Infrared Spectroscopy for the Detection of Irradiated Meats

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Abstract: The aim of the present study was to investigate the possibility of using infrared spectroscopy for detecting the irradiation of meats. Samples of beef meat containing fat were subjected to gamma irradiation at doses of 0, 1.5, 3 and 4.5 kGy at room temperature. Then irradiated and non-irradiated beef meat samples were examined by Fourier-transform infrared (FT-IR) spectroscopy post irradiation treatments and after 3 months of frozen storage at -18 °C. The results showed that the spectra of both irradiated and non-irradiated meat samples were relatively complex showing several bands that contributing to many functional groups belonging to meat components. However, a new peak at 1779.60 Cm^{-1} appeared in the FT-IR spectra of all irradiated samples, while did not detected in any of the control ones. The new peak corresponds to the carbonyl (C=O) stretching vibration of 2-dodecylcyclobutanone, a radiolytic product of palmitic acid and useful marker of irradiation in lipid-containing meats. It was possible to correctly detect all irradiated samples post irradiation and after frozen storage through the application of FT-IR spectral analysis. Therefore, it could be concluded that FT-IR spectroscopy is a promising tool as a rapid and sensitive non-destructive analysis for detecting the irradiation of lipid-containing meats. The analysis can be applied for quality control and enforcement of accurate labeling regulations in irradiated meat products.

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1. Introduction

Food safety is a subject of growing importance worldwide. The widespread and increasing incidence of foodborne diseases and the resultant social and economic impact on the human population have brought out food safety to the forefront of public health concerns. One reason is the emergence of new types of harmful bacteria or evolving forms of older ones that can cause serious illness. This has prompted public health authorities worldwide to reassess their methods of food safety assurance, and to resort to a more cost-effective, preventive method that is known as hazard analysis and critical control point [HACCP] (**Dewaal *et al.*, 2010; Molins *et al.*, 2001; Sharma *et al.*, 2008; WHO, 2008**).

Food irradiation is such a control measure in the production of several types of raw or minimally processed foods such as poultry, meat and meat products, fish and seafood, fruits and vegetables. In the production of these foodstuffs, irradiation may be a critical control point (**Molins *et al.*, 2001**). It has been recognized as a reliable and safe method for preservation of food, being one of the few technologies which address both food quality and safety by virtue of its ability to control spoilage and foodborne pathogenic microorganisms without significantly affecting sensory attributes of food products. After many years of research and development of national and international standards, more than 60 countries have regulations allowing food irradiation of at least one product (**Blackburn, 2011; Chauhan *et al.*, 2009; IAEA, 2009**). Proven as wholesome and toxicologically safe over many years, the number and volume of irradiated food products in the market have grown steadily. Global commercialization of food irradiation lags in spite of the general knowledge that the process can be used to reduce food losses and to control contamination causing illness and death while eliminating the need for the use of many potentially harmful chemicals.

Proper control of irradiation processing of food is very critical for upholding regulatory controls, checking compliance against labeling requirements, facilitating international trade and enhances consumer confidence and choice. Therefore, the development of analytical methods for correct identification of irradiated samples from non-irradiated samples has become very important (**Chauhan *et al.*, 2009; Obana *et al.*, 2006; Stefanova *et al.*, 2010**).Various physical, chemical, biological and microbiological methods have been developed to reliably determine the irradiation status of a wide variety of foods. However, there is a need for fast, simple and sensitive methods.

Infrared (IR) spectroscopy is a vibrational spectroscopic technique deals with the infrared part of the electromagnetic spectrum and exploits the principle that molecules have specific discrete energy levels corresponding to frequencies at which they rotate or vibrate (**Carbonaro and Nucara, 2010; Sun, 2009**). Fourier transform infrared (FT-IR) spectroscopy is a fairly new technique for collecting infrared spectra (**Damez and Clerjon. 2008**). It is a powerful instrumental tool for both qualitative and quantitative analysis of food components owing to the substantial functional group information contained within the IR spectrum (**Amamcharla *et al.*, 2010**). The advantage of FT-IR spectroscopy is that it can be applied to food in different forms such as dried, liquid, solid and fresh, among others. In addition, it is becoming an attractive alternative to the existing analytical techniques in food analysis because its increased sensitivity, resolution, high signal-to noise ratio, multiple-component analysis and rapid measurement capabilities (**Amamcharla *et al.*, 2010; Dogan *et al.*, 2007; Santos *et al.*, 2010; Yang and Irudayaraj, 2001**). Therefore, the aim of the present work was to study the possibility of detecting the irradiation of beef meat using the Fourier transform infrared (FT-IR) spectroscopy.

2. Materials and Methods

Materials:

Beef meat with fat was excised from three beef carcasses at the butcher's shop (after 3 hrs of slaughtering and dressing) and used separately as replication of samples (three separate replicates). The obtained beef meat for each carcass was divided into samples of approximately 150 g and aerobically packaged in polyethylene pouches which were sealed by heat. The observed samples for each carcass replicate were subdivided into 4 groups of samples for irradiation treatments.

Irradiation and storage of samples:

Packaged samples of the beef meat were transported for irradiation treatments in a cool box. Packages of the control non-irradiated meat samples were left at room temperature during the irradiation of samples, while the rest of the meat packages were irradiated at doses of 1.5, 3, and 4.5 kGy. Irradiation of meat samples was carried out at room temperature using an experimental Co-60 source located at the National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt. After irradiation of samples, each of the observed groups for non-irradiated and irradiated meat samples was divided into two parts. The first part of samples was taken for the day zero analyses, while samples of the second part were frozen stored at -18°C for 3 months.

Infrared spectroscopy

The meat sample was chopped in a conventional food processor to obtain a homogenous fat distribution of ground meat. About 50 g of the ground meat were dried at 50 °C under vacuum and grinded in a mortar. Then infrared spectroscopy was performed using a Matteson Galaxy Series FT-IR Model 3025 interfaced with a pionex computer. Frozen meat samples were thawed in the refrigerator overnight before spectroscopic analysis.

3. Results and Discussion

FT-IR spectral analysis of irradiated and non-irradiated beef meat samples:

Irradiated and non-irradiated beef meat samples were subjected to FT-IR spectral analysis post irradiation treatments and the representative infrared spectra of the meat samples in the 4000-500 Cm^{-1} region are shown in Figs. 1-4. As shown from Fig. 1, the spectrum of control non-irradiated beef meat samples is relatively complex showing several bands that arise from the contribution of many functional groups belonging to proteins, lipids and other compounds. However, the results in the present study will be focused mainly on the FT-IR spectra of samples in the 2000-1750 Cm^{-1} region, in which, a new peak appeared in the infrared spectra of the irradiated samples. As can be seen, the presented results clearly show the appearance of absorption band at 1779.60 Cm^{-1} in the infrared spectra of all irradiated beef meat samples (Figs. 2-4).The detected band corresponds to the carbonyl (C=O) stretching vibration of 2-dodecylcyclobutanone (2-DCB) as previously identified by **Hijas (2010)**. However, this band was not found in the infrared spectra of the control non-irradiated meat samples (Fig.1).The different sample replicates within each treatment almost gave similar spectra when FT-IR experiments were carried out in the present study.

Alkylcyclobutanones including 2-DCB, the radiolytic product produced from palmitic acid, have been recognized as chemical markers of irradiation in lipid-containing foods including meats (**Boyd *et al.*, 1991; Crone *et al.*, 1993; Stevenson, 1994; Stevenson *et al.*, 1990; Stewart *et al.*, 2000**) and their concentrations generally increases linearly with irradiation dose (**Crone *et al.*, 1992a; Lee *et al.*, 2000; Park *et al.*, 2001**). They are unique radiolytic products formed from fatty acids and produced solely as a result of irradiation and not any other processing method (**Gadgil *et al.*, 2002**) and officially adopted to detect irradiated foods containing fats (**Obana *et al.*, 2006; Stefanova *et al.*, 2010**).

The most common methods of isolating cyclobutanones from lipid-containing food include extraction of fat, separation of the radiolytic 2-alkylcyclobutanones by adsorption chromatography and their analysis using gas chromatography-mass spectrometry. Recent studies have employed supercritical fluid extraction, accelerated solvent extraction or direct solvent extraction which could successfully reduce the extraction time (**Stefanova *et al.*, 2010**). However, FT-IR spectroscopy is a rapid and reagentless non-destructive analytical technique (**Cordella *et al.*, 2002**).

With rapid development in infrared spectroscopic instrumentation, software and hardware, the application of this technique has expanded into many areas of food research. Currently, infrared spectroscopy has becoming one of the most spectroscopic, fast, and non-destructive tool for food quality analysis and control (**Sun, 2009**). FT-IR spectroscopy could be used in the investigation of functional properties of food components (**Bao *et al.*, 2008; Bhattacharjee *et al.*, 2005; Carbonaro and Nucara, 2010; Carbonaro *et al.*, 2008; Li-Chan, 2007; Martin-del-Campo *et al.*, 2007; Yang and Irudoyaraj, 2001**) and successfully applied for detection, discrimination, identification, classification and studying antibiotic resistance of bacteria including foodborne pathogens (**Amiali *et al.*, 2008; Burgula *et al.*, 2006; Kuham *et al.*, 2009; Panagou *et al.*, 2011, Pebuffo *et al.*, 2007, Oberreuter and Brodbeck, 2003**). One of the strengths of FT-IR spectroscopy is its ability, as an analytical technique, to obtain spectra from a very wide range of different compounds. FT-IR spectra of pure compounds are generally so unique that they look like molecular "fingerprints". For most common materials, the spectrum of an unknown compound can be identified by comparison with a library of known compounds (**Santos *et al.*, 2010**).

FT-IR spectral analysis of irradiated and non-irradiated beef meat samples after 3 months of frozen at – 18 °C:

An ideal detection method should measure a specific radiation effect, and should not be affected by processing parameters and storage conditions or the length of time between irradiation processing and analysis (**Chauhan *et al.*, 2009**). In the present study, irradiated and non-irradiated beef meat samples were also subjected to FT-IR spectral analysis after 3 months of frozen storage at -18°C. The results clearly show that the same band that corresponds to the (C=O) stretching frequency of 2-DCB at 1779.60 Cm^{-1} was observed in the infrared spectrum of each of the irradiated samples, while not detected in the spectrum of any of the control non-irradiated ones (Fig.5). As for samples of the day zero analysis, similar FT-IR spectra were almost observed for the different sample replicates within each of the examined treatment. These results clearly indicate the efficiency of FT-IR spectroscopy in detecting the radiolytic 2-DCB in all irradiated meat samples after frozen storage.

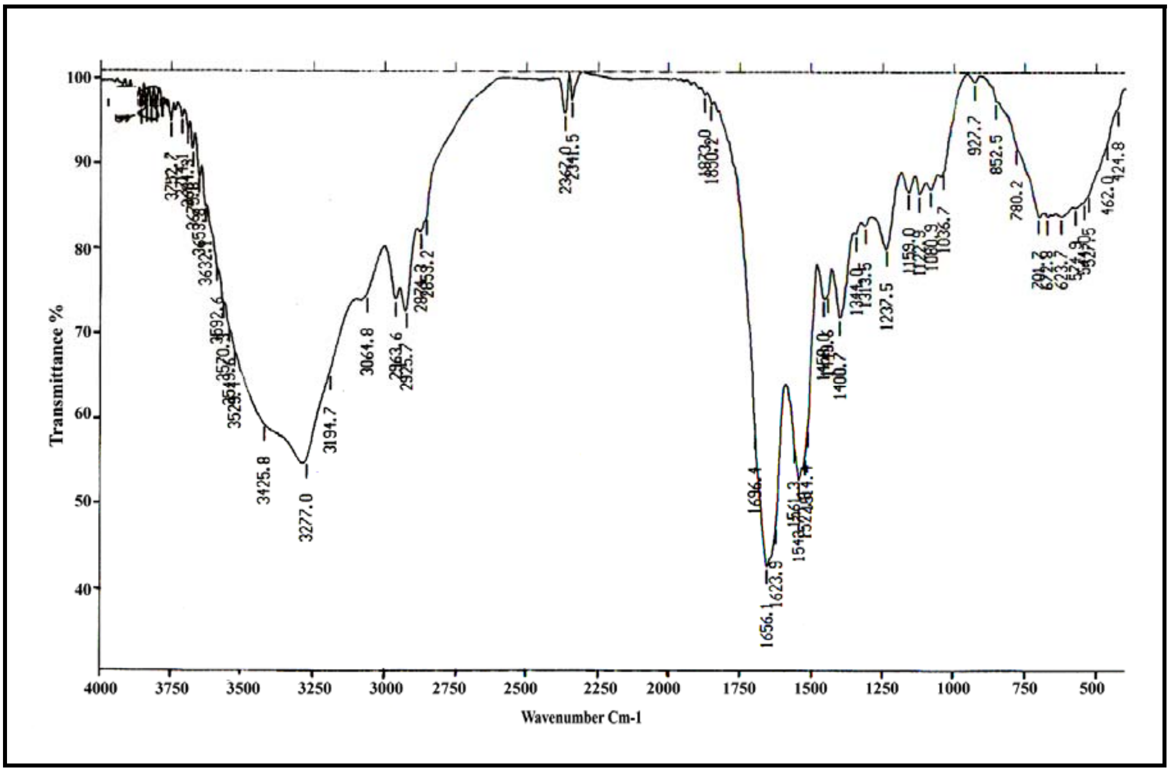

Figure 1. Representative FT-IR spectrum of control non-irradiated beef meat (Zero time).

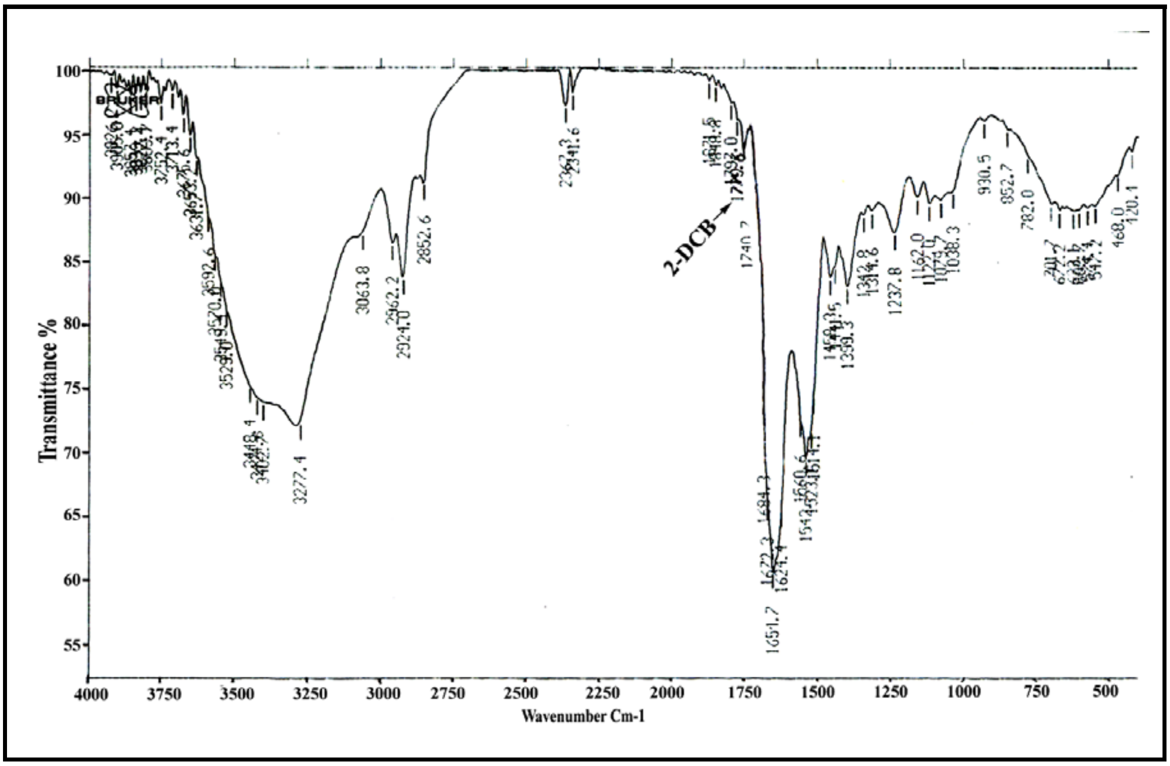

Figure 2. Representative FT-IR spectrum of beef meat irradiated at dose of 1.5 kGy (Zero time). 2-DCB = 2-dodecylcyclobutanone.

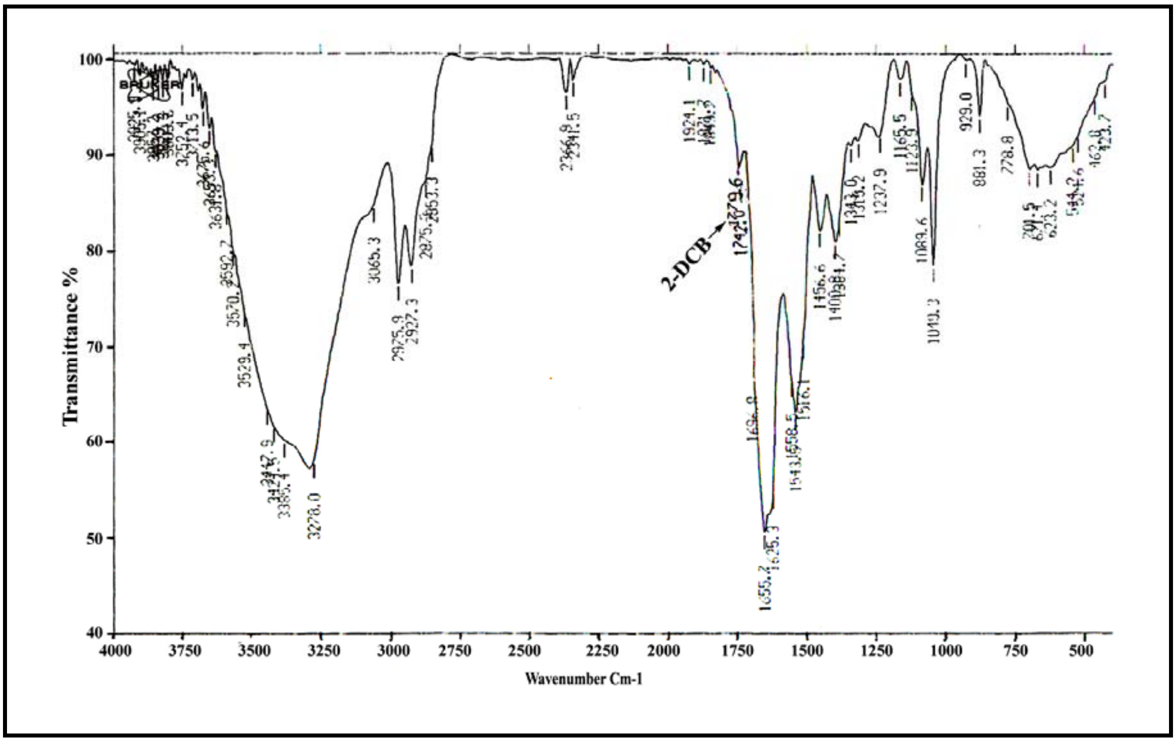

Figure 3. Representative FT-IR spectrum of beef meat irradiated at dose of 3 kGy (Zero time). 2-DCB = 2-dodecylcyclobutanone.

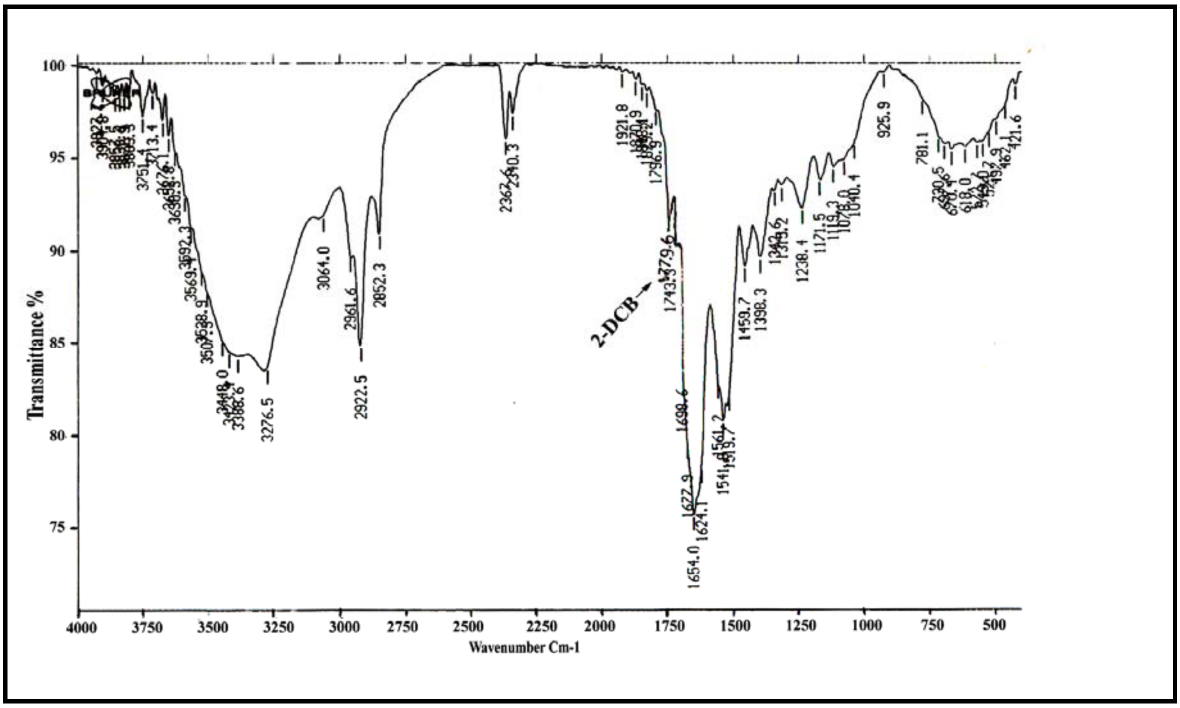

Figure 4. Representative FT-IR spectrum of beef meat irradiated at dose of 4.5 kGy (Zero time). 2-DCB = 2-dodecylcyclobutanone.

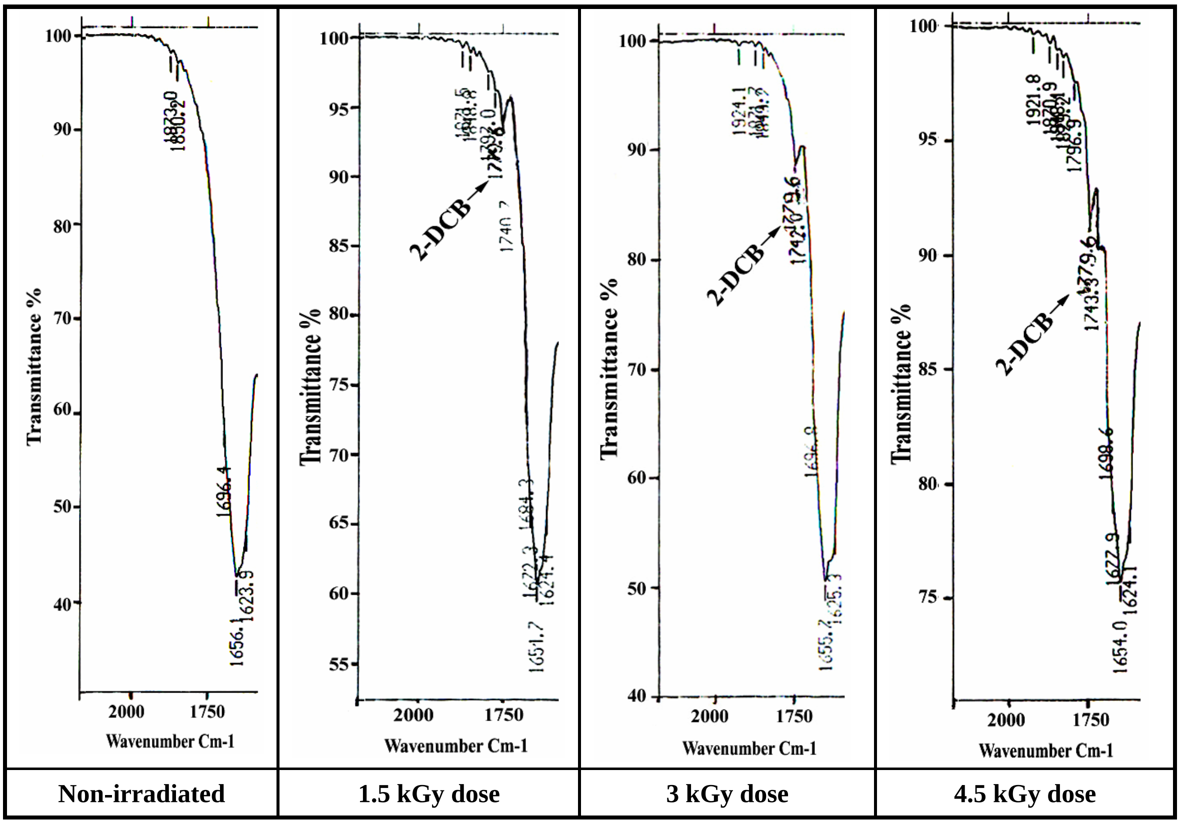

Figure 5. Representative FT-IR spectra (in 2000 -1750 Cm^{-1} region) of non-irradiated and irradiated beef meat after 3 months of frozen storage at -18°C. 2-DCB = 2-dodecylcyclobutanone.

Effects of drying of meat samples prior to spectral analysis on the detection of 2-DCB in the irradiated samples:

The results of the present study further show that drying of meat samples prior to spectral analysis did not affect the detection of 2-DCB in the irradiated samples. The obtained results agree with the results obtained by **Obana *et al.*(2006)** which showed that 2-DCB compound was stable in samples of cooked beef, poultry and egg with conventional cooking, which resulted in a temperature less than 100 °C inside the sample, making it a reliable indicator to detect the irradiation history of the raw materials before cooking. In addition, **Crone *et al.* (1992b)** reported that 2-DCB was useful for the detection of irradiated cooked chicken when the irradiated chicken thighs were heated at 200 °C for 25 min and the internal temperature was 88 °C, while cooking did not generate 2-DCB. The obtained results in the current study also give an indication for the possible application of FT-IR spectral analysis for the detection of cooked irradiated meat products, but further studies are needed.

4. Conclusion

In the present study, it was possible to detect all irradiated beef meat samples post irradiation treatments and after 3 months of frozen storage at -18°C through the application of FT-IR spectral analysis. Therefore, it could be concluded that Fourier-transform infrared spectroscopy (FT-IR) is a promising tool as a rapid and sensitive non-destructive analysis for detecting the irradiation of fat-containing meats and can be successfully applied for quality control and enforcement of accurate labeling regulations in irradiated meat products.

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