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Effects of irradiation on *trans* fatty acids formation in ground beef

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Abstract

In order to give the consumer the assurance that meat processed by irradiation is a safe product, a great deal of research has been developed in the world. The effect of irradiation on the hygienic quality of meat and meat products is considered as related to the control of meat-borne parasites of humans; elimination of pathogens from fresh meat and poultry; and elimination of pathogens from processed meat. Lipid oxidation and associated changes are the major causes of the quality deterioration of meat during storage. Irradiation of lipids induces the production of free radicals, which react with oxygen, leading to the formation of carbonyls, responsible for alterations in food nutritional and sensorial characteristics. *Trans* fatty acids are present in ground beef and can also be formed during its processing. Interestingly, the *trans* fatty acids, due to their chemical and physical characteristics, show more resistance to the oxidizing process. This property motivated us to investigate the level of the *trans* fatty acids, as well as the level of oxidation in irradiated ground beef. Irradiation of ground beef was performed by gamma rays from a ^{60}Co source. The applied radiation doses were 0; 1.0; 2.0; 3.0; 4.0; 5.0; 6.0; 7.0 and 8.0 kGy. Lipid peroxidation in terms of TBA number and carbonyl content was monitored during storage. The sample characteristics and *trans* fatty acids composition were measured, following irradiation and after 60 and 90 days of storage at –10°C. © 2002 Published by Elsevier Science Ltd.

Keywords: Gamma-radiation; Lipids; Ground meat; Irradiated food

1. Introduction

Among the existing technologies for food preservation, irradiation of food is recognized as a safe and effective method for a range of specific applications. Ionizing radiation uses the high energy of gamma rays or accelerated electrons, thereby ionizing molecules. The use of this treatment on fresh meat could extend shelf life and protect the host against pathogenic bacteria. On the other hand, irradiation treatment brings about some biochemical changes that could affect the nutritional adequacy of food (Giroux and Lacroix, 1998).

Typical composition of ground beef is about 18% lipids and its fatty acids content is divided into 46% saturated, 51% mono-unsaturated and 3% poly-unsaturated (Johnson et al., 1994).

Some of the fatty acids found in meat play important roles in metabolism. Recent interest in *trans* fatty acids (TFAs) was sparked off by epidemiological evidence linking *trans* fatty acids to higher plasma total cholesterol and low-density-lipoprotein (LDL) cholesterol and increased the incidence of coronary heart disease (CHD) (Fritsche et al., 1988).

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The present study investigated the level of the *trans* fatty acids, as well as the level of oxidation, in irradiated ground beef.

2. Experimental

2.1. Samples

Samples of ground beef were purchased locally in São Paulo, Brazil.

2.2. Irradiation

Irradiation took place in a ^{60}Co Gammacell 220 (A.E.C.L.) installed in Instituto de Pesquisas Energéticas e Nucleares (IPEN)- São Paulo, Brazil. The applied radiation doses were 0, 1, 2, 3, 4, 5, 6, 7 and 8 kGy with a dose rate of 5.8 kGy/h. The samples were irradiated at 25°C (room temperature).

2.3. Lipid analysis

After irradiation the fatty acids of ground beef were extracted according to Folch et al., 1957. The extraction was done after 60 and 90 days of storage, in order to verify the effects of storage time upon the fatty acids level.

2.4. Trans fatty acids analysis

The fatty acid composition was determinated on the lipid extracts after methylation with sulfuric acid and ammonium chloride (Hartman and Lago, 1973). The fatty acid methyl esters (FAME) were analyzed using a CG-500 chromatograph, equipped with fused silica capillary column SP-2560 (100 m, 0.25 mm) and flame ionization detector (FID). Nitrogen was used as the carrier gas. Thermal gradient ranged from 150 to 230°C at 6°C/min. Injector and FID temperature was 250°C. Heptadecanoic acid (C17, Sigma) was added to all samples as an internal standard before the preparation of FAME.

2.5. Statistical analysis

Statistical analysis was developed using a GraphPad Instat, 2.01 version, GraphPad Software.

3. Results and discussion

The major components of lipids from ground beef usually are triacylglycerides and glycerolphospholipids (phospholipids) that may be accompanied by sterols and their esters, fatty acids, sphingolipids, hydrocarbons, etc. Fatty acids range from C12 to C24 in chain length. C16 palmitic acid usually is the major saturated fatty acid, and oleic C18:1 and linoleic C18:2 are the major unsaturated fatty acids.

The fatty acids composition after different storage time for each irradiation doses is presented in Tables 1–3. The main *trans* fatty acid group in ground beef is 18:1. The above results for 18:2 support the observation of Scholfield et al. (1963), that the irradiation observation of the *trans* bond in a poly-unsaturated system is suppressed by the other *cis* and *trans* ethylenic bonds in the molecule.

Table 1
Fatty acid composition of non-irradiated ground beef

Fatty acids	0 days	60 days	90 days
14:00	2.53±0.19	2.34±0.19	2.53±0.19
16:00	25.34±0.09	25.2±0.09	25.18±0.09
18:00	7.28±0.10	7.24±0.10	7.44±0.10
Saturated fatty acid	35.15±0.21	34.78±0.21	35.15±0.21
16:01	1.91±0.04	1.88±0.04	1.82±0.04
18:1 n-9	37.07±0.36	36.77±0.36	36.34±0.36
18:2 n-6	23.09±0.56	24.06±0.56	24.08±0.56
18:3 n-3	0.95±0.03	0.92±0.03	0.89±0.03
20:3 n-6	0.53±0.02	0.52±0.02	0.49±0.02
20:4 n-6	0.62±0.02	0.58±0.02	0.57±0.02
22:5 n-6	0.39±0.05	0.31±0.05	0.31±0.05
22:6 n-3	0.29±0.03	0.29±0.03	0.35±0.03
Unsaturated fatty acid	64.85±0.28	65.33±0.28	64.85±0.28

Table 2
Fatty acid composition of ground beef at 4 kGy

fatty acids	0 days	60 days	90 days
14:00	2.43 ± 0.09	2.34 ± 0.09	2.53 ± 0.09
16:00	25.34 ± 0.08	25.2 ± 0.08	25.18 ± 0.08
18:00	7.68 ± 0.22	7.24 ± 0.22	7.44 ± 0.22
Saturated fatty acid	35.45 ± 0.33	34.78 ± 0.33	35.15 ± 0.33
16:01	1.98 ± 0.35	1.98 ± 0.35	1.92 ± 0.35
18:1 n-9	35.57 ± 0.40	34.77 ± 0.40	35.04 ± 0.40
18:2 n-6	20.29 ± 0.13	20.06 ± 0.13	20.08 ± 0.13
18:3 n-3	0.99 ± 0.00	0.99 ± 0.00	0.98 ± 0.00
20:3 n-6	0.57 ± 0.04	0.52 ± 0.04	0.49 ± 0.04
20:4 n-6	0.75 ± 0.10	0.58 ± 0.10	0.57 ± 0.10
22:5 n-6	0.29 ± 0.02	0.31 ± 0.02	0.27 ± 0.02
22:6 n-3	0.19 ± 0.02	0.19 ± 0.02	0.15 ± 0.02
Others	3.92 ± 0.99	5.82 ± 0.99	5.35 ± 0.99
Unsaturated fatty acid	64.55 ± 0.33	65.22 ± 0.33	64.85 ± 0.33

Table 3
Fatty acid composition of ground beef at 8 kGy

Fatty acids	0 days	60 days	90 days
14:00	2.63 ± 0.15	2.34 ± 0.15	2.53 ± 0.15
16:00	25.34 ± 0.18	25.2 ± 0.18	24.98 ± 0.18
18:00	7.68 ± 0.22	7.24 ± 0.22	7.44 ± 0.22
Saturated fatty acid	35.65 ± 0.46	34.78 ± 0.46	34.95 ± 0.46
16:01	1.88 ± 0.03	1.88 ± 0.03	1.82 ± 0.03
18:1 n-9	31.57 ± 0.63	30.77 ± 0.63	30.31 ± 0.63
18:2 n-6	18.29 ± 0.12	18.06 ± 0.12	18.08 ± 0.12
18:3 n-3	0.95 ± 0.03	0.92 ± 0.03	0.89 ± 0.03
20:3 n-6	0.57 ± 0.04	0.52 ± 0.04	0.49 ± 0.04
20:4 n-6	0.75 ± 0.10	0.58 ± 0.10	0.57 ± 0.10
22:5 n-6	0.69 ± 0.21	0.31 ± 0.21	0.31 ± 0.21
Others	9.65 ± 1.69	12.18 ± 1.69	12.85 ± 1.69
Unsaturated fatty acid	64.35 ± 0.53	65.22 ± 0.53	65.32 ± 0.53

There is a decrease of fatty acid and an increase of *trans* fatty acid which occur due to a change in molecular structure of fatty acid, breaking down double bonds, forming free radical and *trans* fatty acids.

The results showed an increase in *trans* fatty acids related to the increase on irradiation dose in ground beef. These results also showed that irradiation induces the *trans* fatty acids formation (Table 4).

Irradiation is a physical method of food processing, consisting of exposing food to ionizing radiation during a limited period of time (Olszyna-Marzys, 1998). The autoxidative process induced by ionizing irradiation in fat is the same as that which occurs in other food processing. However, with irradiation, it is quite accelerated (ICGFI, 1992).

Low irradiation doses (<10 kGy) can kill at least 99.9% of Salmonella in meats and even higher percentage of *Escherichia Coli* 0157:H7 (Oslon, 1998). But irradiation is known to generate hydroxyl radicals that can initiate chain reactions of lipid oxidations in aqueous and oil emulsion systems. Irradiation could produce a large amount of hydroxyl radicals in meat because over 75% of muscle cells are composed of water (Thakur and Sigh, 1995). Irradiation was conducted on fresh-trimmed meat, which incorporated a minimum of fat. It is known that autoxidation of unsaturated fats

Table 4
Levels of trans fatty acids at different radiation doses, analyzed after irradiation after 60 and 90 days of storage at $-10^{\circ}C$

DOSE (kGy)	% Trans fatty acids		
	Storage time (days)		
	0	60	90
0	4.60 ± 0.31	4.40 ± 0.31	5.00 ± 0.31
1	8.00 ± 0.00	8.00 ± 0.00	8.00 ± 0.00
2	8.50 ± 0.25	8.30 ± 0.25	8.00 ± 0.25
3	8.00 ± 0.00	8.00 ± 0.00	8.00 ± 0.00
4	8.50 ± 0.29	8.00 ± 0.29	8.50 ± 0.29
5	8.50 ± 0.29	8.50 ± 0.29	8.00 ± 0.29
6	9.50 ± 0.12	9.30 ± 0.12	9.50 ± 0.12
7	9.50 ± 0.00	9.50 ± 0.00	9.50 ± 0.00
8	11.00 ± 0.50	10.50 ± 0.50	10.00 ± 0.50

does not normally take place in animal cells, because it is kept in check by the inhibitory antioxidants (Hampson, 1996).

Irradiation continues to offer a well-known and very useful method of producing radicals and of studying their important reactions for biology, both in vitro and in vivo (Pryor, 1978). The results show that although there is an increase of *trans* fatty acids there is also a decrease in linoleic acid due to oxidation of lipid (Tables 1–3).

The fatty acids are quite susceptible to oxidative process, because the hydrogen of carbons adjacent to double bonds can be replaced by radical species with higher reactivity or through energetic activation like heat, luminosity and ionizing radiation, that induced the production of *trans* fatty acids.

4. Conclusions

Although the gamma radiation has been an excellent method to conserve meat, the molecular structure of this meat can be changed, and this fact is observed in this paper. The total *trans* fatty acids in non-irradiated ground beef is smaller than the irradiated one. The extraction done in samples irradiated after 90 days of storage is similar to the extraction done at the day of storage.

The increase of *trans* fatty acids in the irradiated ground beef is one of the important factors that can be considered in the irradiation process.

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