituto Adolfo Lutz [20], the water content was determined by drying the sample in laboratory stove Tecnal brand, model TE-393/2 at 105 ºC.

Were weighed 1 gram of the fresh sample on porcelain crucibles and placed in the stove for three hours, removing and carrying outweighing, return the stove for 30 minutes until constant weight.

2.2.10. Ash

Using the protocol of the Analytical Standards of the Instituto Adolfo Lutz [20], in order to determine ash.

Were weighed 1 gram on porcelain crucibles and incinerated in muffle, model FDG 3P-S, furnace with temperature programmed to reach 550 ºC, for four hours, and after cooling in desiccator a new weighing was carried out.

2.3. Statistical Analysis

The statistical analysis was performed using the software SAS (Statistical Analytical System; SAS Institute, N. C. USA, version 9,2) [21]. The means of the four treatments were evaluated by the Tukey test and the level of significance was 5%.

3. RESULTS AND DISCUSSION

3.1 Visual Aspect

Table 1 shows the means values of the evolution of the visual aspect though a subjective scale of values in peas.

Table 1: Mean values of the evolution of the visual aspect though a subjective scale of values in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC

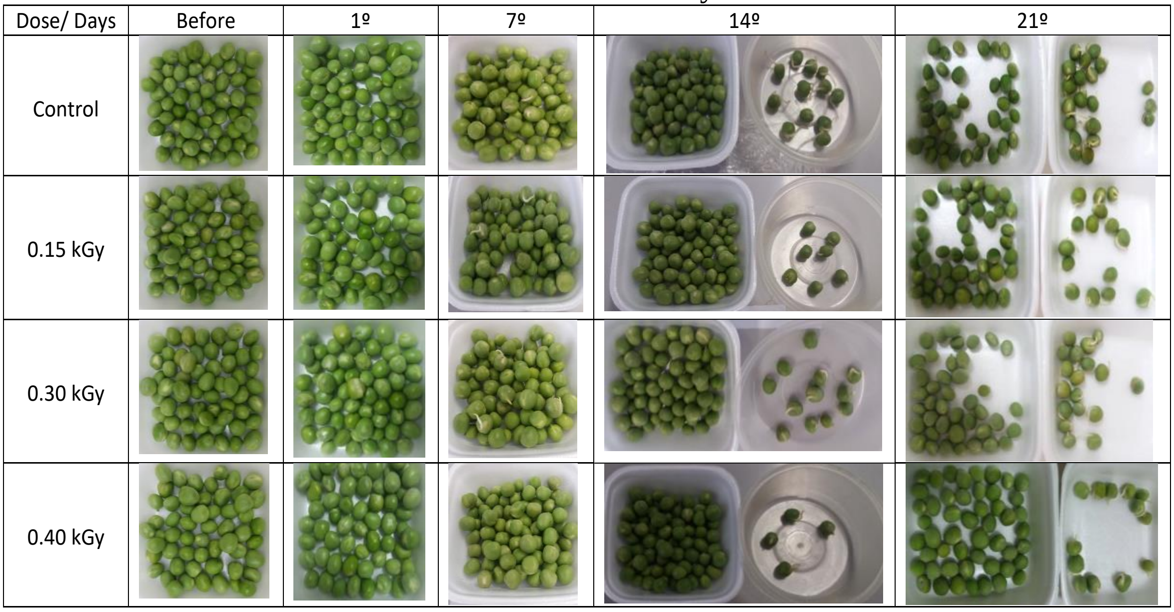
Visual Aspect				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	0.40±0.00[a]	0.30±0.00[a]	0.23±0.10[a]	0.20±0.00[ab]
0.15 kGy	0.40±0.00[a]	0.30±0.00[a]	0.23±0.10[a]	0.30±0.00[a]
0.30 kGy	0.40±0.00[a]	0.27±0.10[a]	0.23±0.10[a]	0.17±0.10[b]
0.45 kGy	0.40±0.00[a]	0.33±0.10[a]	0.30±0.10[a]	0.23±0.10[ab]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

In the results, it was verified that, there was no significant difference between the doses of gamma radiation and control group, independently of the evaluation period Table 1. Such data differ from those obtained by Chitarra M and Chitarra A. [22], when analyzing the visual aspect of irradiated fresh tomatoes, obtained the best results with dose of 0.25 kGy in 15 days of storage.

In the treatment of 0.30 kGy the grains presented an increase in their germination during the experimental period, there is the possibility of this radiation dose to have stimulated the germination of the fresh peas. In order to better elucidate the results, Figure 2 showing the evolution of the visual aspect.

Figure 2: Photographs of pea samples irradiated with increasing gamma radiation doses on different evaluation days.



3.2 Weight loss

Table 2 presents mean values of the weight loss in percentage. In the results, it was verified that, there was no significant difference between gamma radiation doses and control group, independently of the evaluation period.

Table 2: Mean values of the evolution of the weight loss (%), in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Weight Loss (%)				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	0.97±0.22[a]	5.07±1.59[a]	10.17±3.42[a]	14.91±4.76[a]
0.15 kGy	1.22±0.36[a]	3.88±0.56[a]	9.50±3.65[a]	13.47±1.40[a]
0.30 kGy	1.12±0.30[a]	3.40±0.70[a]	9.63±3.36[a]	13.06±1.46[a]
0.45 kGy	1.20±0.33[a]	4.42±0.55[a]	7.27±2.53[a]	11.88±2.74[a]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

The irradiated grains the loss of fresh mass decrease proportionately with increasing gamma radiation dose. The results of lower weight loss were obtained for the peas irradiated with 0.45 kGy, these data agree with Santillo [17], that obtained the smaller weight loss in nectarines with 0.40 kGy and greater losses with control and doses higher than 0.80 kGy.

According to Konica Minolta [23] sprouting leads to a rapid transfer of dry matter and water from the edible organ to the sprout and as a consequence weight loss. In this work it can be verified that for all treatments, there was a growing loss of weight over the days of analysis Table 2 and from the images Figure 2, observed sprouting in all treatments.

3.3 Color

For color evaluation the results were divided into three tables: Table 3, present mean values of the evolution of the luminosity, Table 4, shows mean values of the evolution of the chroma value and the Table 5, presents mean of the evolution of the hue-angle.

Table 3: Mean values of the evolution of the luminosity, in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

	Luminosity			
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	35.66 ± 3.15^{ab}	43.51 ± 5.91^{b}	35.85 ± 3.84^{a}	28.54 ± 2.12^{bc}
0.15 kGy	31.28 ± 3.48^{b}	43.83 ± 8.73^{ab}	34.90 ± 3.29^{a}	31.63 ± 2.92^{ab}
0.30 kGy	31.17 ± 5.07^{b}	44.88 ± 9.29^{ab}	43.43 ± 5.50^{a}	26.88 ± 1.19^{c}
0.45 kGy	43.09 ± 3.45^{a}	58.55 ± 0.22^{a}	34.80 ± 4.92^{a}	33.27 ± 1.38^{a}

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 4$)

With the results found in the luminosity analysis [24, 25], it was verified that there was no statistical difference between gamma radiation doses and the control sample in the analyzes of periods 1 and 14 days. However, in the 7 and 21 day periods, the highest dosage 0.45 kGy presented a significant increase in the luminosity of the peas compared to the control group. According to Brackmann et al. [24], the value that expresses the luminosity of the sample varies from 0 to 100, and the closer to 0 the darker the color of the sample and the closer to 100 the clearer. Based on this information it can be said that there was a greater loss in coloration of these peas because it is closer to the range 100.

Table 4: Mean values of the evolution of the chroma value, in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Chroma Value				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	32.98±1.89[a]	31.26±4.18[a]	22.37±5.36[a]	14.28±2.20[ab]
0.15 kGy	25.85±1.31[b]	29.60±2.59[a]	27.06±5.01[a]	16.18±1.51[a]
0.30 kGy	22.11±4.68[b]	30.39±2.17[a]	26.17±2.17[a]	12.74±1.47[b]
0.45 kGy	31.90±3.62[ab]	35.57±0.07[a]	24.16±2.79[a]	16.36±0.69[a]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 4$)

In the chromaticity analysis, a significant difference was observed only in the groups treated with 0.15 kGy and 0.30 kGy compared to the control group at 1 day after irradiation and these two were not different from each other Table 3. Visually, it was possible to observe a decrease in saturation (loss of color) in all the pea grain samples during the monitoring days Figure 2.

For the results of the hue-angle, shows in the Table 5, a significant difference was observed only on the first day of analysis shortly after irradiation of the peas, this difference being significant only in the group treated with 0.30 kGy gamma radiation dose, which presented a decrease compared to the control group. No significant difference between the groups was observed in the follow-up of subsequent analyzes.

Table 5: Mean values of the evolution of the hue-angle, in peas (*Pisum sativum* L.), under the application of different gamma radiation dose, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Hue-Angle				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	-1.09±0.01[b]	-1.04±0.03[ab]	-1.03±0.02[a]	-0.98±0.02[a]
0.15 kGy	-1.05±0.02[ab]	-1.07±0.01[b]	-1.07±0.04[a]	-1.00±0.02[a]
0.30 kGy	-1.03±0.02[a]	-1.03±0.03[ab]	-1.08±0.03[a]	-1.01±0.02[a]
0.45 kGy	-1.04±0.02[ab]	-1.01±0.00[a]	-1.05±0.03[a]	-0.98±0.04[a]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 4$)

3.4 Hardness

Table 6 presents a mean value of the evolution of the hardness (N/s).

Table 6: Mean values of the evolution of the hardness (N/s), in peas (*Pisum sativum* L.), under the application of different gamma radiation dose, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Hardness (N/s)				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	11.71±1.13[a]	13,18±1,54[a]	13.25±1.17[a]	10.51±2.17[b]
0.15 kGy	10.38±2.26[a]	14,53±1,38[a]	13.41±1.57[a]	9.99±1.58[b]
0.30 kGy	10.84±1.93[a]	12,78±1,96[a]	13.86±2.23[a]	11.36±2.57[b]
0.45 kGy	12.50±2.09[a]	13,47±1,51[a]	14.00±1.41[a]	14.18±1.32[a]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 10$)

Data on texture analysis Table 6 showed that only the group at the 0.45 kGy dose and a period of 21 days after irradiation showed an increase when compared as a control group.

According to AOAC [18], the firmness of the pulp, measured by the penetration test, allows us to distinguish the different stages of maturation. This can be justified by the fact that when fruit ripens, the degradation of pectic substances occurs, causing softening of the pulp [22].

3.5 pH

The pH analysis as a function of the storage of the fresh peas is presented in Table 7.

Table 7: Mean values of the evolution of the pH, in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

pH				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	5.65±0.29[a]	6.59±0.32[a]	6.48±0.05[a]	6.55±0.14[a]
0.15 kGy	5.96±0.41[a]	6.27±0.06[a]	6.35±0.04[b]	6.36±0.04[ab]
0.30 kGy	5.55±0.08[a]	6.31±0.01[a]	6.35±0.05[b]	6.24±0.04[b]
0.45 kGy	5.76±0.03[a]	6.22±0.02[a]	6.12±0.02[c]	6.17±0.02[b]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

The results showed that the evaluations performed at periods 1 and 7 days after irradiation were not able to significantly after pH in any of the treatments and were similar to those obtained by Costa [26], on the first day of evaluation. When analyzing the period of 14 and 21 days after irradiation, it was possible to notice significant alterations, and all the irradiated samples showed a decrease in pH when compared to the control, and the dose of 0.30 kGy and 0.40 kGy presented a decrease in to all samples in 21 days.

When studying tomatoes irradiated with 0.25 kGy, 0.50 kGy, 1 kGy and 2 Gy for a period of 20 days Chitarra, M and Chitarra A [22] observed that there was oscillation over the pH value with storage time, and that there was a small increase in the value of pH with development of maturation.

Study carried out by AOAC with fresh and dehydrated grapes, irradiated with doses of 0.50 kGy, 1.0 kGy, 1.5 kGy and 2.0 kGy accompanied for 21 days not found significant differences throughout their trials.

3.6 Total Soluble Solids (TSS)

Table 8 presents mean values of the evolution of the total soluble solids (ºBrix) in peas.

Table 8: Mean values of the evolution of the total soluble solids, in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Total Soluble Solids (TSS)				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	13.61 ± 0.18^{a}	14.49 ± 0.17^{b}	17.75 ± 0.35^{a}	19.08 ± 0.56^{a}
0.15 kGy	11.57 ± 0.35^{b}	12.99 ± 0.46^{c}	18.06 ± 0.38^{a}	17.25 ± 0.17^{b}
0.30 kGy	12.58 ± 0.59^{ab}	13.99 ± 0.88^{bc}	14.98 ± 0.22^{b}	19.02 ± 0.12^{a}
0.45 kGy	13.43 ± 0.44^{a}	16.41 ± 0.34^{a}	14.47 ± 0.25^{b}	17.56 ± 0.54^{b}

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

In the evaluation of total soluble solids, different from the one found in the previous analyzes, it was possible to observe that in all periods of treatment significant differences were verified, being a significant decrease in ºBrix when compared to the control in the following situations: 1 and 7 days and 0.15 kGy dose 14 days, and 0.30 and 0.40 kGy doses.

The results obtained in this study differ from those performed by Santillo [17] with nectarines, by AOAC [18] with fresh and dehydrated grapes and Brazaca [27] with fresh plums and all did not find significant differences during the period of their experiments.

3.7 Total Titratable Acidity (TTA)

Table 9 present shows the mean values of the evaluation of the total titratable an acidity in peas.

Table 9: Mean values of the evolution of the total titratable acidity, in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Total Titratable Acidity (TTA)				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	0.14 ± 0.01^{c}	0.07 ± 0.02^{c}	0.09 ± 0.01^{c}	0.08 ± 0.01^{c}
0.15 kGy	0.25 ± 0.02^{b}	0.12 ± 0.02^{b}	0.12 ± 0.01^{b}	0.14 ± 0.02^{b}
0.30 kGy	0.24 ± 0.01^{b}	0.12 ± 0.00^{b}	0.15 ± 0.00^{a}	0.15 ± 0.02^{b}
0.45 kGy	0.28 ± 0.01^{a}	0.14 ± 0.01^{a}	0.13 ± 0.01^{a}	0.17 ± 0.02^{a}

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

The results present a significant increase in all the evaluation periods and gamma radiation doses compared to the control group, except for the 0.30 kGy dose and 14 days compared to the control group, which did not differ significantly. For the studies performed by Santillo [17] with nectarines by Brazaca [27] with fresh plums, they did not obtain significant differences between the treatments.

3.8 Ratio (SST/TTA)

The results of the mean values of the evolution of the ratio in peas, is shown in Table 10.

Table 10: Mean values of the evolution of the ratio SST/ TTA, in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Ratio (SST/ TTA)				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	12.37±0.16[a]	28.20±7.13[a]	25.68±3.38[a]	30.26±2.31[a]
0.15 kGy	6.01±0.51[b]	14.04±1.46[b]	19.39±1.16[bc]	15.92±2.23[b]
0.30 kGy	6.74±0.35[b]	15.55±0.98[b]	21.40±0.32[ab]	16.39±1.43[b]
0.45 kGy	6.02±0.13[b]	15.01±1.60[b]	14.58±1.66[c]	13.60±1.46[b]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

As found in the data obtained in the TTA analysis, the ratio showed significant differences between the irradiated and control groups, with a decrease in values, but in the same way as in TTA, the 0.30 kGy dose and 14 day period compared with the control group, did not differ statistically. [27], which irradiated plums, there was an increase in ratio during storage time, but there was no statistical difference comparing the control group in relation to the study.

3.9 Water Content

Table 11: Presents mean values of the evolution of the water content (%), in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Water Content (%)				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	77.07±0.79[a]	73.06±1.03[bc]	70.91±5.89[a]	71.07±3.88[a]
0.15 kGy	77.84±0.25[a]	75.88±1.15[ab]	74.76±1.12[a]	76.07±0.40[a]
0.30 kGy	78.07±2.42[a]	75.97±0.74[a]	76.17±2.02[a]	74.89±1.05[a]
0.45 kGy	73.21±1.28[b]	72.00±1.37[c]	72.73±1.39[a]	75.14±0.45[a]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

The results presented on the water content, shows that the evaluation periods 1 and 7 days present a increase in the 0.45 kGy dose 1 day, and in the 0.30 kGy dose 7 days, both comparing with the group control. In addition, none of the irradiated groups presented statistical alteration for the 14 and 21 days evaluation periods.

Comparing the results obtained in this work and the water values found in the literature for fresh pea, with no radiation process: 76.94% [28], 76.80% [29], 73.90% [30] and 76.86% [31], it is noted that all water values in this study Table 11 are in the reference mean.

3.10 Ash

When evaluating the ash fraction in percentage, present in Table 12, it is verified that the gamma radiation dose did not affect the pea grains.

Table 12: Mean values of the evolution of the ash (%), in peas (*Pisum sativum* L.), under the application of different gamma radiation doses, evaluated in four distinct periods 1, 7, 14 and 21 days after irradiation and cooling remaining at 8 ºC.

Ash (%)				
Doses	**1 day**	**7 days**	**14 days**	**21 days**
control	1.53±0.41[a]	1.85±0.70[a]	0.99±0.35[a]	1.19±0.10[a]
0.15 kGy	0.89±0.14[a]	1.75±0.83[a]	0.79±0.10[a]	1.03±0.06[a]
0.30 kGy	1.35±0.33[a]	2.50±0.70[a]	0.64±0.15[a]	1.13±0.15[a]
0.45 kGy	2.30±1.04[a]	2.91±1.13[a]	0.73±0.11[a]	0.99±0.10[a]

For each column, distinct letters denote significant differences between doses of treatment with gamma radiation and control (Tukey test $p < 0.05$, $n = 3$)

Comparing the results obtained in this work and the ash values found in the literature for fresh pea, with no radiation process: 0.93% [28], 1.00% [29], 0.79% [30] and 0.87% [31], it is observed that in the evaluation periods 1 and 7 days the values are considerably higher than those found in the literature and the data of the periods of 14 and 21 days are in the reference average.

CONCLUSION

It was observed that in all parameters analyzes gamma radiation doses used did not affect significantly the shelf life of the grains.

The 0.30 kGy dose increased the germination of the peas and the 0.45 kGy dose was insufficient to inhibit sprout growth in peas.

.

REFERENCES

[1] COUTO, F. A. A. Aspectos históricos e econômicos da cultura da ervilha. **Informe Agropecuário**, v. 14, n. 158, p. 5-7, 1988.

[2] FILFUEIRA, F. A. R. **Novo manual de oleicultura: agrotecnologia moderna na produção e comercialização de hortaliças**. 3 rd ed. Viçosa: UFV, 2008.

[3] GRITTON, E. T. Field pea. Hybridization of crop plants. In: Madison: **American Society of Agronomy**, p. 347-356, 1980.

[4] CARVALHO, O. T. **Carotenóides e composição centesimal de ervilhas (*Pisum sativum* L.) cruas e processadas**. 79 p. Dissertação (Mestrado em Ciência dos Alimentos) Faculdade de Ciências Farmacêuticas, Universidade de São Paulo, São Paulo/ Brazil, 2007.

[5] KEWSCIENCE, Plants of the world online, USA. 2018. Available at: <http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:60454055-2#children>. Last accessed: 04 Fev. 2019.

[6] CEAGESP - Companhia de Entrepostos e Armazéns Gerais de São Paulo. **Guia Ceagesp – Ervilha Comum**, BRA. 2018. Available at: http://www.ceagesp.gov.br/guia-ceagesp/ervilha-comum/. Last accessed: 04 Fev. 2019.

[7] IBGE – Instituto Brasileiro de Geografia e Estatística, **Produção Agrícola Municipal Tabela 1612 - Área plantada, área colhida, quantidade produzida, rendimento médio e valor da produção das lavouras temporárias- Ano 2017.** Updated: 13/09/2018 – Available at: < https://sidra.ibge.gov.br/Tabela/1612#resultado>. Last accessed: 10 Nov. 2018.

[8] SASAKI, F. F.; AGUILA, J. S. del; GALLO, C. R.; ORTEGA, E. M. M.; JACOMINO, A. P. J; KLUGE, R. A. Alterações fisiológicas, qualitativas e microbiológicas durante o armazenamento de abóbora minimamente processada**. Brazilian Horticulture,** v. 24, p. 170-174, 2006.

[9] DURIGAN, J. F. Desafios e potências dos produtos minimamente processados. **Visão Agrícola**, v. 7, p. 88-91, 2007.

[10] RICKMAN, J. C.; BARRETT, D. M.; BRUHN, C. M. Review: Nutritional comparison of fresh, frozen and canned fruits and vegetables. Part 1. Vitamins C and B and phenolic compounds. **Journal of the Science of Food and Agriculture**, v. 87, p. 931-944, 2007.

[11] CESTARI JUNIOR, A. **Avaliação do potencial de aplicação do processo de irradiação para a redução de *Salmonella* spp. em diferentes variedades de mangas (*Mangifera indica* L.) minimamente processadas e avaliação da vida-de-prateleira**. 64 p. Dissertação (Mestrado em Ciências) Faculdade de Ciências Farmacêuticas da Universidade de São Paulo – São Paulo/ Brazil, 2005.

[12] FRIJA, S. N. **Alterações nutricionais, organolépticas e de textura dos produtos hortícolas conservados – Uma revisão**. 88 p. Dissertação. (Mestrado em Tecnologia e Segurança Alimentar) Universidade Nova de Lisboa, Lisboa/ Portugal, 2012.

[13] FELLOWS, P. J. **Food Processing Technology: Principles and Practices**. 2rd ed. Trad F.C. OLIVEIRA, Porto Alegre, Artmed, cap. 8, p. 207-219, 2006.

[14] KUME, T.; FURUTA, M.; TODOROKI, S.; UENOYAMA, N.; KOBAYASHI, Y., Status of food irradiation in the world. **Radiat. Phys. Chem**., v. 78, p. 222-226, 2009.

[15] PIMENTEL, R.M.A.; SPOTO, M.H.F.; WALDER, J.M.M. Irradiação gama permite aplicações em produtos embalados. **Visão Agrícola,** n. 7, p. 53-55, 2007.

[16] NEVES, L. C.; MANZIONE, R. L.; VIEITES, R. L. Radiação gama na conservação pós-colheita da nectarine (*Prunus persica* var. *nucipersica)* frigoconservada. **Revista Brasileira Fruticultura**, v. 24, p. 676-679, 2002.

[17] SANTILLO, A. G., **Efeitos da radiação ionizante nas propriedades nutricionais das uvas de mesa *benitaka* e uvas passas escuras**. 96 p. Dissertação (Mestrado em Ciências na área de Tecnologia Nuclear – Aplicações). Instituto de Pesquisas Energética e Nucleares, São Paulo/ Brazil, 2011.

[18] AOAC - ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. **Official Methods of Analysis of AOAC International**. Official method. 20rd ed. USA, 2016.

[19] INSTITUTO ADOLFO LUTZ. **Normas analíticas: métodos químicos e físicos para análise de alimentos.** São Paulo, 4 rd ed. digital, 2008.

[20] SAS - **Statistical Analysis System Institute**. Sas/Qc software: usageand reference. 2rd ed. Cary, v. 2, 1996.

[21] FABBRI, A. D. T. **Estudo da radiação ionizante em tomates in natura (*Lycopersicum esculentum* Mill) e no teor de licopeno no molho**, 85 p. Dissertação (Mestrado em Tecnologia Nuclear) Instituto de Pesquisas Energéticas e Nucleares, São Paulo/ Brazil, 2009.

[22] CHITARRA, M. I. F.; CHITARRA, A. B. **Pós-colheita de frutas e hortaliças: fisiologia e manuseio,** UFLA, Lavras/ Brazil, 2005.

[23] KONICA MITOLTA. Available at: http://konicaminolta.com.br/produtos.php. Last accessed: 12 Jan. 2019.

[24] BRACKMANN, A.; EISERMANN, A. C.; WEBER, A.; GIEHL, R. F. H.; PAVANELLO, E. P.; BOTH, V. Qualidade da maça 'gala' armazenada em atmosfera controlada associada à absorção e ao controle da síntese e da ação do etileno. **Ciência Rural**, v. 38, p. 2151-2156, 2008.

[25] SALATA, A. C.; KAMO, A. R. GODOY C.; HIGUTI, A. R. D.; CARDOSO, A. I. I.; EVANGELISTA, R. M., Produção e qualidade de ervilha submetidas a diferentes níveis de adubação potássica. **Nucleus**, v. 8, p. 129-134, 2011.

[26] COSTA, S. M., **Condicionamento témico e irradiação de ameixas 'gulfblaze' frigorificadas**. 83 p. Tese. (Doutorado em Agronomia) Faculdade de Ciências Agronômicas - UNESP, Botucatu/ Brazil, 2011.

[27] BRAZACA, S. G. C. Valor nutricional de produtos de ervilha em comparação com a ervilha fresca. **Ciência Tecnologia Alimento**, v. 26, p. 766-771, 2006.

[28] UNICAMP, **Brazilian Table of Food Composition - TACO**, 2011, 4 rd ed, Campinas. Available at: http://www.nepa.unicamp.br/taco/contar/taco 4 edição ampliada e revisada. Last accessed: 15 Jan. 2019.

[29] USP, **Brazilian Table of Food Composition - TBCA**, 2017, version 6.0. Available at: http://www. http:fcf.usp.br/tbca/. Last accessed: 22 Nov. 2018.

[30] USDA, **Agricultural Research Service. National Nutrient Database for Standard Refer**

nce Release 1. Beltsville, 2019. Available at: <https://ndb.nal.usda.gov/ndb/nutrients/report?nutrient1=207&nutrient2=255&nutrient3=401&fg=11&max=25&subset=0&offset=150&sort=c&totCount=767&measureby=g> .Last accessed: 05 Mar. 2019.

[31] CARVALHO, O. T. **Carotenóides e composição centesimal de ervilhas (Pisum sativum L.) cruas e processadas.** 2007. 79 p. Dissertação (Mestrado em Ciência dos Alimentos)- Faculdade de Ciências Farmacêuticas, Universidade de São Paulo, São Paulo.