

## Radiation effects on vitamin A and $\beta$ -carotene contents in liver products

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**Abstract** The movement toward commercialization of the process and the recent actions of various governmental agencies to accept irradiated foods as wholesome, even when high doses are applied has stimulated increased interest in this treatment. Concern for the fate of vitamins when foods are irradiated is almost entirely centered on maintenance of their biological function as essential nutrients. The aim of this work was to assess the effects of ionizing radiation on vitamin A and  $\beta$ -carotene contents in commercialized food products of animal origin, specifically fresh bovine liver and pork *pâté de foie*. As present Brazilian legislation has no restriction of dose limits to be applied on foods, the  $^{60}\text{Co}$  gamma irradiation doses for these experiments were 3 kGy and 30 kGy. The results show a full retention of vitamin content when the applied dose was 3 kGy and a loss of about 60% when the dose was 30 kGy. When applying high doses, it would be necessary to consider this content reduction and proceed to a vitamin supplement when necessary.

**Key words** vitamin A •  $\beta$ -carotene • ionizing radiation

### Introduction

The principal interest in treating foods with ionizing radiation is to ensure their preservation. This can involve inactivation of several kinds of microorganisms that may contaminate foods and cause spoilage and also food borne pathogens. Another purpose in irradiating foods is to secure decontamination or disinfestation with regard to bacteria, yeasts, molds and insects or to produce a chemical change in the food itself when such change improves some characteristics of the food or its processing [15].

Macronutrients in irradiated foods undergo little change, and as a consequence, the normal nutritional values of proteins, lipids and carbohydrates of foods are maintained [16–18]. Vitamins have varying sensitivity to radiation treatments and are the only components of foods that need to be considered from a dietary impact standpoint. Like thermal treatments, radiation processing of foods can cause some loss of vitamins. Work summarized in some reviews has shown that some vitamins are quite insensitive to ionizing radiation, whereas others are rather radiation sensitive. Among fat-soluble vitamins, authors consider the ranking of sensitivities the following: vit E, carotene, vit A, vit D and vit K from most sensitive to least sensitive [18]. However, many factors influence the radiation resistance of a vitamin, such as the composition of the food under consideration, the packaging atmosphere, and the temperature during irradiation and post-irradiation storage. On the other hand, a mutual protection is exerted when different substances are irradiated together. This is the case of most foodstuffs that consist of a great number of compounds [2].

The lack of vitamin A in diet can cause xerophthalmia, ceratomalacia, blindness and death [10]. Beta-carotene is

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known to exhibit antioxidant properties and is referred to as one of the antioxidant vitamins, even though  $\beta$ -carotene is not, strictly speaking, a vitamin but a provitamin that converts in the body to vitamin A as needed. The capability is also known of antioxidant vitamins to protect against radiation damage [13]. Concomitantly, a rapidly growing body of animal, epidemiological and clinical intervention studies support the hypotheses that antioxidant vitamins protect the body against certain types of cancer, cardiovascular disease, cataracts, arthritis, diabetes and Alzheimer's disease [3, 6, 10]. On the other side, the fact that carotenoids can act whether as antioxidants or pro-oxidants in some conditions had been reported [4, 11].

Food sources of vitamin A for man include the actual vitamin A (retinol) stored mainly in animal liver and the provitamin A carotenoids (primarily  $\beta$ -carotene) of vegetal origin. In both cases carotenoids are the original source of vitamin A. While vitamin A and the provitamin A carotenoids are essentially equivalent nutritionally, their radiation chemistry is not necessarily the same [15].

Foods are irradiated to prevent food borne diseases with doses in the cold pasteurization range (up to 5 kGy). On the other hand, higher doses are required for radiation sterilization of food, for instance, for immune-compromised hospital patients or to obtain shelf-stable meat products (10–70 kGy).

The effect of radiation on vitamins is greatly dependent on the environment in which the vitamin exists. The aim of this work was to assess the effects of ionizing radiation on vitamin A and  $\beta$ -carotene contents in commercialized food products of animal origin, specifically fresh bovine liver and pork *pâté de foie*. As the present Brazilian legislation has no restriction of dose limits to be applying on foods [8], the doses chosen for these experiments were 3 kGy and 30 kGy.

## Materials and methods

### Materials

Six different lots of bovine liver samples weighing each 100 g were obtained at the meat market and kept frozen. Similarly, six different lots of industrialized pork liver *pâté* weighing 100–125 g each kept at a refrigerator (about 7°C) were employed. According to the producer, the *pâté* content was: 9.3% proteins, 20% fats, 63% water, 2% salt, 3% starch. It also contained the usual stabilizers, antioxidants and flavors.

### Irradiation

A panoramic  $^{60}\text{Co}$  gamma radiation source (Yoshigawa Kiko Ltd was employed for irradiation at a dose of 3 kGy for both bovine liver and *pâté de foie* samples. The dose rate was about 0.7 kGy/h at a distance of 10 cm from the source. The irradiation of the bovine liver samples started at  $-15^\circ\text{C}$  and ended at about  $4^\circ\text{C}$ . On the other hand, irradiation of *pâté de foie* samples started at  $7^\circ\text{C}$  and ended at about  $20^\circ\text{C}$ . For the second part of the experiments, irradiation of *pâté de foie* samples was performed with a dose of 30 kGy using a  $^{60}\text{Co}$  gamma radiation source Gammacell 220 (AECL), dose rate 7.7 kGy/h. Dosimetric

measurements were previously performed using Fricke dosimetry.

### Beta-carotene and vitamin A analysis

For vitamin A activity determination methods based on spectrophotometric measurements are considered quite adequate [1]. In this case samples of bovine liver and *pâté de foie* weighing 2–5 g were used. The Carr-Price photometric method described by Strohecker and Henning [14] and adopted by Instituto Adolfo Lutz [5] based on absorbance reading at 620 nm of the blue solution obtained with  $\text{SbCl}_3$  in chloroform was employed. A saponification with KOH in absolute ethanol was followed by a petroleum ether extraction. The extracts were washed with distilled water until free of alkali. Aliquots of the extracts were transferred to spectrophotometer cells and evaporated under nitrogen. The samples were dissolved in 3 ml chloroform, added 3 drops of acetic anhydride and 7 ml of Carr-Price reagent (25% w/v  $\text{SbCl}_3$  chloroform solution). The calibration curve was prepared using vitamin A acetate from 10–50 International Units (IU), being  $1\text{ g} = 2.8 - 2.9 \times 10^6$  IU [14].

The determination of  $\beta$ -carotene employs the yellow color measurement of its solution in organic solvents. The spectrum of  $\beta$ -carotene is characterized by two peaks of maximum absorbance whose location can vary depending of the solvent [14]. The petroleum ether extracted samples were measured directly at 447–451 nm. The results were expressed as IU (1 gram of  $\beta$ -carotene =  $1.6 \times 10^6$  IU of vitamin A). Beta-carotene measurements were not possible in *pâté de foie* samples because the corresponding petroleum ether extracts remained uncolored.

## Results and discussion

Carotenoid retention and vitamin A values are dependent on the method applied for food processing. A retention ranging from 89.1 to 56.0% for carotenoid content in carrot was found when raw shredded, steam cooking, water cooking with pressure, water cooking without pressure and moist/dry cooking were compared [12]. On the other hand, Getoff and colleagues established the transients and cooperative action of beta-carotene, vitamin E and C in biological systems *in vitro* under irradiation [4].

For practical purposes, the radiation sensitivity of vitamin A and  $\beta$ -carotene are described adequately by the retention of their activities in the assayed conditions. Experimental data of vitamin A and  $\beta$ -carotene contents as well as the retention percentage after irradiation with a dose of 3 kGy from bovine liver samples is shown in Table 1. In both cases, the total content was preserved in spite of quite different values of vitamin A and  $\beta$ -carotene contents found among different samples.

Table 2 presents the results of vitamin A content determinations of the pork liver product when irradiated with a dose of 3 kGy. Also in this case, the vitamin A content remained unchanged before and after irradiation. The results from the experiments with the application of a considered sterilizing dose, 30 kGy, are presented in Table 3. In this case, a loss of about 60% of vitamin A activity was found in the irradiated samples.

**Table 1.** Mean and standard deviation of vitamin A and  $\beta$ -carotene content from unirradiated (0 kGy) and irradiated (3 kGy) bovine liver samples and retention % (vit A – 12 replications,  $\beta$ -carotene – 24 replications).

	Vitamin A (I.U./100 g)	$\beta$ -Carotene (I.U./100 g)
0 kGy	88.717 $\pm$ 54.985	12.526 $\pm$ 15.441
3 kGy	93.691 $\pm$ 57.213	12.390 $\pm$ 16.638
Retention (%)	106 $\pm$ 8	98 $\pm$ 21

**Table 2.** Mean and standard deviation of vitamin A content from unirradiated (0 kGy) and irradiated (3 kGy) pork *pâté de foie* samples and retention % (6 replications).

	Vitamin A (I.U./100 g)		Retention (%)
0 kGy	3 kGy		
12.208 $\pm$ 1.720	13.000 $\pm$ 1.755		107 $\pm$ 9

**Table 3.** Mean and standard deviation of vitamin A content from unirradiated (0 kGy) and irradiated (30 kGy) pork *pâté de foie* samples and retention % (6 replications).

	Vitamin A (I.U./100 g)		Retention (%)
0 kGy	30 kGy		
11.088 $\pm$ 844	4.369 $\pm$ 912		39.4 $\pm$ 12

In foods, radiation-induced losses of vitamin A and provitamin carotenoids were described in varying degrees in different environments. In general, when vitamins are exposed to levels of irradiation sufficient to cause some losses due to destruction, this is because bonds are broken in the vitamin molecules themselves, which produces inactive vitamin fragments. Additionally, antioxidant vitamins can combine with free radicals and lose their vitamin activity, or free radicals and their products can attack and destroy vitamin structure or activity [9].

There are few experiments described so far in the literature using similar products. When pork liver was irradiated with a dose of 5 kGy at 0°C a 4% loss was found after a week. After 4 weeks a loss of 13% was found [7]. In similar conditions *pâté de foie* has showed losses of 10% and 18%, respectively [1]. Other authors described a vitamin A loss of 16% from chicken meat irradiated with 59 kGy at -25°C when compared with the frozen sample [2].

The present results have shown that loss of vitamin A occurred only when irradiation took place at very high dose (30 kGy) while maintaining as close as possible normal commercial conditions. It means that for the 3 kGy dose, no radiation-induced processes involved could be manifested by a reduction of vitamin A content. As liver products are an important source of vitamin A in human diet, these results permit to conclude that liver products could be irradiated without nutritional restraint using a cold pasteurization dose. When applying higher dose, it would be necessary to consider a content reduction and proceed to a vitamin supplement when necessary.

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