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Determination of changes induced by gamma radiation in nectar of kiwi fruit (*Actinidia deliciosa*)

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ABSTRACT

The kiwi (*Actinidia deliciosa*; Actinidaceae) is an exotic fruit to Brazil, introduced from southeastern China. The kiwi fruit presents a high nutritional value, rich mainly in vitamin C and fibers, calcium, iron and phosphorus, which give it an excellent nutritional value. Its quality attributes and flavor has lead to acceptance in consuming markets, mainly among children. The objective of this work was to formulate a non-alcoholic sweetened drink based on kiwi fruits, to submit the drink to gamma radiation using increasing doses: 0 (control), 0.5, 1.0 and 2.0 kGy, and to evaluate changes in physical and chemical quality attributes. We found that no significant difference was observed between treatments relative to the control. So we could conclude that for the doses tested significant alterations in the physiochemical characteristics of the kiwi nectar were introduced.

1. Introduction

The kiwi (*Actinidia deliciosa*; Actinidaceae) is an exotic fruit to Brazil, introduced from southeastern China. The fruit is densely covered with light brown fur. Kiwi fruits display tolerance to low temperatures for conservation, allowing storage for up to 8 months (Schuck, 1992).

Kiwi is one of the only fruits which does not have a specific regulation from the Brazilian Ministry of Agriculture about standardization and classification. Therefore, there are no official rules for commercialization, classification, selection and packing for kiwi in Brazil.

The kiwi fruit presents a high nutritional value, rich mainly in vitamin C and fibers, calcium, iron and phosphorus, which turns it into an excellent nutritional option, with an important association between quality attributes and flavor, with great acceptance in consuming markets, mainly among children. Kiwi contains an enzyme, actinine, with meat softening properties (Carvalho and Lima, 2002).

The concentration and composition of sugars have a main role in flavor. Kiwi contains high levels of soluble sugars, in particular glucose, fructose and sucrose (Carvalho and Lima, 2002). According to Wildman and Luh (1981), ripen kiwi contains around 5.8% fructose, 4.2% glucose, 2.8% sucrose, with a average total sugar of around 12.8%.

Estimating the contents of ascorbic acid, vitamin C in fruits and vegetables is important because of its major role in human nutrition, but also because its degradation can favor non-enzymatic browning and cause the development of off-flavors (Bernhardt, 1997). Further, ascorbate is an important indicator of quality, as a thermo-labile vitamin, the presence of vitamin C can indicate that other nutrients are preserved.

Irradiation is an excellent method of food conservation, as well as reinforces the action of other applied processes for the same purpose. Irradiation satisfies completely the objectives of giving food nutritional stability, sanitary conditions and a long shelf life (EMBRARAD, 2007).

Investigations demonstrated that macronutrients, such as proteins and carbohydrates are relatively stable at doses of up to 10 kGy, and that, micronutrients, mainly vitamins can be sensitive to any method of food conservation. The sensitivity of various types of vitamins to irradiation and other methods for food conservation is variable; vitamins C and B_1 (thiamin) are the most sensitive to irradiation. In general, the process of irradiation with acceptable dose cause little chemical changes in foods, whereas the food nutritional quality is no more affected than when it is treated with other conventional methods of preservation (Villavicencio et al., 1998).

Iemma et al. (1999) investigated losses in ascorbate in irradiated orange juice. Munhoz-Burgos (1985) irradiated natural or concentrated orange, mandarine and passion fruit juices, pasteurized or not, immediately after canning, demonstrating that variations in pH, soluble solids, total acidity and vitamin C were not significantly different up to doses of 0.5 kGy, but at 2 kGy variations were significant. The combined process of irradiation

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with heating or refrigeration has been used to preserve fruit juices. However, the commercial use of fruit juices requires optimization of dose to minimize the development of undesirable sensorial traits, and to improve economical aspects of the process (Munhoz-Burgos, 1985).

The principal processed products obtained from fruits are juices and nectars (sweetened drink). In this work, a non-alcoholic sweetened drink was prepared from Kiwi, containing 50% pure juice and sugar, and ready to consume (Tocchini, 1995), which was treated with irradiation at doses of 0.5, 1.0 and 2.0 kGy.

The objective of this work was to evaluate changes in physical and chemical quality attributes caused by irradiation.

2. Material and methods

This work was conducted at the Food Irradiation laboratory of the Centro de Energia Nuclear na Agricultura—CENA.

Kiwi fruits (*Actinidia deliciosa*) were locally purchased. The fruits were washed in a bleach solution, peeled, and cut in half. The juice was extracted by home centrifuge Walita, pre-filtered, centrifuged at 5000 rpm, and filtered. Mineral water was added to 50% volume, and sucrose to reach 16 °Bx. It was made to undergo ultra filtration with ceramic membrane of 0.10 μm at a pressure of 3 bar at 45 °C for clarification, according to Lopes et al. (2005). The drink was kept in 500 mL plastic bottles (PET), and exposed to the following doses: 0.5, 1.0 and 2.0 kGy.

Irradiation was conducted in a Cobalt 60 source, model Gammabeam 650, Nordion (CENA/USP). The dose rate was 0.712 kGy/h.

Dosimetry was performed using 5-mm-diameter alanine dosimeters (Bruker Instruments, Rheinstetten, Germany), and the free radical signal was measured with Bruker EMS 104 EPR Analyzer. The actual dose was within 0.02 of the target dose. Samples were turned 360° continuously during the irradiation process to achieve uniform target doses and the non-irradiated control was placed outside the irradiation chamber to have the same environmental temperature effect as that of the irradiated sample.

2.1. Physico-chemical analyses

2.1.1. Soluble solids content

Estimated in refractometer RT-30ATC and expressed in Brix, according to AOAC (2005).

2.1.2. Titrable acidity

Determined and estimated as the volume in mL of NaOH required to titrate 100 mL of drink to reach pH 8.2, expressed in percent of citric acid, with the drink diluted 1:10, according to AOAC (2005)

2.1.3. pH

Determined using pHmeter MB-10, according to AOAC (2005).

2.1.4. Total ascorbic acid

Determined according to Jacobs (1985), using oxalic acid and titrating with a dichloro-benzeneindophenol solution. Estimated based on volume in mL of the the solution of 2,6-dichlolophenolindophenol used to titrate 50 mL of drink, until becoming light pink, expressed in mg ascorbic acid/100 mL kiwi drink.

2.1.5. Color

The colorimeter Minolta CR-200B was used, previously calibrated in white according to pre-determined standards, according to Bible and Singha (1997).

Three values of chroma were evaluated: a^*, b^* and L. The value a^* characterizes the color from the red (+a^*) to the green ($-a^*$); the value b^* indicates the color from the yellow (+b^*) to the blue ($-b^*$). The value L determine the light ranging from white ($L=100$) to black ($L=0$). The chroma is the ratio between a^* and b^*, where the real color can be obtained. Hue angle is the angle between a^* and b^*, indicating the color saturation of the analyzed object.

To estimate chroma value, the following formula was adopted (1) and to estimate the hue angle, formula (2) (Estevez and Cava, 2004).

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

$$H^\circ = \mathrm{arcpg}\left(\frac{b^*}{a^*}\right) \tag{2}$$

2.2. Sensorial analyses

Sensory acceptances of the irradiated and non-irradiated kiwi nectar were done with 41 non-expert panelists. The panel consisted of adults (from 18 to 50 years old), of both sexes who were consumers of kiwi, who gave reactions concerning consumption of kiwi, and who had given their consent. They were selected by aleatoric base. The sensorial analysis was constituted by color, smell, flavor, texture and overall acceptance.

Panelists were instructed to evaluate each attribute using a nine-point hedonic scale ranging from "extremely dislike" to "extremely like". Test of acceptability of hedonic scale was used, since it is necessary to know the consumers "affectionate status" regarding the product, inferring the preference, in other words, the most favorite samples are the more accepted and vice versa. The scales were balanced, once they present equal number of positive and negative categories (1–9) (Ferreira, 2000).

About 50 mL of each kiwi nectar treatment were given individually to the panelists and a three-digit code was used for the sample. Mineral water was provided to wash the oral cavity after tasting each treatment. Red light was used to mask possible induction by the color in others attributes (Ferreira, 2000).

2.3. Statistical analyses

The experimental design was complete randomized with three replications. Results were analyzed (ANOVA) using the F-test, and mean comparisons were tested based on Tukey ($p<0.05$) using SAS (Statistical Analysis System Institute, 1996).

3. Results and discussion

3.1. Tenor of soluble solids

The obtained variations of Brix (Brix degrees) of the kiwi nectar irradiated at doses of: 0 (control), 0.5, 1.0 and 2.0 kGy are in Table 1.

The sample which received radiation dose of 2.0 kGy presented a larger amount of soluble solids, following by dose of 0.5 kGy. The nectar irradiated at 1.0 kGy was found to have the same amount of soluble solids as the control, in other words, the same value for °Bx.

Statistical differences were verified among the treatments, indicating that the irradiation influenced this parameter, confirmed in a study accomplished by Spoto and Verruma-Benardi (2002) in orange juice irradiated at several doses.

Table 1
Variation of °Bx, titled acidity, pH and ascorbic acid of kiwi nectar irradiated at 0.5, 1.0. 2.0 kGy plus the control.

Dose	°Bx	Titled acidity (%)	pH	Total ascorbic acid
Control	16.70 ± 0.0[(b)a,b]	8.8 ± 0.11[(b)b]	3.5 ± 0.1[(a)a,b]	108.00 ± 0.0[(a)a,b]
0.5	16.60 ± 0.0[(c)]	9.2 ± 0.1[(a)]	3.2 ± 0.1[(b)]	108.00 ± 0.0[(a)]
1.0	16.70 ± 0.0[(b)]	8.2 ± 0.1[(c)]	3.0 ± 0.1[(c)]	54.00 ± 0.0[(b)]
2.0	16.80 ± 0.0[(a)]	8.8 ± 0.1[(b)]	3.0 ± 0.1[(c)]	54.00 ± 0.0[(b)]

[a] Mean ± standard deviation.
[b] Means with different word(s) in the vertical significantly differ at the level of 5%.

Table 2
Median values of *L*, *a**, *b**, croma and hue angle of kiwi nectar.

Dose	Parameters				
	L	*a**	*b**	Croma	Hue angle
Control	22.03 ± 0,00[(a)a,b]	−2.23 ± 0.00[(a)]	5.33 ± 0.00[(a)]	5.78	−1.17
0.5	23.20 ± 0,00[(a)]	−2.05 ± 0.00[(a)]	4.95 ± 0.00[(a)]	5.36	−1.18
1.0	23.68 ± 0,00[(a)]	−2.19 ± 0.00[(a)]	5.40 ± 0.00[(a)]	4.91	−1.11
2.0	22.23 ± 0,00[(a)]	−1.76 ± 0.00[(a)]	4.47 ± 0.00[(a)]	4.80	−1.20

[a] Mean ± standard deviation.
[b] Means with different word(s) in the vertical differ significantly at the level of 5%.

Table 3
Sensorial Analysis about color, smell, flavor, texture and acceptance.

Samples	Parameters				
	Color	Smell	Flavour	Texture	Acceptance
Control	6.19 ± 1.92[(a)a,b]	6.14 ± 1.84[(a)]	6.32 ± 1.79[(a)]	6.26 ± 1.82[(a)]	6.41 ± 1.98[(a)]
0.5	5.68 ± 1.93[(a)]	5.44 ± 1.93[(a)]	5.76 ± 1.82[(a)]	5.78 ± 1.71[(a)]	5.75 ± 1.92[(a)]
1.0	5.48 ± 2.10[(a)]	5.88 ± 2.33[(a)]	6.29 ± 1.69[(a)]	6.22 ± 1.95[(a)]	5.95 ± 1.80[(a)]
2.0	5.24 ± 1.92[(a)]	5.60 ± 2.18[(a)]	5.43 ± 1.56[(a)]	5.95 ± 1.95[(a)]	5.51 ± 1.78[(a)]

[a] Mean ± standard deviation.
[b] Means with different word(s) in the vertical differ significantly at the level of 5%.

In the research they found values above the literature value for fruit. The kiwi nectar needs sucrose addition to reach 15 °Bx (ideal to nectar), which allowed an ideal palate for the consumption in terms of sugar percentage.

3.2. *Titled acidity*

The obtained variations of the titled acidity (% of citric acid) of the irradiated kiwi nectar are given in Table 1.

The dose of 0.5 kGy presented an increase in the acidity tenor, indicating that the treatment influenced for the increase, followed by the control that did not differ statistically of the doses of 2.0 and 1.0 kGy presented a smaller acidity among the analyzed samples.

The tenors of total acids vary from 1.0% to 1.5%, citric acid being the principal. In this work were found values above the one of the literature for kiwi.

Study accomplished by Leite et al. (2006) showed tenors of total acids for the sample non-irradiated 16.04%, and for the sample irradiated 16.58% and 15.85% for the doses of 1.0 and 2.0 kGy, respectively.

These values differ from the values found in this work; which could be explained by the degree of fruit maturation.

3.3. *pH*

The obtained variations of the pH of the irradiated kiwi nectar are given in Table 1.

There was a decrease in the value of the pH with increasing dose, which resulted in more acid nectar.

In agreement with Matsumoto et al. (1983), the pH value for un-irradiated kiwi nectar should be around of 3.3. However, that value was obtained for the sample that was submitted to the irradiation dose of 0.5 kGy.

Leite et al. (2006) showed values of pH 3.38 for the samples irradiated at the doses of 1.0 and 2.0 kGy, and 3.41 for the non-irradiated sample. These values are same as the values found for in this work.

3.4. *Total ascorbic acid*

The results of total tenor of ascorbic acid (nectar mg/100 mL) of the irradiated kiwi nectar are given in Table 1.

Irradiation at doses of 1.0 and 2.0 kGy induced a reduction of 50% relative to the control and to the samples irradiated with dose of 0.5 kGy.

3.5. *Color analysis*

According to Table 2, the treatment does not induce significant alterations in the color parameters.

There was not a linear decrease in the treatments, but the treatments did not induce statistically significant differences between the samples. Lee et al. (2008) and Jo et al. (2003), present in their study a decrease of color values in their irradiation treatments for tamarind juice and fresh green tea, respectively; but Kim et al. (2006) found that *Curcuma aromatica* extracts got an improvement in color by gamma radiation.

3.6. *Sensorial analysis*

The sensorial analysis did not find significant statistical difference among the aspects analyzed (color, aroma, flavor, texture and overall acceptance) for doses used, according to Table 3.

Those results are similar to Lee at al. (2008) and they were in agreement with previous studies (Song et al., 2007), that did not find significant change in irradiated tamarind juice and fresh vegetable juices, when compared with un-irradiated juices.

4. Conclusion

We conclude that the irradiation did not induce significant alterations in the physiochemical and sensorial characteristics of kiwi nectar, with the exception for total ascorbic acid at doses of 1.0 and 2.0 kGy.

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