Evaluation on Physical Properties of Irradiated Collards Greens (*Brassica oleracea* L var. *acephala)*

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Abstract. The *Brassica* family is well-known all over the world, and among its species, Collard greens (*Brassica oleracea* L. var. *acephala*), also called kale, is the most consumed in Brazil, as an ingredient of salads and also as a complement in a typical Brazilian dish called "*feijoada*". Food irradiation is a worldwide spread technology, used to improve the quality of vegetables, extending their shelf-life and reducing microorganisms present in leafs. Color is the first sensorial aspect perceived by consumers, being an important factor of refusal. The objective of this paper was to analyze the color of irradiated kale by electron beam processing. The kale samples were irradiated at IPEN-CNEN/SP electron accelerator (Radiation Dynamics Inc. USA, 1.5 MeV-25mA), at doses of 1.0, 1.5kGy, to compare with the control sample (not irradiated). Statistical analysis was done to compare the efficacy of different radiation doses. Slight differences in color measurement were observed in the irradiated samples and the quality of kale was maintained until the seventh day of storage.

1. Introduction

The "*feijoada*" is a typical Brazilian dish and was introduced by Africans slaves; nowadays, made with black beans, smoked sausage, jerked meat, and some other salt pork, served with rice, manioc flour, orange slices and collards (kale). Sliced collard is briefly cooked in garlic and olive oil for a healthy, tasty side dish. These collards are a traditional accompaniment to the Brazilian "*feijoada*", but they go with almost any meal and salad components. Collards have an important role in this dish due to their high level of anti-oxidant compounds, making digestion easier.

The effective potential to ensure the safety and quality of fresh-cut fruits and vegetables of Electron Beam irradiation is well established [1, 2, 3, 4,5]. Fruits and vegetables are highly nutritious and are very attractive owing to their characteristics of color, which is an important criterion for acceptance by consumers [6]. Research identified that the color of our environment affects our perception of quality and the most color choices are unconscious [7]. Light reflected from the products carries information used by consumers and inspectors who judge many quality aspects [8,9]. The attractive color on food indicates the flavor we will taste and appetite is stimulated in a direct reaction caused by color [7] .The quality and acceptance of products are associated with sensorial parameters such as color, texture and flavor. The preservation of these parameters influences the quality of the final product [6, 10] The vegetables quality is dictated by color parameters and changes induced by irradiation; such as discoloration and loss of firmness (softening) are affected with high doses [11] but sensory characteristics like color or crispiness were not affected by irradiation up to 2.0kGy [12].

2. Material and methods

Samples of collards greens (var. *acephala*) were supplied by Hydrofarm Manufacture at São Paulo city.

2.1 Sample preparation

Samples of whole kale were obtained and put into the isothermal box previously refrigerated with ice to maintain the temperature nearly 5ºC during the transportation. Stalks were removed, samples did not exceed 3.5 mm height and leafs of kale were sanitized, placed in a polyethylene bag and stored at refrigerated temperature (4 ± 1°C).

2.2 Irradiation

Samples were irradiated in ambient temperature at IPEN-CNEN Electron Accelerator, a Dynamitron Machine (Radiation Dynamics Co. Model JOB-188, New York, USA 0.5-1.5MeV and 0,3 – 25 mA), with1.5 MeV energy, and electrical current 0.31mA, scan 100 cm and support speed 6.72 m/min. Applied doses were 0 (control) 1.0, 1.5kGy with dose rate of 1,1kGy and density $1g \cdot cm^{-3}$.

2.3 Measurement of color / color analyses

Using a Hunter colorimeter model Color Quest XE (Hunter lab) color was measured in terms of “L” (lightness; 0 = dark and 100 bright), “a” (negative = greenness and positive = redness) and “b” (negative = blueness and positive = yellowness). The measuring aperture diameter was 25.4mm and $D_{65}/10^o$ was the illuminant / viewing geometry and calibrated with the standard black and white tiles. Color values for collards were measured on days 1, 3, 6 and 8.

2.4 Statistical analysis

Statistical analysis of the results was done using analysis of variance One-way ANOVA and was processed with *GraphPad Prism*, version 5.

3. Results

According to the analysis of variance, for values “a” (Table 1), the collards samples showed significant differences ($p<0.05$) between the days 1 to 3; 1 to 8 and 3 to 6. With the samples irradiated with doses of 1.0kGy, the differences happened between the days 1 to 6 and 1 to 8. Samples treated with 1.5kGy did not show significant differences, maintaining the green color.

No significant differences were observed for value “b” (Table 1), between control sample (0kGy) and irradiated sample with a dose of 1.5kGy, during the days 1 to 3 and 6 to 8; however, significant differences could be observed for the other days. Only the first day showed significant difference between the samples treated with 1.5kGy and the Control sample (0kGy).

Collard Green				
		Doses (kGy)		
Days	Values	0	1.0	1.5
	L	36,79 ± 0,57^{a}	36,48 ± 0,57^{ab}	37,59 ± 0,57^{ab}
1	a	-7,70 ± 010 ^{ab}	-7,54 ± 010 ^{a}	-7,71 ± 010 ^{ab}
	b	14,78 ± 0,47 ^{ab}	14,02 ± 0,47 ^{ab}	13,93 ± 0,47 ^{a}
	L	37,58 ± 1,22 ^{ab}	40,02 ± 1,22 ^{ab}	38,61 ± 1,22^{a}
3	a	-7,90 ± 0,08 ^{a}	-7,95 ± 0,08 ^{a}	-8,05 ± 0,08 ^{a}
	b	14,92 ± 0,40 ^{ab}	15,69 ± 0,40 ^{ab}	15,53 ± 0,40 ^{a}
	L	45,44 ± 1,17 ^{ab}	45,18 ± 1,17^{a}	43,30 ± 1,17 ^{ab}
6	a	-7,80 ± 0,29 ^{a}	-8,26 ± 0,29 ^{a}	-8,26 ± 0,29 ^{a}
	b	20,32 ± 0,56 ^{ab}	20,30 ± 0,56 ^{ab}	19,34 ± 0,56 ^{a}
	L	45,44 ± 1,17 ^{ab}	45,18 ± 1,17 ^{a}	43,30 ± 1,17 ^{ab}
8	a	-7,80 ± 0,29 ^{a}	-8,26 ± 0,29 ^{a}	-8,26 ± 0,29 ^{a}
	b	20,32 ± 0,56 ^{ab}	20,30 ± 0,56 ^{ab}	19,34 ± 0,56 ^{a}

Table. Values of *L, a* and *b* Collard green during different storage time.
Same letter are not significantly different ($p \leq 0,05$)

All the samples had significant differences to “L” values (Table 1). On the first day, the differences were between those treated with 1.0kGy and 1.5kGy. Similar differences were observed on the 3th day between the control samples and irradiated with 1.0kGy. From 6th to 8th days, only samples treated with 1.5kGy and control (0kGy) showed significant differences.

Analyzing the control sample and the samples treated with 1.0kGy and 1.5kGy, separately, significant differences could be seen in the control sample between the days 3 to 6, 1 to 6 and 1 to 8. For the irradiated samples with 1.0kGy, between the 6th and 8th days no significant differences were observed. Samples treated with 1.5kGy, from day 1 to 3 and from 6 to 8, there were not significant differences.

4. Discussion

Our results from color measurement could indicate that irradiation treatment did not cause changes between control and irradiated samples. Similar results were observed with skin apricot treated with doses under 1.0kGy [13]. Drake (1999) [14] treated pears and apples under 0.9kGy and did not observe any changes in these products. Papaya treated with 1.5kGy [15], ginseng and red ginseng treated at doses of 2.0, 8.0 and 16kGy [16] ,black pepper treated at doses of 2 to 16kGy [17], romain lettuce at doses of 0.5 and 1.0kGy [1], cantaloupe treated at doses 1.0kGy and 1.5kGy did not show color changes before and after the forth day of storage. All the irradiation treatment increased L value [18].

According to Han (2004) [1] ribs and leafs of Romain lettuce treated with 3.2kGy induced the loss of green pigmentation (increasing “a” value), accelerating the discoloration (increasing “b” value); vegetables became more yellowish, increasing darkening (decreasing “L” value), with more accentuated results for the ribs. Irradiated almonds at doses of 3.0, 7.0 and 10kGy became darker during storage and remained constant until the 8th week of storage

[19]. Blueberries exposed to 1.1kGy and 1.6kGy became darker after irradiation and the “L” values increased. The “a” and “b” values decreased in all samples, compared with the control at the end of storage [4]. Gomes (2008) [3] irradiated spinach leaves up to 1.0kGy showing that the color was not affected, however after 7 days, “b” value became significant higher (more yellowish), “a” value became lower (decrease of greenness), but no significant differences between the irradiated sample and control sample were observed in 15 days of storage.

Chlorophyll is the principal pigment in green plants and is easily degraded during processing [20]. It has been well established that chlorophylls are susceptible to chemical and physical changes during processing of vegetables [21]. The greenness degree, attributed to chlorophyll pigments, is important in determining the final quality of these kinds of vegetables [22].

Conclusion

In our study, under our conditions, color quality attribute of collards did not change when submitted to e-beam treatment, with doses of 1.0 and 1.5kGy, for the fresh product package, at controlled refrigerated temperature. No significant effects, due to the irradiation treatment, were observed in the color of the collards.

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