Radiation Physics and Chemistry 99 (2014) 79–85

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Improving microbiological safety and maintaining sensory and nutritional quality of pre-cut tomato and carrot by gamma irradiation

Cs. Mohácsi-Farkas [a,*], B. Nyirő-Fekete [a], H. Daood [b], I. Dalmadi [c], G. Kiskó [a]

[a] Department of Microbiology and Biotechnology, Faculty of Food Science, Corvinus University of Budapest, Somlói út 14-16, H-1118 Budapest, Hungary
[b] Szent István University, Regional Knowledge Centre, Páter K. utca 1, H-2100 Gödöllő, Hungary
[c] Department of Refrigeration and Livestock Products' Technology, Faculty of Food Science, Corvinus University of Budapest, Ménesi út 43-45, H-1118 Budapest, Hungary

HIGHLIGHTS

- 1 kGy dose improves sufficiently the microbial safety of pre-cut tomato and carrot.
- Low-dose radiation treatment eliminates *Listeria monocytogenes* from pre-cut produce.
- 1 kGy dose does not diminish significantly the organoleptic quality.
- Low-dose irradiation causes tolerable losses even in the most sensitive vitamins.

ARTICLE INFO

Article history:
Received 5 September 2013
Accepted 22 February 2014
Available online 4 March 2014

Keywords:
Low-dose irradiation
Pre-cut produce
Microbiological safety
Antioxidant vitamins

ABSTRACT

Pre-cut tomato and carrot were irradiated with doses of 1.0, 1.5 and 2 kGy. Unirradiated control and irradiated samples were compared organoleptically by a sensory panel. Microbiological analyses were performed directly after irradiation and during post-irradiation storage for 8 days at 5 °C. Ascorbic acid contents, composition of carotenoids and tocopherols were determined. Statistically significant differences of sensory scores between unirradiated and irradiated samples were observed only in the texture of sliced carrots. Total aerobic viable cell counts have been reduced by about two log cycles with 1.5 kGy dose. Total coliforms and moulds were below the detection limit of 15 CFU/g in the irradiated samples during the refrigerated storage. Yeasts were relatively resistant part of the microbiota of pre-cut tomatoes, but 2 kGy dose reduced them below the detection limit. In pre-cut tomatoes, alpha-tocopherol and some carotenoids seemed to be the most radio-sensitive losing approximately one-third of their original concentrations at the dose of 2 kGy. At this dose tocopherols and the level of ascorbic acid decreased also one-third of the initial level in sliced carrots. Additional experiments were conducted to study the effect of irradiation and storage on the population of *Listeria monocytogenes* and *Listeria innocua* artificially inoculated on cut tomato and carrot. Cell numbers of both test organisms decreased by at least two log-cycles as an effect of 1 kGy dose. Our studies confirmed earlier findings on a temporary antilisterial effect of freshly cut carrot tissue. No re-growth of *Listeria* was observed during the studied storage period. The results of these studies suggest that irradiation with 1 kGy gamma rays could improve sufficiently the microbiological safety of the investigated pre-cut produce to satisfy the requirement of low microbial raw diets with acceptable nutritional quality and without diminishing significantly the organoleptic parameters of the commodities.

1. Introduction

During recent decades a growing concern over produce-associated foodborne illnesses could be noted (Sivapalasingam et al., 2004), thus a need for new tools to ensure safety of fresh and fresh-cut produce became evident (SCF, 2002; Niemira and Fan, 2006). The currently used treatments such as washing, chemical disinfection or warm water dips are not particularly effective in reducing bacterial populations, as they are embedded in biofilms or shielded inside "microniches".

According to an Information Statement of the Institute of Food Science and Technology (IFST, 2006) "irradiation, carried out under conditions of Good Manufacturing Practice, is commended as an effective, widely applicable food processing method judged to be safe on extensive available evidence, that can reduce the risk of

* Corresponding author.
E-mail address: csilla.farkas@uni-corvinus.hu (Cs. Mohácsi-Farkas).

http://dx.doi.org/10.1016/j.radphyschem.2014.02.019
0969-806X © 2014 Published by Elsevier Ltd.

food poisoning, control food spoilage and extend the shelf life of foods without detriment to health and with minimal effects on nutritional and sensory quality." These properties of food irradiation give a high application potential, particularly for an ever growing population of consumers with weakened immunity.

Because health care trends have moved away from stringent sterile diet towards clean (low microbial count) diet, our intention is to investigate the use of low dose irradiation to minimize the risk of foodborne diseases to an acceptable level without completely eliminating the microbiota. Experiments show that *Listeria monocytogenes*, an environmental contaminant, is among the most radiation resistant non-sporeforming pathogenic bacteria (Farkas, 1998; Horak et al., 2006). In addition, *L. monocytogenes*' ability to grow at refrigerated temperatures is of great concern for fresh-cut produce.

As part of an FAO-IAEA coordinated research programme on "The developments of irradiated foods for immuno-compromised patients and other potential target groups", we are studying the technological feasibility of ionizing radiation to increase the variability, availability and acceptability of foods for immuno-compromised consumers. In the present paper we report on studying the effects of gamma irradiation on two representatives of fresh produce; pre-cut tomatoes and carrots.

2. Materials and methods

2.1. Source of fresh commodities and preparation of experimental batches

Fresh red mature tomatoes (pH 4.0 ± 0.2) and carrots (pH 4.9 ± 0.3) were purchased at the local market. Sample preparation and radiation processing were performed on the same day. After washing with tap water, tomatoes were diced into segments of 2–3 cm while carrots were peeled and sliced into pieces with thickness of 3–4 mm. Approximately 100 g portions of pre-cut produce were placed aerobically in plastic containers covered by plastic lid.

2.2. Radiation treatment and storage conditions

Pre-cut produce were irradiated at 12 °C with doses of 1.0 kGy, 1.5 kGy, and 2.0 kGy at a dose rate of 6.12 kGy/h by a ^{60}Co irradiator in the AGROSTER Co., Ltd., Budapest. All samples were transported to the radiation facility and back to the laboratory in coolers. Irradiated and unirradiated fresh-cut produce were stored in a refrigerator at 5 °C for up to 8 days.

2.3. Estimation of sensorically acceptable radiation dose

Unirradiated control and irradiated experimental batches were analysed sensorically by 15 untrained panelists directly after the radiation treatment. Sensory testing was carried out at a regular kitchen in normal day-light. Panelists received refrigerated samples (approx. 100 g) in transparent plastic containers. Colour, odour, taste and texture were scored using a nine-score preference-scale (from score (9) as excellent to score (1) as non-marketable). Beyond calculating mean scores, the results of organoleptic testing were ranked and evaluated statistically by Kramer's method. This statistical method is especially suitable where actual values are not meaningful – for example, in evaluations of sensory data when it may be more convenient to rank series of samples in order of preference or difference. The method is based on the expansion of the multinomial distribution, using the treatment designation as terms of the multinomial, and number of replications as the power (Kramer, 1960).

2.4. Analysis of carotenoids, tocopherols and ascorbic acid

Ascorbic acid content was estimated in unirradiated and 1 kGy treated samples, while analyses for carotenoids and tocopherols were performed with unirradiated and 2 kGy irradiated samples. Irradiated and control samples were stored frozen until the investigation.

2.4.1. Instrument

A Waters Alliance chromatograph consisting of a separation module (gradient pump and auto sampler, Model 2695), a photodiode-array detector (Model 2996) and a fluorescent detector (Model 2675) was used for HPLC analysis. "Empower" Software was applied for operating the chromatograph.

2.4.2. Analysis of carotenoids

Extraction of pigments started with disintegration of 5 g of tomato samples and 3 g of carrot samples in a crucible mortar in the presence of quartz sand, followed by removal of water with 20 mL methanol. The mixture was then transferred to an Erlenmeyer flask. The residues were dissolved in 50 mL of 1:5 methanol–1,2-dichloroethan, collected with the previous extract and mechanically shaken for 15 min. The methanolic phase was separated from the less polar 1,2-dichloroethan by adding 2 mL of doubly distilled water. The pigment-containing solvent was dehydrated over anhydrous Na_2SO_4 and evaporated to dryness under vacuum. The residues were re-dissolved in HPLC grade acetone. After filtration through a filter paper and a PTFE 0.45 μm syringe filter, the clear solution was injected into the HPLC coloumn (Biacs and Daood, 1994). Separation of carotenoids was performed on Nucleodur ISIS, 3 μm, 15 cm × 4.6 mm coloumn

Table 1
Sensory testing of pre-cut irradiated produce.

Radiation dose (kGy)	Score means								Rank sums			
	Colour		Odour		Taste		Texture		Colour	Odour	Taste	Texture
					Tomato							
0	7.87	± 1.13	7.20	± 1.97	7.13	± 2.10	7.13	± 1.85	27.00	24.50	23.00	25.50
1	7.60	± 1.60	6.27	± 2.22	5.60	± 2.16	6.60	± 1.40	31.50	30.00	34.00	32.50
2	7.60	± 0.99	6.13	± 2.56	5.67	± 2.85	6.73	± 1.44	31.50	35.50	33.00	32.00
					Carrot							
0	7.87	± 1.06	6.73	± 2.63	7.47	± 1.19	8.07	± 1.22	25.00	27.50	23.50	19.00
1	7.07	± 1.20	7.47	± 1.51	6.60	± 1.99	6.80	± 1.37	32.00	26.50	31.50	31.00
2	7.27	± 1.91	6.27	± 2.55	6.07	± 2.40	6.00	± 1.60	33.00	36.00	35.00	40.00[a]

[a] Rank sums within the range 22–38 are not significantly different at $\alpha \leq 0.01$ probability level (Kramer, 1960).