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Consumer rejection threshold for strawberry radiation doses

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ABSTRACT

Strawberries have a short shelf life. The use of irradiation has been suggested as a possible solution to increase the shelf life of foods and decrease the outbreaks of food-borne diseases. However, undesirable sensory attributes are observed at certain doses. Therefore, this study aimed at ascertaining the consumer rejection threshold (CRT) and the detection threshold (DT) for radiation doses in strawberries. Consumers participated in paired preference tests and in triangular tests to determine the CRT and DT, respectively. The CRT and DT were 3.6 kGy and 0.405 kGy, respectively. The DT was below the lower limit (1.5 kGy) and the CRT was greater than that of the upper limit (3.0 kGy) of radiation doses generally recommended for strawberries. The main sensory change observed was a decrease in firmness of the fruit as the dosage increased. The calculated CRT serves as a guideline for producers and industries that market or intend to market irradiated strawberries.

Industrial relevance: We present the calculation of the consumer rejection threshold (CRT) for strawberry radiation doses. The CRT serves as a guideline for producers and industries that market or intend to market irradiated strawberries. Furthermore, the CRT may encourage the use of higher doses of radiation than those of generally recommended for strawberries, thus resulting in the increased elimination of pathogenic and spoilage microorganisms and consequently, a greater availability of microbiologically safe strawberries with a longer shelf life, thus reducing losses.

1. Introduction

The strawberry (*Fragaria* ssp.) is considered one of the most important small fruits because it has a high productivity and an attractive flavor (Françoso, Couto, Canniatti-Brazaca, & Arthur, 2008). However, the strawberry encounters two problems regarding microorganisms: fungal rot and the potential presence of pathogenic microorganisms. Strawberries have a short shelf life, and losses during storage can reach up to 40% (Vachon, D'Aprano, Lacroix, & Letendre, 2003). Furthermore, there have recently been numerous disease outbreaks transmitted by contaminated strawberries. There was an outbreak of *E. coli* O26 in Massachusetts, USA, in 2006 (CDC, 2010), and in 2011 in Oregon, USA, one person died and 15 others became ill when they consumed strawberries contaminated with *E. coli* O157:H7 (Falkenstein, 2011; Goetz, 2011). These facts emphasize the need for the use of a preservation technique that ensures the supply of microbiologically safer, fresh strawberries with a longer shelf life without compromising sensory and nutritional characteristics.

The use of irradiation on foods has become prominent in recent years because of its potential to eliminate pathogenic and spoilage microorganisms in fresh fruits and vegetables (FAO/IAEA, 2012; Lynch, Tauxe, & Hedberg, 2009). Irradiation is a technique that prevents the splitting of living cells, such as bacteria, fungi, and higher organisms, by modifying their molecular structure (Del Mastro, 1999; Fellows, 2006). Studies have shown that irradiation can eliminate pathogenic microorganisms and extend the shelf life of strawberries by more than one week (Thomas, 1993; Zegota, 1988).

When controlled radiation doses are administered, changes in the nutritional and sensory characteristics of the food are minimal (Fellows, 2006; Hernandes, Vital, & Sabaa Srur, 2003). However, no single optimal dose can be applied to all foods. Food may develop undesirable sensory attributes at certain doses, and these changes will vary depending on the food and the applied dose.

In strawberries, a modified texture is the primary sensory change caused by irradiation (D'Amour, Gosselin, Arul, Castaigne, & Willemot, 1993; Thomas, 1993; Yu, Reitmeier, & Love, 1996; Yu et al., 1995). In these fruits the higher the radiation dose, the lower the firmness of the fruit (Thomas, 1993). Certain radiation doses may be considered transition points, in which sensory changes can result in the sensory perception or rejection of strawberry by the consumer. These transition points are called thresholds.

Abbreviations: CRT, consumer rejection threshold; DT, detection threshold.

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The detection threshold (DT) is a widely used concept in sensory science and it represents the minimum limit at which an individual can perceive a stimulus (Meilgaard, Civille, & Carr, 2008). To use a technology such as irradiation in strawberries, this threshold may be defined as the minimum dose of radiation at which perceptible sensory changes begin to occur in the fruit.

Initial sensory changes to strawberries caused by low doses of radiation may be minimal or even desirable, such as an increased sweetness in the fruits reported by some studies (Behrens, Barcellos, Frewer, Nunes, & Landgraf, 2009; Camargo, 2004), and may not affect the acceptability of the product. Therefore, it would be notable to investigate the dose at which the consumer's sensory rejection of strawberries occurs. Prescott, Norris, Kunst, and Kim (2005) proposed this type of rejection study and suggested the concept of a consumer rejection threshold (CRT). This new concept is based on the evaluation of consumer preference using paired preference tests within a constant-stimulus threshold procedure.

The CRT methodology was initially used to evaluate “cork taint” in wine (Prescott et al., 2005) and was subsequently used to determine the CRT for defects in coffee (Deliza, Alves, Ribeiro, Silva, & Farah, 2005) and 1,8-cineole (eucalyptol) in Australian red wine (Saliba, Bullock, & Hardie, 2009). However, this method is also suitable for determining the CRT of radiation doses in strawberries because lower doses of radiation result in small sensory changes that may not cause sensory rejection of strawberries and higher doses may result in more intense sensory changes, thus causing the sensory rejection of strawberries. Therefore, there is a transition point between non-rejection and rejection.

In an attempt to assist producers and industries that market or intend to market irradiated strawberries, this study sought to determine the CRT and DT of radiation dosage on strawberries.

2. Methodology

This study was approved by the Research Ethics Committee of the Health Sciences Center of the Universidade Federal do Espírito Santo (UFES), Brazil, under number 65403.

2.1. Sensory evaluation

Regular strawberry consumers were recruited among the students and staff of UFES and the residents of Alegre — ES, Brazil. Participants in the CRT study consisted of 62 women and 31 men between 18 and 40 years old, with the majority (58%) between 20 and 30 years old. The participants in the DT study comprised 55 women and 25 men between 18 and 40 years old, with the majority (57.5%) between 20 and 30 years old.

Sensory tests were carried out in the Laboratory of Sensory Analysis of UFES, in individual booths and under white light.

2.2. Materials

The strawberries (*Fragaria ananassa* Duch.) of the Camino Real variety, harvested in 2012, were purchased from a producer in the southeast region of Brazil. Harvest, selection, and packaging in polyethylene terephthalate (PET) containers with perforated lids were performed. The use of these PET containers protects the fruits from physical and mechanical stresses, and also reduces losses via dehydration and the respiration rate. The utilization of perforated PET containers is a common practice in Brazil and recommended by the Ministry of Agriculture, Livestock, and Supply (MAPA, 2007).

After cooled, the strawberries were divided into several lots, one lot was composed of non-irradiated strawberries (control) and the remaining lots were composed of strawberries to be irradiated at different doses, according to a completely randomized design (CRD).

To ensure uniformity in the storage conditions, lots of strawberries (control and irradiated) were packaged in styrofoam boxes together with sealed plastic containers containing ice, so that there would be no direct contact between ice and the strawberries, which could cause chilling injury. The temperature of the strawberries was monitored before and after the irradiation process by means of an infrared thermometer with laser sight, encountering an average temperature of 8 °C. Strawberries were irradiated in the Gamma Radiation Laboratory of the Center for Development of Nuclear Technology in Belo Horizonte — MG, Brazil, using a cobalt-60 source in a Category II Multipurpose Panoramic irradiator with an activity of 2200 TBq.

In addition to literature review, the researchers conducted preliminary tests in order to determine which sensory changes occur in strawberries subjected to different radiation doses and to select the doses to be studied in the methodologies of the CRT and DT.

Control strawberries and irradiated strawberries at doses of 0.5 kGy, 1.0 kGy, 1.5 kGy, 2 kGy, and 3 kGy were analyzed. It was found that the use of a dose of 2 kGy resulted in a loss in the firmness of the fruit, and at a dose of 3 kGy this change was even more pronounced. However, the change caused by the dose of 3 kGy might not be sufficient to result in rejection of the strawberry. Thus, the following doses were used in the CRT and DT determinations:

- For the determination of CRT: 0.5, 1, 2, 3, and 4 kGy.
- For the determination of DT: 0.125, 0.25, 0.5, 1, 1.5, and 2 kGy.

2.3. Procedure

The CRT and DT were determined according to the procedures proposed by Prescott et al. (2005), which are briefly described below.

To determine CRT, each judge performed five paired preference tests, one for each radiation dose. Each pair consisted of one sample of non-irradiated strawberries and one sample of irradiated strawberries in one of the above-described doses. To determine CRT, the judges tried both samples and indicated which he or she preferred on the assessment form. After rinsing their mouths with filtered water, the judges received a new pair of coded samples every 5 min. The radiation doses were presented in ascending order, and the position of the irradiated sample within each pair was randomized.

The DT was determined using six triangular tests, and in each series, one of the three samples was irradiated and the others were not. The judges were asked to identify the different sample. The radiation doses were presented in ascending order, and the position of the irradiated sample within each test was randomized.

The CRT and DT were calculated by interpolation. The CRT was the lowest dose at which a statistically significant percentage of judges preferred the control sample. The DT was considered the lowest dose at which the statistically significant percentage of judges identified the irradiated sample. The criterion for significant detection or rejection as a function of radiation dose was based on binomial distribution tables for the triangular and paired comparison tests, respectively (ISO, 2004, 2005; Meilgaard et al., 2008).

3. Results

To calculate the CRT the graph in Fig. 1 was plotted, where it is possible to visualize the proportions of judges who preferred the control sample over the irradiated sample for each dose studied. For the number of 93 judges and a probability level of 5%, the significance criterion, i.e., the minimum proportion of responses needed to establish significant preference is 0.61 (ISO, 2005). This ratio is shown by the dashed line in Fig. 1.

The proportion of judges who preferred the control sample to the irradiated sample at 3 kGy was 0.56, below the significance criterion. The proportion of judges who preferred the control sample to the irradiated sample at 4 kGy was 0.64, above the proportion for the significance