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ANALYSE OF TEXTURE IN BABY CARROT (*Daucus carota*) SUBJECTED TO THE PROCESS OF IONIZING RADIATION

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ABSTRACT

The carrot is a vegetable of great economic value due to its versatility in the food industry and can be used as raw or minimally processed vegetable or aggregating value to the product, transforming the fresh carrots in baby carrots. It is well known that the application of gamma radiation in food may help in maintaining the quality of food. The aim of this study was to analyze the effects of the low doses of ionizing radiation on texture of minimally processed baby carrot after the processing in a Multipurpose 60Co irradiator. It can be concluded that the treatment with low doses of gamma radiation keep the quality of fresh-cut baby carrot.

1. INTRODUCTION

The versatility for culinary meals and salads together with the benefits of compounds that benefit health as minerals, phytonutrients and dietary fibers make the carrot (*Daucus carota*) one of the most important constituents of salads worldwide [1,2]. A considerable number of papers have been directed for understanding the degradation of texture due the processes of conservation [1-20].

The combination of irradiation with minimum processing could improve the safety and qualit y of minimally processed vegetables and extend the self-life on the product [21]. It has been reported that gamma irradiation causes changes and injuries within the structure of plant tissues that can result in an increase of the dehydratation rates as observed in carrots, potatoes and apples. The microstructures indicated that the irradiated samples become less densely packed separated cells. The effect of gamma irradiation on the texture of plants was investigated and can occur as undesirable texture effects changes, like damage inside the tissue, loss of turgor pressure, being associated with the softening of vegetable tissues because of the degradation of polymers, as cellulose and pectin. It can occur loss of moisture conferring (leading hardness to plant tissue) during the storage too [7,11,22-35] .The aim of this research was to determine the effect gamma radiation in textural properties.

2. MATERIAL AND METHODS

2.1. Fresh raw material and storage conditions

Commercially prepared baby carrots were purchased in local market of São Paulo city. The carrots were stored at 5 °C ± 1.

2.2. Gamma radiation treatment

Samples of baby carrot were irradiated using a Multipurpose ^{60}Co Irradiator at Instituto de Pesquisas Energéticas e Nucleares-IPEN/CNEN (São Paulo, Brasil). The applied doses were 0, 3.0, 5.0 kGy with a mean dose rate of 4.5 kGy h^{-1}. Harwell Gammachrome YR Bath 64-530 nm dosimeters were used for the measurement of radiation dose. The irradiated and control samples (triplicate) were stored at 5 °C ± 1.

2.3.Texture measurement

The texture analyses were performed using entire samples with the samples horizontally positioned in a heavy duty place and readings were made in the middle of the sample. It was used a texturometer T.A.XT. Plus (Stable Micro System) with a load cell of 50 kg and speed was 1.5 mm s^{-1}. The puncture test was performed using the stainless steel probe (p/2) with 2 mm of diameter. Texture was the maximum force calculated (N) Resistance to the measuring penetration (mm fixed depth) imposed to the metal probe [36]. The reading was done in triplicate for each treatment with 30 readings per treatment.

2.4. Statistical analysis

The results were analyzed by analysis of variance (ANOVA) and mean comparison by Tukey test at 5 % significance in the statistical program *GraphPad Prism 5*.

3. RESULTS AND DISCUSSION

The effect of different irradiation doses about the mechanics properties of baby carrots are show in Figure 1

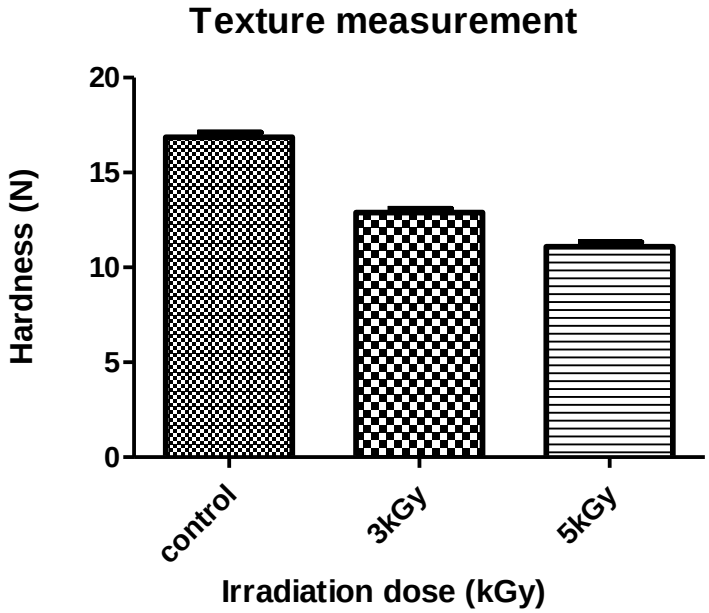

Figure 1. Variation of hardness with irradiation doses for carrot.

The hardness (maximum peak force during compression cycle (first expended to the first bite) and can be change by the term firmness) can be defined the mechanical property that is related to the energy expended on the bite. The statistical analysis showed that the irradiated samples showed significant differences ($p < 0.05$) compared to the control sample. The baby carrots showed reduction in hardness values with increasing doses of radiation, being in agreement with the results obtained by Hajare (2006), carrot samples irradiated with 2.0 kGy and noted that there was no significant difference in firmness after irradiation and also during storage in the central region; however in the peripheral region was significant difference after radiation. Some authours [11,12,14] reported that with increasing irradiation doses (up to 12 kGy) there was a decrease in texture (such as hardness, cohesiveness, springiness, gumminess and chewiness) demonstrating that the microstructures clearly intact and well defined cell wall of the control sample became less dense and separated by the application of the dose of 9.0 kGy, causing the softening of tissue. Analyzing the variation of the samples can be observed that the samples irradiated with 5.0 kGy required less work to rupture (Table 1).

Table 1. Texture values and percentage of loss of texture of baby carrots.

Samples	Texture measurement (N)	Loss of texture (%)
Control	16.85 ± 1.44^{a}	---
3.0 kGy	12.88 ± 1.13^{b}	24
5.0 kGy	11.09 ± 1.26^{c}	34

The force applied to measure the hardness of the samples obtained average values of 16.85, 12.88, 11.09 N for the control samples, 3.0 kGy and 5.0 kGy, respectively. There were

significant differences between samples. The sample of 3.0 kGy was reduced by 3.97 N, representing a 24 % reduction in texture over control sample. The sample of 5.0 kGy achieved a decrease of 5.76 N (34 % reduction) than the control sample. Among the samples irradiated with 3.0 kGy and 5.0 kGy it was a decreased of 1.79 from the sample of 3.0 kGy to 5.0 kGy (10 % of reduction). These values are in agreement with results reported by Rastogi (2006) which used the combined effect of gamma radiation and obtained 25 % of reduction in texture compared with the control sample of carrots. Rastogi (2005) found values close to the results obtained with a percentage reduction in texture of 24.36, 47.18, 63.33, 69.23 % for carrots samples of 3.0, 6.0, 9.0 and 12 kGy, respectively. The sample of 3.0 kGy achieved 24.36 % in the texture of the result being close to the 3.0 kGy sample obtained in the present. Nayak (2007) achieved a reduction of 34 % over the sample.

The exposure to gamma radiation results in the breakdown of cell structure intact in control samples that have defined cell walls, and after treatment turns into less densely packed cells with large cell space can be attributed to increasing doses of a softening of the samples [14]. In despite of the texture loss observed in this paper, previous data of sensory evaluation of baby carrots at 1kGy showed good acceptance by panelist.

3. CONCLUSIONS

It can be concluded that the treatment with low doses of gamma radiation keep the quality of fresh-cut baby carrot.

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REFERENCES

1. E. M. Goncalves, J. Pinheiro, M. Abreu, T. R. S. Brandao, C. L. M. Silva, "Carrot (*Daucus carota* L.) peroxidase inactivation, phenolic content and physical changes kinetics due to blanching", *Journal of Food Engineering,* **97,** pp.574-581 (2010).

2. S. N. Hajare, V. S. Dhokane, R. Shashidhar, A. Sharma, J. R. Bandekar, "Radiation Processing of Minimally Processed Carrot (*Daucus carota*) and Cucumber (*Cucumis sativus*) to Ensure Safety: Effect on Nutritional and Sensory Quality", *Journal of Food Science*, **71**, pp.198-203 (2006).

3. X. I. T. Araya, M. Hendrickx, B. E. Verlinden, S. V. Buggenhout , N. J. Smale , C. Stewart , A. J. Mawson, "Understanding texture changes of high pressure processed fresh carrots: A microstructural and biochemical approach", *Journal of Food Engineering,* **80**, pp.873-884 (2007).

4. N. Belie, “Use Of Physico-Chemical Methods For Assessment Of Sensory Changes In Carrot Texture And Sweetness During Cooking”, *Journal of Texture Studies,* **33**, pp.367-388 (2002).

5. Z. K. Brown, P. J. Fryer, I. T. Norton, S. Bakalis, R. H. Bridson “Drying of foods using supercritical carbon dioxide — Investigations with carrot”, *Innovative Food Science and Emerging Technologies*, **9**, pp. 280-289 (2008).

6. S. V. Buggenhout, D. N. Sila, T. Duvetter, A. Van Loey, and M. Hendrickx “Pectins in Processed Fruits and Vegetables: Part III—Texture Engineering”, *Comprehensive Reviews In Food Science And Food Safety*, **8**, pp.105-117 (2009).

7. M. A. Chaudry, N. Bibi, M. Khan, M. Khan, A. Badshah, M. J. Qureshi “Irradiation treatment of minimally processed carrots for ensuring microbiological safety”, *Radiation Physics and Chemistry*, **71**, pp.169-173 (2004).

8. R. G. Klaiber, S. Baur, G. Wolf , W. P. Hammes, R. Carle “Quality of minimally processed carrots as affected by warm water washing and chlorination”, *Trends Innovative Food Science and Emerging Technologies*, **6**, pp.351-362 (2005).

9. G. Knockaert, A. D. Roeck, L. Lemmens, S. V. Buggenhout, M. Hendrickx, A. V. Loey, “Effect of thermal and high pressure processes on structural and health-related properties of carrots (*Daucus carota*)”, *Food Chemistry*, **125**, pp.903-912 (2011).

10. L. Lemmens, I. Colle, G. Knockaert, S. V. Buggenhout, A. V. Loey, M. Hendrickx, “Influence of pilot scale in pack pasteurization and sterilization treatments on nutritional and textural characteristics of carrot pieces”, *Food Research International*, **xxx,** pp.xxx-xxx (2011).

11. C. A. Nayak, K. Suguna, N. K. Rastogi “Combined effect of gamma-irradiation and osmotic treatment on mass transfer during rehydration of carrots”, *Journal of Food Engineering*, **74**, pp.134-142 (2006).

12. C. A. Nayak , K. Suguna , K. Narasimhamurthy , N. K. Rastogi, “Effect of gamma irradiation on histological and textural properties of carrot, potato and beetroot”, *Journal of Food Engineering*, **79**, pp.765-770 (2007).

13. L. Neri, I. Hernando, I. Perez-Munuera, G. Sacchetti, P. Pittia, “Effect of Blanching in Water and Sugar Solutions on Texture and Microstructure of Sliced Carrots”, *Journal of Food Science*, **76(1)**, pp.E24-30 (2011).

14. N. K. Rastogi, “Impact of gamma-irradiation on some mass transfer driven operations in food processing”, *Radiation Physics and Chemistry*, **73**, pp.355-361 (2005).

15. N. K. Rastogi, K. Suguna, C. A. Nayak, K. S. M. S. Raghavarao, “Combined effect of gamma irradiation and osmotic pretreatment on mass transfer during dehydration”, *Journal of Food Engineering*, **77**, pp.1059-1063 (2006).

16. N. K. Rastogi, L. T. Nguyen, V. M. Balasubramaniam, "Effect of pretreatments on carrot texture after thermal and pressure-assisted thermal processing", *Journal of Food Engineering*, **88**, pp.541-547 (2008).

17. D. Rico, A. B. Martın-Diana, J. M. Barat, C. Barry-Ryan, "Extending and measuring the quality of fresh-cut fruit and vegetables: a review", *Trends in Food Science & Technology*, **18**, pp**.**373-386 (2007).

18. A. D. Roeck, D. N. Sila, T.Duvetter, A. V. Loey , M. Hendrickx, "Effect of high pressure/high temperature processing on cell wall pectic substances in relation to firmness of carrot tissue", *Food Chemistry*, **107**, pp**.**1225-1235 (2008).

19. D. Roeck, J. Mols, T. Duvetter, A. V. Loey, M. Hendrickx, "Carrot texture degradation kinetics and pectin changes during thermal versus high-pressure/high-temperature processing: A comparative study", *Food Chemistry*, **120**, pp.1104-1112 (2010).

20. N. Sila, T. Duvetter, A. D. Roeck, I. Verlent, C. Smout, G.K. Moates, B. P. Hillsb, K. K. Waldronb, M. Hendrickxa, A. V. Loe "Texture changes of processed fruits and vegetables: potential use of high-pressure", *Processing Trends in Food Science & Technology*, **19**, pp.309-319 (2008).

21. C. G. Martins, J. H. Behrens, M. T. Destro, B. D. G. M. Franco, D. M. Vizeu, B. W. Hutzler, M. Landgraf, "Gamma radiation in the reduction of *Salmonella* spp. inoculated on minimally processed watercress (*Nasturtium officinallis*)", *Radiation Physics and Chemistry*, **71**, pp.89-93 (2004).

22. N. El-Assi, D. J. Huber, J. K. Brecht, "Irradiation induced changes in tomato fruit and pericarp firmness, electrolyte efflux, and cell wall enzyme activity as influenced by ripening stage", *Journal of American Society Horticultural Science*, **122**, pp.100-106 (1997).

23. R. E. Glegg, Z. I. Kertesz, "After effect in the degradation of cellulose and pectin by gamma rays", *Science*, **124**, pp.893-894 (1956).

24. R. E. Glegg, "The influence of oxygen and water on the after-effect on cellulose degradation by gamma rays", *Rad Res*, **6**, pp.469-73 (1957).

25. R. E. Glegg, Z. I. Kertesz, "Effect of gamma radiation on cellulose", *Journal Polymer Science*, **26**, pp.289-297 (1957).

26. L. R. Howard, G. H. J. Miller, A. B. Wagner, "Microbiological, chemical and sensory changes in pico de gallo", *Journal of Food Science*, **60**, pp.461-464 (1995).

27. Z. I. Kertesz, R. E. Glegg, F. P. Boyle, G. F. Parsons, J. R. Massey, "Effect of ionizing radiation on plant tissues. III. Softening and changes in pectin and cellulose of apples, carrots, and beets", *Journal of Food Science*, **29**, pp.40-48 (1964).

28. B. B. Mishra, S. Gautam, A. Sharma, "Shelf-life extension of fresh ginger (*Zingiber officinale*) by gamma irradiation", *Journal of Food Science*, **69(9)**, pp.274-279 (2004).

29. F. J. McArdle, J. V. Nehemias, "Effects of gamma irradiation on pectic constituents of fruits and vegetables", *Food Technology*, **10**, pp.599-601 (1956).

30. N. K. Rastogi, K. S. M. S. Raghavarao, "Increased mass transfer during osmotic dehydration of irradiated potatoes", *Journal of Food Science*, **69(6)**, pp.E259-E263 (2004a).

31. N. K. Rastogi, C. A. Nayak, K. S. M. S. Raghavarao, "Influence of osmotic pretreatments on rehydration characteristics of carrots", *Journal of Food Engineering*, **65(2)**, pp.287-292 (2004b).

32. L. P. Somogyi, R. J Romani, "Irradiation induced textural changes in fruits and its relation to pectin metabolism", *Journal Food Science*, **29**, pp.366-371 (1964).

33. J. Wang, Y. Chao, "Drying characteristics of irradiated apple slices", *Journal of Food Engineer*, **52**, pp.83-88 (2002).

34. J. Wang, Y. Chao, "Effect of ^{60}Co irradiation on drying characteristics of apple", *Journal of Food Engineering*, **56**, pp.347-351 (2003a).

35. J. Wang, Y. Chao, "Effect of gamma irradiation on quality of dried potato", *Radiation Physics and Chemistry*, **66**, pp.293-297 (2003b).

36. M. C. Bourne, "Texture profile analysis", *Food Technology*, **32(7)**, pp.62-66 (1978).

37. T. C. F. Nunes, V. D. Rogovschi, A. D. T. Fabbri, S. F. Sabato, "Evaluation of ensorial Properties of Baby Carrots (*Daucus Carota*) Treated By Ionizing Radiation", *Radiation Physics and Chemistry*, submitted (2011).