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Physicochemical, microbiological and sensory acceptance alterations of strawberries caused by gamma radiation and storage time

Milton de Jesus Filho[a,*], Carmelita Zacchi Scolforo[a], Sérgio Henriques Saraiva[a], Christiano Jorge Gomes Pinheiro[b], Pollyanna Ibrahim Silva[a], Suzana Maria Della Lucia[a]

[a] Department of Food Engineering, Centro de Ciências Agrárias e Engenharias, Universidade Federal do Espírito Santo, Alto Universitário, s/n, 29500-000, Alegre, ES, Brazil

[b] Department of Rural Engineering, Centro de Ciências Agrárias e Engenharias, Universidade Federal do Espírito Santo, Alto Universitário, s/n, 29500-000, Alegre, ES, Brazil

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ABSTRACT

Consumer demand for food similar to one unprocessed has justified new studies seeking reduced changes in its physicochemical characteristics, the sensory acceptance and the microbiological safety. Irradiation increases the shelf life of foods, according to data in the literature. This study evaluated possible changes during the storage of non-irradiated and irradiated strawberries, the last treated at doses of 1, 2, 3 and 4 kGy, all of them stored at 8 ± 1 °C. The pH, total titratable acidity, ascorbic acid content, weight loss, firmness, the microbiota of natural contaminants and sensory acceptance of strawberries were analyzed. Influence of radiation dose and storage period on the physicochemical characteristics, microbiological quality and sensory acceptance of strawberries were observed. Although control strawberry presented better results for the ascorbic acid content, for firmness and for weight loss, it should be emphasized the effect of irradiation on inactivating mesophilic aerobics and markedly reducing of molds and yeasts. In addition, irradiated strawberries at 2 kGy presented the same hedonic mean on acceptance tests during 12 days of storage. It is suggested to use the 2 kGy dose as an alternative for strawberry conservation, since only minor changes were observed in the product during the 12 days of storage and it was the treatment that obtained better microbiological quality and maintenance of sensory acceptance during the storage period studied. Therefore, irradiation is a method that may be a substitute and could be used along with conventional methods, providing strawberries quality with a longer shelf life.

1. Introduction

Strawberry (*Fragaria x ananassa* Duch.) is among the most consumed fruits in the world. It is considered a pulpy and succulent food that presents antioxidant compounds, mainly anthocyanins, which are also associated with the reddish color of the fruit; in addition, it supplies minerals and vitamins of the B complex. It is also a source of ascorbic acid, potassium, calcium and phosphorus (Giampieri et al., 2015; Giné-Bordonaba and Terry, 2016; Li et al., 2017).

However, it is a very perishable pseudofruit (Neri et al., 2014; Chen et al., 2016), and its handling during and after harvesting makes the fruit more susceptible to changes in color, chemical compounds and sensory characteristics, besides those changes caused by the action of microorganisms (Zhang et al., 2011). Thus, conservation technologies that avoid the aforementioned changes which are, in most cases, undesirable, should be used in processing in order to maintain the physical, chemical and sensory characteristics appealing to the consumer, besides being safe in microbiological terms.

In this context, researchers have studied non-conventional conservation methods, such as irradiation (Françoso et al., 2008; Akran and Kwon, 2010; Hussain et al., 2012; Maraei and Elsawy, 2017; Calado et al., 2018; Odueke et al., 2018). Several studies have achieved satisfactory results by applying gamma radiation to food, as an alternative way to increase shelf life and reduce the number of existing microorganisms (Maraei and Elsawy, 2017). This technique is safe in food preservation and not aggressive to the environment, because it does not produce residues (Da Silva and Da Roza, 2010). Among the main advantages of its application in the food industry are: absence of chemical preservatives, low operating cost and little or no heating at all. However, even if the use of irradiation causes the aforementioned benefits, this conservation method may cause physicochemical, nutritional and sensory changes in the food, depending on the dosage used (Fellows,

* Corresponding author.
E-mail addresses: miltonfilhoea@gmail.com (M.d. Jesus Filho), carmelitazs@yahoo.com.br (C.Z. Scolforo), sergiohsaraiva@gmail.com (S.H. Saraiva), christrieste@yahoo.it (C.J.G. Pinheiro), pollyannaibrahim@yahoo.com.br (P.I. Silva), smdlucia@yahoo.com.br (S.M. Della Lucia).

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2006; Roberts, 2014).

Several works have been developed in order to evaluate possible changes in characteristics or effects inherent to the quality of food, with the intention of increasing the shelf life of some products. Data from the literature have shown positive effects in the use of this technique for food preservation. Odueke et al. (2018) studied the shelf life of foods that simulate dairy products and it was found that the irradiation was able to prolong their shelf life from 14 to 28 days to approximately 100 days, in products irradiated with the dose of 5 or 10 kGy. Chen et al. (2017) observed that gamma radiation at 1 and 2.5 kGy doses were able to enhance the activities of superoxide dismutase, catalase and peroxidase to continuously eliminate the superoxide anions and hydrogen peroxide generated and to keep them at low levels, which guarantees the quality of the storage and postpones the process of senescence in blueberries. Studies with mycotoxins concluded that, although ochratoxin A is resistant, irradiation was able to eliminate 90% of it in aqueous solutions and 24% in food matrices (Calado et al., 2018). Rice, fresh fruits and vegetables were irradiated with the dose of 1 kGy and the reduction of microbial contamination was verified without affecting the sensory acceptance of these products (Feliciano et al., 2017). Finally, in strawberries, irradiation stimulated the biosynthesis of some phenolic compounds such as pyrogallol, gallic acid, catechol, chlorogenic and ellagic acid (Maraei and Elsawy, 2017).

Thus, the objective of this study was to evaluate possible changes in physicochemical characteristics, microbiological quality and sensory acceptance of irradiated and non-irradiated strawberries during their storage period.

2. Materials and methods

The strawberries (*Fragaria x ananassa* Duch.) of the Camino real variety came from the township of Guaçuí, Espírito Santo, Brazil. They were harvested, selected, removed from the sepal and pedicel, washed and conditioned under refrigeration at 8 ± 1 °C in a polyethylene terephthalate packaging (Brasil, 2007).

2.1. Irradiation

After refrigeration, strawberries were divided into different lots: one not to be irradiated (control) and the other of strawberries that would receive radiation at different dosages (1.0 kGy, 2.0 kGy, 3.0 kGy and 4.0 kGy), according to a completely randomized design (CRD).

To ensure homogeneity of the storage conditions, the lots were kept in styrofoam boxes with ice in sealed plastic packs. These storage conditions prevented direct contact of strawberries and ice, thus preventing the occurrence of cold damage. The styrofoam boxes of the control lot were stored in the Laboratory of Sensory Analysis of the Federal University of Espírito Santo, in the city of Alegre, ES, Brazil (CCAE-UFES), while the boxes of the other lots were transported to the irradiation site. The storage temperature of both lots was approximately 8 °C.

The irradiation occurred at 8 ± 1 °C one day after the harvest, at the Laboratory of Gamma Radiation of the Centre for Development of Nuclear Technology (CDTN), in Belo Horizonte, Minas Gerais, Brazil, with a Cobalt 60 source in a Category II Panoramic Multipurpose Radiator (MDS Nordion, Canada), Model/serial number IR-214 and type GB-127, with a maximum activity of 2200 TBq or 60,000 Ci. At the time of irradiating the fruits, the activity of the source was 1,838,177.02 GBq or 49,680.46 Ci. The strawberries were irradiated at a dose rate of 1.872 kGy/h.

Preliminary tests were required to determine the radiation doses to be applied in the samples, and the total number of treatments in the experiment depended on the quantity of doses defined, plus control (non-irradiated) treatment. The doses used in this experiment were based on the work of Françoso et al. (2008) and Scolforo (2014) and in perceptible changes in tested strawberries, such as a clear change in firmness.

2.2. Study of changes during storage

Analyzes were carried out in the laboratories of the Federal University of Espírito Santo, Alegre, ES, Brazil, in three storage times of the strawberries and conducted at refrigeration temperature (8 ± 1 °C): Time 1 (one day after irradiation), Time 2 (five days after irradiation) and Time 3 (twelve days after irradiation). Time 1 was chosen according to the transport logistics of the samples to the laboratories for analysis, after irradiation in Belo Horizonte. Time 2 was chosen according to the useful life of the control strawberry (without treatment), which corresponds, on average, to seven days after harvest; and Time 3 was chosen based on the shelf life of the irradiated strawberry, this being, on the average, 14 days after harvest (Thomas, 1993), depending on the dosage used.

2.2.1. Physicochemical analyzes

2.2.1.1. Firmness of the fruit. The firmness of the fruit was determined with a SoilControl® digital penetrometer (model PTR-100). The results were expressed in Newton (N) (Pineli, 2009).

2.2.1.2. Ascorbic acid. It was determined by the titration method with 2,6-dichlorophenolindofenol. An aliquot of approximately 5 g of each sample was homogenized with a mixer (Britânia®/model: Ultra Mixer/XB986B). After that, it was transferred to a test tube and received 5 mL of the extraction solution of metaphosphoric acid and acetic acid. These samples were centrifuged in a FANEM centrifuge (model: 206 BL); 2 mL of the supernatant were used for dilution with the extraction solution in a 25 mL volumetric flask. Then 2 mL of the diluted solution were added with 5 mL of the extraction solution. Then the samples were titrated with the solution of 2,6-dichlorophenolindofenol diluted in distilled water (1:10). The results were expressed as mg of ascorbic acid.100 g^{-1} of fruit, according to the official methodology of 967.21 AOAC with modifications (Association of Official Analytical Chemists (AOAC), 1995).

2.2.1.3. pH. The pH was measured in an ION LAB® digital bench pH meter (Phb500 model), according to the methodology indicated by AOAC (2005).

2.2.1.4. Weight loss. It was determined by weighing the trays containing each treatment at the initial time (time 1) and at times 2 and 3, calculated by Eq. (1) (Pineli, 2009):

$$WL = (Pi - Pf)^{*}\,100/Pi \tag{1}$$

Where: WL: Weight loss; Pi: Tray weight at time 1; and Pf: Tray weight at time 2 or 3.

2.2.1.5. Total titratable acidity. The determination of the total titratable acidity was done by titrimetric, according to the modified AOAC Methodology (1995) using a solution of 0.1 N NaOH and the phenolphthalein indicator. The samples were homogenized with a mixer (Britânia®/model: Ultra Mixer/XB986B) and an aliquot of approximately 5 g of each sample was transferred to a beaker of distilled water. The mixture was filtered and transferred to an erlenmeyer for titration. The results were expressed in milligrams of citric acid. 100 mg^{-1} of strawberry.

2.2.1.6. Color. The color analyzes were performed with a KONICA MINOLTA® colorimeter (Model CM-5, New Jersey, United States of America), obtaining the coordinates L*, a*, b*, where L* indicates the brightness (expresses the level of color clarity), ranging from black (L* = 0) to white (L* = 100), a* consists of the axis ranging from red to green, b* varies from yellow to blue. Chroma (C), hue angle (h) and overall difference of color (ΔE) were also analyzed (Caner and Aday, 2009).