ISOTOPE & RAD. RES., 37, 1, 55 - 75 (2005).
ISSN 0021-1907
INIS ISRRAC EG

IMPROVING THE QUALITY OF READY-TO-EAT MEALS BY GAMMA IRRADIATION
2 - BAKED DE-BONED CHICKEN MEAT WITH POTATOE SLICES OR BAKED FISH AND COOKED RICE

BADR, H.M. [1], *RADY, A.H.* [1], *KHALAF, H.H.* [2] *and ABDEL-DAIEM, M.H.* [1]

(1) Nuclear Research Center, Atomic Energy Authority, Egypt and (2) Food Science Department, Faculty of Agriculture, Moshtohor, Zagazig University, Banha Branch, Egypt.

Key words: Ready-to-eat meals, Irradiated food, Irradiated chicken meat, Irradiated potatoes, Irradiated fish, Irradiated rice.

تحسين جودة الوجبات الجاهزة باستخدام أشعة جاما
٢ – لحم الدجاج المطهى فى الفرن مع شرائح البطاطس أو شرائح السمك المطهية فى الفرن والأرز المطهى

هشام محمد بدر و على حسن راضى و حسن حسن خلف و محمد حسن عبد الدايم

خلاصـــــة

أجريت هذه الدراسة لبحث مدى إمكانية استخدام أشعة جاما فـــى تحســين جــودة الوجبــات الجاهزة، حيث تم تجهيز عينات الوجبات والتى تضمنت لحم صدور الدجاج المطهية فى الفرن مع شرائح البطاطس – شرائح السمك المطهية بالفرن مع شرائح البصل والفلفل – الأرز المطهى ثــم عرضت لأشعة جاما بالجرعات صفر ، ١,٥ ، ٣ ، ٤,٥ كيلو جراى وخزنت بالتبريد عند درجــة ٤ ± ١°م وتم دراسة تأثير الإشعاع والتخزين بالتبريد على كل من الخـــواص الميكروبيولوجيــة والكيماوية والحسية للعينات.

أظهرت النتائج أن معاملة عينات الوجبات تحت الدراسة بالجرعات الإشعاعية المختلفة قد أدى إلى خفض العدد الكلى للبكتريا، البكتريا المحبة للبرودة ، الخمائر والفطريات الكليـــة وتناســب الانخفاض فى الأعداد مع الجرعة الإشعاعية مما أدى إلى زيادة فترة تخزينها بالتبريد فضلاً عــن أن المعاملة بالجرعـــة ١,٥ كيلوجــراى أدت إلـــى خفــض أعــداد كــل مــن بكتريــا عائلــة *Enterobacteriaceae* و *Staphylococcus aureus* و *Enterococcus faecalis* ، بينمــا أدت الجرعة الإشعاعية ٣ كيلوجراى إلى القضاء التام على هذه الميكروبات، كما أظهرت النتــائج عدم وجود بكتريا *Salmonella* فى جميع عينات الوجبة المعاملة وغير المعاملة بالإشعاع وكذلك

Accepted in February 2005.

عدم وجود بكتريا *Vibrio sp.* فى عينات شرائح السمك المطهية سواء المعاملة أو غير المعاملة بالإشعاع. بالإضافة إلى ذلك، لم يكن هناك تأثيراً ملحوظاً للمعاملات الإشعاعية على التركيب الكيماوى أو رقم الأس الهيدروجينى للعينات بينما أدت إلى زيادة قيم حمض الثيوباربتيوريك فى عينات لحم الدجاج ولحم السمك، فى حين أدى تخزين العينات بالتبريد إلى حدوث زيادة تدريجية فى قيم حمض الثيوباربتيوريك فى لحم الدجاج والسمك وكذا حدوث انخفاض تدريجى طفيف فى رقم الأس الهيدروجينى للعينات تحت الدراسة سواء المعاملة أو غير المعاملة بالإشعاع. من ناحية أخرى لم تؤثر المعاملات الإشعاعية على الخواص الحسية لجميع العينات من حيث المظهر والرائحة والطعم وأدت إلى إطالة مدة قابلية عينات الوجبة حسياً وعلى ذلك تعتبر الجرعة الإشعاعية ٣ كيلوجراى جرعة مثالية لتحسين جودة الوجبات الجاهزة.

ABSTRACT

The present investigation was carried out to study the possibility of using gamma irradiation for improving the quality of ready-to-eat meals. The prepared meals (included baked chicken meat with potato slices or baked fish and cooked rice) were subjected to gamma irradiation at doses of 0, 1.5, 3 and 4.5 KGy followed by cold storage (4±1 °C). The effects of irradiation and cold storage on the microbiological aspects, chemical and organoleptic properties of samples were studied.

The results showed that irradiation of the prepared meals decreased the initial total bacterial count, total psychrophilic bacteria and total yeast and molds, proportionally to the applied dose, hence prolonged their refrigerated shelf-life. Moreover, irradiation at dose of 1.5 KGy reduced the counts of Enterobacteriaceae, Staphylococcus aureus and Enterococcus faecalis, while 3 KGy dose completely eliminated these bacteria in all samples. Salmonella was not detected in all irradiated and non-irradiated meals and Vibrio sp. were absent in irradiated and non-irradiated baked fish. On the other hand, gamma irradiation had no remarkable effects neither on the chemical composition of the main component of meals nor on their pH, while it increased the thiobarbituric acid (TBA) value for baked chicken and fish meat. However, cold storage gradually increased the values of TBA and gradually decreased the pH value for irradiated and non-irradiated samples. Finally, irradiation treatments had no effects on the sensory properties (appearance, odor and taste) of all meals and extended their time of sensory preference.

INTRODUCTION

Ready-to-eat meals are items of convenience and lifestyles and are consumed predominantly by one-person households, working couples and increasingly by the elderly. In recent years, the market for chilled ready meals has shown substantial growth largely due to consumer's perception that chilled foods are closer to fresh than frozen foods (Roybka, 2001). In 1996, the value of ready meals marketed in Germany, France, UK, Spain and Italy was reported to be 800000-900000 ton/year (5-6 billion $). The USDA's national food consumption survey data showed that the consumption of ready-to-eat meals in 1997 was estimated at 37% of the per capita consumption of all food types. Recently, the market of ready meals in Europe is expected to grow by 20% from the current values to exceed $6.8x10^{12}$ € by 2005 (Hilliam and Boyle, 1996 and Redmond et al., 2004). These pre-cooked meals covering a wide range of commodities including meat, poultry fish, vegetables, pasta and desserts are manufactured with increasing scale for use in the home and various sectors of the catering industry (Grant and Patterson, 1992 and O'Leary et al., 2000). This leads many companies to trying out new products or modifying traditional ones. With each step, the introduction or growth of a pathogen may occur.

Recently, there is increased public focus on microbial aspects of food safety. In part, this is due to certain high profile cases affecting the food service and food production industry resulting in death, illness and massive product recalls. Furthermore, we have also moved rapidly from local manufacturers producing our food to national industries and now international trade with wholesalers packaging products in ways appealing to local productions. The larger market size and wide geographic distribution of products mean that if problem occur, many people will be at risk and extremely large outbreaks with hundreds of thousands of cases will occurred (Todd, 2001).

Cooking exerts a selective effect on the type of microorganisms present on the cooked ready foods. The microflora of the cooked foods consists of heat resistant microorganisms belongs to the spore formers, which may include potentially pathogenic strains. This is in addition to the possibility of recontamination of the cooked food by many microorganisms including pathogenic bacteria during slicing, portioning operation or handling (Grant and Patterson, 1992). Moreover, many types of ready-to-eat food may be stored in the refrigerator, which allows pathogenic microorganisms, if present, to grow and reach numbers that can cause illness. Therefore, the increase in food borne diseases throughout the world is perhaps not surprising especially as we are living in an age with a rapidly growing and migrating society (Todd, 2001).

On the other hand, food borne diseases are common and widespread global problem. Although most of these cases are mild and self-limiting, the socioeconomic impact is high because of the large estimated number of cases. Food borne diseases are typically under reporting and the number represents only a fraction that may be less than 1 % of these actually occurring (Kaferstein, 1997 and Motarjemi et al., 1997).

Treating foods with ionizing energy offers many benefits to consumers, retailers and food manufacturers depending on the treatment used. Certainly, the most important benefit is improving microbiological quality of food. Additional benefits include the replacement of chemical treatments and extended shelf-life in addition to the fact that products can be processed in the package, as a terminal treatment, thereby eliminating the possibility of cross contamination prior to consumer use (Satin, 2002).

Irradiation process had an excellent potential to improve the safety of ready-to-eat foods and can be an additional step to further ensure the safety of ready meals with extending their shelf-life. The present study aims to prepare samples of ready-to-eat meals (baked de-boned chicken breast meat with potato slices or baked fish and cooked rice) and to investigate the possibility of improving their quality by low doses of gamma irradiation during cold storage.

MATERIALS AND METHODS

Preparation of ready-to-eat :

Baked de-boned chicken breast meat with slices of potatoes :

De-boned chicken breast fillets, of freshly slaughtered carcasses, were well washed with the tap water and mixed with salt and spices mixture (consisting of black pepper, cumin, ginger, fennel, cloves and coriander), then left for two hours in the refrigerator for seasoning. The seasoned chicken fillets were put in trays with slices of pre-washed peeled potatoes, tomatoes, onion, in addition to corn oil, tomato juice, salt and the same spices mixture. The trays were placed in the oven and their contents were baked until well cooking (135°C for 30 min), then left to cool down to room temperature. The baked product was divided into appropriate samples (~ 150g of the baked potato slices + one fillet of the baked chicken) in tightly sealed polyethylene pouches (under aerobic conditions).

Baked fish :

Frozen Keshr Bayad fish fillets *(Lates niloticus)* were purchased from EL-Masrya Company for Fish Marketing at Zagazig City, EL-Sharkia Governorate, Egypt. Frozen fish fillets were left to thaw for 12 h at 4±1°C and well washed with tap water. The washed fillets were mixed with salt, lemon juice, vinegar, garlic and spices mixture (consisting of black pepper, cumin, ginger, fennel, cloves and coriander), then left for one hour in the refrigerator for seasoning. The seasoned fish fillets were put in trays with slices of pre-washed green pepper, onion and tomatoes in addition to corn oil, tomato juice, salt and the same spices mixture. Trays were put into oven and their contents were baked until well cooking (135°C for 40 min). The baked fish was left to cool down to room temperature and divided into samples of ~150g in tightly sealed polyethylene pouches (under aerobic conditions).

Cooked rice :

Small cuts of onion were fried in the corn oil till the darken of their color. At that time, the washed rice was added and mixed with the fried onion, then water and salt were added and the rice was left for cooking on a reduced fire. The cooked rice was left to cool down to room temperature and divided into samples of ~150g in tightly sealed polyethylene pouches (under aerobic conditions).

Irradiation process:

For each of those prepared meals, packaged samples were transported in an ice chest for irradiation treatment immediately after their preparation (except some of them, which were refrigerated stored at 4±1°C to serve as control non-irradiated samples). Samples were exposed to gamma irradiation at doses of 1.5 , 3 and 4.5 KGy using a Russian Medical Sterilized CM-20 Gamma cell at the National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt.

Storage of samples :

Irradiated and non-irradiated samples of the prepared meals under investigation were cold stored at 4±1°C and periodically subjected to analysis at 3 days intervals. Sampling for analysis was stopped with the rejection of samples if one or more of the following signs was observed:

(1) Visual observation of microbial growth on the surface of samples (R1).
(2) Deterioration of the odor (R2).
(3) If the total plate count exceeded 10^7 cfu/g (R3).

Analytical Methods :

Microbiological analysis :

Before opening, the outer surface of pouches containing samples was sterilized using cotton wetted with 70% ethanol. Under aseptic conditions, the polyethylene pouches were opened and twenty grams of well-mixed sample were transferred into 500 ml conical flask containing 180 ml of saline solution (0.85% NaCI) to give 1: 10 dilution. Further serial dilutions were also prepared and the appropriate dilutions were used in the microbiological determinations.

- *Microbial flora :*

Total bacterial count was determined according to pour colony count method using plate count agar medium as recommended by the APHA (1992). The plates were incubated at 30°C for 3-5 days. Total psychrophilic bacteria were enumerated on plate count agar medium after incubation at 5°C for 7 days as recommended by APHA (1992). Total molds and yeasts were counted on oxytetracycline glucose yeast extract agar medium according to the Oxoid Manual (1982). The plates were incubated at 25°C for 3-5 days. The count of *Enterobacteriaceae* was determined on violet red bile dextrose agar medium after incubation at 37°C for 20 - 24 h as described by Roberts et al., (1995).

- *Food borne pathogens :*

Staphylococcus aureus was enumerated on Baird-Parker medium using surface plating technique as recommended by IAEA (1970). The inoculated plates were incubated at 37°C for 24 hours. *Enterococcus faecalis* was counted on kanamycin aesculine azide agar medium using surface plating technique and incubation at 35°C for 16-24 h according to the Oxoid (1998). Colonies were considered as *Enterococcus faecalis* if they were porcelain white and surrounded by a black zone. The detection *of Salmonella* was carried out using the most probable number technique (MPN) according to IOS (1978). After enrichment at 37°C for 24 hours in buffer peptone at first then in selenite broth, the cultures were streaked on brilliant green agar and incubated at 37°C for 24 hours, then biochemical examination in Triple Sugar Iron agar (TSI) and lysine decarboxylase broth was performed. Samples of the baked fish were examined for the presence of *Vibrio sp.* using Thiosulphate Citrate Bile salt Sucrose (TCBS) agar medium as described by Lee (1990). Twenty five grams of fish samples were homogenized in 225 ml of alkaline peptone water and incubated at 37°C for 20-24 hours, then subcultures were made on the alkaline peptone water. After incubation at 37°C for 12 h, the cultures were streaked on TCBS agar medium and the plates were incubated at 37°C for 24 h.

Chemical analysis :

Moisture, lipid, protein and ash contents were determined according to AOAC (2000) official methods. Total carbohydrates were extracted from samples of rice according to the method of Herbert et al., (1971), then colorimetrically determined according to Dubois et al., (1965). The total carbohydrates were calculated by difference in muscle samples according to Egan et al., (1981). The pH was assessed using a pH meter on a homogenate consisting of 5g of sample in 50 ml of distilled water as described by Carballo et al., (1995). Thiobarbituric acid (TBA) was determined (as optical density at 538 nm) for muscle samples according to the method described by Tarladgis et al., (1960).

Sensory evaluation :

Irradiated and non-irradiated samples of the prepared ready-to-eat meals were sensory evaluated for their appearance and odor post treatments and during cold storage at 4±1°C, while the taste of samples was evaluated post treatments (on day zero) only for safety precautions. The panel consisted of ten members from our laboratory and scores were obtained (as described by Wierbicki, 1985) by rating the above quality attributes using the following rating scale: 9= excellent, 8= very good, 7= good, 6= below good-above fair, 5= fair, 4= below fair-above poor, 3= poor, 2= very poor and 1= extremely poor. Rating of 5 and 4 indicated that the products were of marginal quality, whereas the rating of 3 (poor) and below indicated that the consumers might not accept the product.

RESULTS AND DISCUSSION

Microbiological aspects :

1- Microbial flora :

- Total bacterial count and total psychrophilic bacteria :

The initial total bacterial counts of non-irradiated baked chicken meat with potatoes, baked fish and cooked rice samples were found to be $2.5x10^5$, $3.2x10^6$ and $6.5x10^5$ cfu/g, while the initial counts for total psychrophilic bacteria were $2.9x10^4$, $4.7x10^3$ and $1.5x10^4$ cfu/g in samples, respectively (tables 1,2,3). This may indicates the presence of spore formers that could survive the cooking of samples in addition to the possible contamination during handling, portioning and packaging of the cooked samples. Many bacterial species can resist cooking process (Jackson et al., 2001). Similar observations were reported by Fang et al., (2003) and Ayçiçek et al., (2004). A great reduction in the total bacterial count and total psychrophilic bacteria was observed for these ready-to-eat samples upon the application of gamma irradiation, proportionally to the applied dose. Further increases in these counts were observed during storage for irradiated and non-irradiated samples, but at higher rates in the controls (tables 1-3). The effectiveness of gamma irradiation in reducing bacterial populations had been well documented and the observed counts may indicates the radio-resistance of some bacterial cells and/ or spores to the applied doses (ICMSF, 1980).

- Total molds and yeast :

The results in tables (1-3) also show that samples of non-irradiated baked chicken meat with potatoes, baked fish and cooked rice had an initial counts of 1.8×10^4, 1.5×10^4 and 2.7×10^4 cfu/g for total molds and yeast.

Table (1): Effects of gamma irradiation and cold storage (4±1°C) on microbial flora of baked de-boned chicken meat with potato slices.

Storage (days)	Microbial determinations (cfu/g) /Irradiation dose (KGy)															
	Total bacterial count				Total psychrophilic bacteria				Total molds and yeast				Enterobacteriaceae			
	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5
0	$2.5x10^5$	$2.8x10^4$	$5.9x10^3$	$7.4x10^2$	$2.9x10^4$	$5.7x10^3$	$5.6x10^2$	4.0x10	$1.8x10^4$	$2.1x10^3$	$3.2x10^2$	6.0x10	$4.2x10^3$	$2.5x10^2$	Nil	Nil
3	$5.4x10^5$	$1.2x10^5$	$7.4x10^3$	$1.5x10^3$	$6.8x10^4$	$8.4x10^3$	$9.2x10^2$	$2.8x10^2$	$4.2x10^4$	$4.7x10^3$	$5.5x10^2$	$2.5x10^2$	$7.6x10^3$	$5.8x10^2$	Nil	Nil
6	$8.5x10^5$	$3.4x10^5$	$8.0x10^3$	$3.4x10^3$	$7.0x10^4$	$1.6x10^4$	$1.8x10^3$	$4.5x10^2$	$6.6x10^4$	$6.4x10^3$	$8.6x10^2$	$4.8x10^2$	$9.0x10^3$	$7.1x10^2$	Nil	Nil
9	$1.9x10^6$	$5.6x10^5$	$2.5x10^4$	$5.8x10^3$	$2.5x10^5$	$5.2x10^4$	$4.4x10^3$	$7.7x10^2$	$8.7x10^4$	$8.2x10^3$	$1.5x10^3$	$7.2x10^2$	$2.8x10^4$	$1.5x10^3$	Nil	Nil
12	R2	$8.4x10^5$	$4.9x10^4$	$7.2x10^3$	R2	$7.6x10^4$	$8.2x10^3$	$2.6x10^3$	R2	$1.4x10^4$	$3.6x10^3$	$1.3x10^3$	R2	$3.2x10^3$	Nil	Nil
15		$1.6x10^6$	$7.5x10^4$	$9.0x10^3$		$8.0x10^4$	$1.6x10^4$	$5.7x10^3$		$3.5x10^4$	$6.2x10^3$	$2.9x10^3$		$6.9x10^3$	Nil	Nil
18		R2	$1.4x10^5$	$3.4x10^4$		R2	$5.2x10^4$	$7.4x10^3$		R2	$8.9x10^3$	$4.2x10^3$		R2	Nil	Nil
21			R2	$7.8x10^4$			R2	$1.5x10^4$			R2	$6.5x10^3$			R2	Nil
24				$1.8x10^5$				$4.6x10^4$				$8.9x10^3$				Nil
27				$4.5x10^5$				$8.2x10^4$				$1.2x10^4$				Nil
30				$7.9x10^5$				$1.8x10^5$				$2.6x10^4$				Nil
33				$1.3x10^6$				$6.3x10^5$				$4.3x10^4$				Nil
36				R2				R2				R2				R2

R2: Rejected due to the deterioration of odor.

Table (2): Effects of gamma irradiation and cold storage (4±1°C) on the microbial flora of baked fish.

Storage (days)	Microbial determinations (cfu/g) /Irradiation dose (KGy)															
	Total bacterial count				Total psychrophilic bacteria				Total molds and yeast				Enterobacteriaceae			
	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5
0	$3.2x10^6$	$6.4x10^5$	$1.8x10^4$	$7.5x10^3$	$4.7x10^3$	$7.3x10^2$	5.0x10	<10	$1.5x10^4$	$2.4x10^3$	$6.5x10^2$	3.4x10	$6.4x10^3$	7.0x10	Nil	Nil
3	$8.7x10^6$	$9.6x10^5$	$4.3x10^4$	$9.7x10^3$	$7.5x10^3$	$9.5x10^2$	$3.2x10^2$	<10	$4.7x10^4$	$3.9x10^3$	$7.9x10^2$	$1.3x10^2$	$7.5x10^3$	$1.4x10^2$	Nil	Nil
6	$2.4x10^7$R3	$2.8x10^6$	$7.1x10^4$	$2.3x10^4$	R3	$2.6x10^3$	$5.7x10^2$	<10	R3	$6.5x10^3$	$1.4x10^3$	$2.8x10^2$	R3	$2.6x10^2$	Nil	Nil
9		$6.5x10^6$	$9.4x10^4$	$3.7x10^4$		$5.3x10^3$	$9.2x10^2$	7.0x10		$1.8x10^4$	$5.9x10^3$	$4.9x10^2$		$3.4x10^2$	Nil	Nil
12		$9.2x10^6$	$2.7x10^5$	$5.6x10^4$		$7.8x10^3$	$1.6x10^3$	$2.9x10^2$		$4.2x10^4$	$8.6x10^3$	$2.9x10^2$		$5.2x10^2$	Nil	Nil
15		R2	$5.3x10^5$	$8.3x10^4$		R2	$3.8x10^3$	$5.4x10^2$		R2	$2.0x10^4$	$8.5x10^2$		R2	Nil	Nil
18			$7.6x10^5$	$1.9x10^5$			$6.9x10^3$	$8.7x10^2$			$2.9x10^4$	$1.2x10^3$			Nil	Nil
21			R2	$4.6x10^5$			R2	$2.4x10^3$			R2	$3.8x10^3$			R2	Nil
24				$7.9x10^5$				$4.5x10^3$				$7.2x10^3$				Nil
27				$1.5x10^6$				$8.6x10^3$				$1.4x10^4$				Nil
30				R2				R2				R2				R2

R2: Rejected due to the deterioration of odor.
R3: Rejected due to increasing the total bacterial count to more than $1x10^7$ cfu/g.

Table (3): Effects of gamma irradiation and cold storage (4±1 °C) on the microbial flora of cooked rice.

Microbial determinations (cfu/g)	Storage (days)	irradiation dose (KGy)			
		0.0	**1.5**	**3.0**	**4.5**
Total bacterial count	0	$6.5x10^{5}$	$1.9x10^{4}$	$3.8x10^{3}$	$2.7x10^{2}$
	3	$9.8x10^{5}$	$4.2x10^{4}$	$5.6x10^{3}$	$4.Sx10^{3}$
	6	$3.2x10^{6}$	$8.7x10^{4}$	$9.2x10^{3}$	$7.6x10^{3}$
	9	R2	$1.8x10^{5}$	$2.3x10^{4}$	$9.7x10^{3}$
	12		R2	4.6x10	$2.6x10^{4}$
	15			R2	$5.4x10^{4}$
	18				R2
Total psychrophilic bacteria	0	$1.5x10^{4}$	$2.1x10^{3}$	$2.3x10^{2}$	<10
	3	$4.7x10^{4}$	$3.2x10^{3}$	$3.9x10^{2}$	<10
	6	$8.2x10^{4}$	6.8x10	$7.3x10^{2}$	8.0x10
	9		9.7x 10	$9.6x\ 10^{2}$	$3.4x\ 10^{2}$
	12		R2	$2.Sx10^{3}$	$7.9x10^{2}$
	15			R2	$1.6x10^{2}$
	18				R2
Total molds and yeast	0	$2.7x10^{4}$	$1.3x10^{3}$	$7.8x10^{2}$	5.0x10
	3	$5.6x10^{4}$	$4.2x10^{3}$	$1.5x10^{3}$	$1.8x10^{2}$
	6	$8.4x10^{4}$	$7.9x10^{3}$	$5.7x10^{3}$	$3.2x10^{2}$
	9	R2	$1.7x\ 10^{4}$	$7.4x\ 10^{3}$	$6.9x\ 10^{2}$
	12		R2	$9.6x10^{3}$	$9.7x10^{2}$
	15			R2	$2.8x10^{3}$
	18				R2
Enterobacteriaceae	0	$4.3x10^{3}$	7.0x10	Nil	Nil
	3	$6.9x10^{3}$	$1.8x10^{2}$	Nil	Nil
	6	$9.2x10^{3}$	$3.6x10^{2}$	Nil	Nil
	9	R2	$8.9x10^{2}$	Nil	Nil
	12		R2	Nil	Nil
	15			R2	Nil
	18				R2

R2: Rejected due to the deterioration of odor.

Molds and yeast are widely distributed in the environment and may be found as a part of the normal flora of food or as airborne contamination, moreover, some spores of molds remained viable after cooking process (Koburger and Marth, 1984 and Pearson and Gillett, 1996). Gamma irradiation at doses of 1.5, 3 and 4.5 KGy reduced the initial counts of molds and yeast by 88.3, 98.2 and 99.67% ; 84, 95.67 and 99.87% and 95.2, 97.1 and 99.8% in the above mentioned ready-to-eat meal components, respectively. The survivors, however, showed another gradual increase in their counts during cold storage but at lower rate in comparison with non-irradiated ones.

- *Enterobacteriaceae* :

The counts of *Enterobacteriaceae* were $4.2x10^3$, $6.4x10^3$ and $4.3x10^3$ cfu/g in non-irradiated baked chicken meat with potatoes, baked fish and cooked rice samples, respectively, indicating the possible contamination after cooking (tables 1 - 3). The presence of these bacteria in cooked meals is an indication of contamination after processing and its determination has replaced the tests for coliforms that have been traditionally used as indicators of contamination after processing (Lee et al., 2005). Exposing ready-to-eat samples under investigation to gamma irradiation at dose of 1.5 KGy greatly decreased the initial counts for *Enterobacteriaceae,* while irradiation at doses of 3 and 4.5 KGy completely eliminated these bacteria which showed no colony forming units post irradiation of samples and during their cold storage at 4±1°C. Similar results were observed by Badr (2004).

2- Food borne pathogens :

- *Staphylococcus aureus* :

Staphylococcus aureus was found at counts of $1.4x10^3$, $6.3x10^2$ and $4.7x10^2$ cfu/g in samples of non-irradiated baked chicken meat with potatoes, baked fish and cooked rice, respectively (tables 4-6). The observed count in the baked fish samples was much lower than that observed by Eleftheriadou et al., (2002) in the cooked fish which reported to be $4x10^3$ cfu/g. *Staphylococcus aureus* can be destroyed by food processing and its presence usually indicates contamination after processing (Tatini et al., 1984). The organism may be present in the nasal passages, throat, hair and skin of the healthy people (Bergdoll, 1990 and Jablonski and Boach, 1997). Irradiation dose of 1.5 KGy reduced the initial counts of this pathogen in the above mentioned samples by 89.3, 85.7 and 93.6% , respectively, but the counts of the organism showed another gradual increase during storage of irradiated and control samples. Samples of ready-to-eat meals that received 3 or 4.5 KGy dose of irradiation showed no viable counts for this pathogen neither post treatments nor during cold storage at 4±1°C. Irradiation as an effective mean for the elimination of *Staphylococcus aureus* was also reported by Lacroix et al., (2004).

- *Enterococcus faecalis* :

Tables (4-6) further show that samples of non-irradiated baked chicken meat with potatoes, baked fish and cooked rice had an initial count of $9x10^2$, $8.2x10^2$ and $3.5x10^4$ cfu/g for *Enterococcus faecalis,* respectively. The isolation of this organism from cooked meats and poultry was also reported by Barakat et al., (2000). This organism is non-spore former and its presence may be due to the possible contamination after cooking. Irradiation of these cooked samples at dose of 1.5 KGy decreased their initial counts of

Table (4): Effects of gamma irradiation and cold storage (4±1°C) on food borne pathogens of baked de-boned chicken meat with potato slices.

Storage (days)	Microbial determinations / Irradiation dose (KGy)											
	Staphylococcus aureus **(cfu/g)**				***Enterococcus faecalis*** **(cfu/g)**				**Presence of *Salmonella***			
	0.0	**1.5**	**3.0**	**4.5**	**0.0**	**1.5**	**3.0**	**4.5**	**0.0**	**1.5**	**3.0**	**4.5**
0	$1.4x10^2$	1.5x10	Nil	Nil	$9.0x10^2$	4.0x10	Nil	Nil	Nil	Nil	Nil	Nil
3	$3.2x10^2$	2.6x10	Nil	Nil	$1.5x10^3$	$1.2x10^2$	Nil	Nil	N.D	N.D	N.D	N.D
6	$6.4x10^2$	4.3x10	Nil	Nil	$2.4x10^3$	$1.9x10^2$	Nil	Nil	-	-	-	-
9	$8.9x10^2$	6.5x10	Nil	Nil	$3.8x10^3$	$2.7x10^2$	Nil	Nil	-	-	-	-
12	R2	9.1x10	Nil	Nil	R2	$3.6x10^2$	Nil	Nil	R2	-	-	-
15		$1.6x10^2$	Nil	Nil		$4.8x10^2$	Nil	Nil		-	-	-
18		R2	Nil	Nil		R2	Nil	Nil		R2	-	-
21			R2	Nil			R2	Nil			R2	-
24				Nil				Nil				-
27				Nil				Nil				-
30				Nil				Nil				-
33				Nil				Nil				-
36				R2				R2				R2

R2: Rejected due to the deterioration of odor.
N.D: Not determined.

Table (5): Effects of gamma irradiation and cold storage (4±1°C) on food borne pathogens of baked fish.

Storage (days)	Microbial determinations / Irradiation dose (KGy)															
	Staphylococcus aureus **(cfu/g)**				***Enterococcus faecalis*** **(cfu/g)**				**Presence of *Salmonella***				***Vibrio.*** **sp. (cfu/g)**			
	0.0	**1.5**	**3.0**	**4.5**	**0.0**	**1.5**	**3.0**	**4.5**	**0.0**	**1.5**	**3.0**	**4.5**	**0.0**	**1.5**	**3.0**	**4.5**
0	$6.3x10^2$	9.0x10	Nil	Nil	$8.2x10^2$	5.0x10	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
3	$9.5x10^2$	$2.6x10^2$	Nil	Nil	$3.7x10^3$	$2.9x10^2$	Nil	Nil	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
6	R3	$5.2x10^2$	Nil	Nil	R3	$4.5x10^2$	Nil	Nil	R3	-	-	-	R3	-	-	-
9		$8.3x10^2$	Nil	Nil		$6.8x10^2$	Nil	Nil		-	-	-		-	-	-
12		$1.7x10^3$	Nil	Nil		$8.5x10^2$	Nil	Nil		-	-	-		-	-	-
15		R2	Nil	Nil		R2	Nil	Nil		R2	-	-		R2	-	-
18			Nil	Nil			Nil	Nil			-	-			-	-
21			R2	Nil			R2	Nil			R2	-			R2	-
24				Nil				Nil				-				-
27				Nil				Nil				-				-
30				R2				R2				R2				R2

R2: Rejected due to the deterioration of odor.
R3: Rejected due to increasing the total bacterial count to more than $1x10^7$ cfu/g.
N.D: Not determined

Table (6): Effects of gamma irradiation and cold storage (4±1°C) on food borne pathogens in cooked rice.

Microbial determinations	Storage (days)	Irradiation dose (KGy)			
		0.0	1.5	3.0	4.5
Staphylococcus aureus (cfu/g)	0	$4.7x10^2$	3.0x10	Nil	Nil
	3	$5.9x10^2$	$1.4x10^2$	Nil	Nil
	6	$7.2x10^2$	$2.3x10^2$	Nil	Nil
	9	R2	$3.4x10^2$	Nil	Nil
	12		R2	Nil	Nil
	15			R2	Nil
	18				R2
Enterococcus faecalis (cfu/g)	0	$3.5x10^4$	$1.7x10^3$	Nil	Nil
	3	$5.4x10^4$	$2.6x10^3$	Nil	Nil
	6	$7.6x10^4$	$4.9x10^3$	Nil	Nil
	9	R2	$6.2x10^3$	Nil	Nil
	12		R2	Nil	Nil
	15			R2	Nil
	18				R2
Presence of *Salmonella*	0	Nil	Nil	Nil	Nil
	3	N.D	N.D	N.D	N.D
	6	-	-	-	-
	9	R2	-	-	-
	12		R2	-	-
	15			R2	-
	18				R2

R2: Rejected due to the deterioration of odor , N.D: Not determined.

Enterococcus faecalis, while the organism was completely eliminated in samples irradiated at dose of 3 or 4.5 KGy as it was not detected post treatments and during storage.

- *Salmonella* and *Vibrio sp.* :

Salmonella was not detected in all irradiated and non-irradiated samples of ready-to-eat meals under investigation. Moreover, samples of irradiated and non-irradiated baked fish showed no viable counts for *Vibrio* sp. Therefore, samples were not further examined for these micro-organisms during storage. Similar results were observed by Patterson et al., (1998). The absence of *Salmonella* and *Vibrio* sp. in ready-to-eat samples undertaken may be due to the care that taken to avoid cross contamination during their preparation (or the absence of *Vibrio* sp. in the raw fish). It is well known that cross-contamination (from raw to cooked foods) is one of the most important causes of the presence of *Salmonella* in the cooked foods.

In general, there are no standards or specifications for such ready-to-eat meals and the published guidelines for their microbiological quality are widely differed. In control non-irradiated samples under investigation, the observed counts for some food borne pathogenic bacteria may be relatively low. However, these counts did not agree, for instance, with the safety requirements of the European Airlines (AEA, 1996). The observed results clearly indicate that irradiation at dose of 3 KGy appeared to be the optimum for improving the quality of such ready-to-eat meals to agree with any safety requirements.

Chemical properties :

1- Proximate composition :

The moisture contents in samples of non-irradiated baked chicken meat, baked fish and cooked rice were 68.93, 70.34 and 60.43%, respectively, while their contents from total lipids, crude protein, ash and total carbohydrates amounted to 11.84, 9.87 and 9.97%, 80.53, 85.60 and 4.57%, 5.24, 4.41 and 2.19% and 2.39, 0.12 and 22.27%, respectively, on dry weight basis. Irradiation treatments of samples undertaken at the different applied doses had no measurable effects on their proximate chemical composition (table 7). Similar findings were observed by Badr (1998).

2- pH

Gamma irradiation at the ascending applied doses induced no real changes in the pH value of baked chicken meat, baked fish and cooked rice samples. However, cold storage induced gradual slight decreases in the pH value for both irradiated and non-irradiated samples (table 8). The observed decreases in the pH of samples during their storage may be due to the formation of acid compounds that may be attributed to the activity of lactic acid bacteria. The radio-resistance of some strains of lactic acid bacteria was documented (ICMSF, 1980).

3- Thiobarbituric acid (TBA) of the baked muscle samples :

Exposing samples of baked chicken and fish meat to the ascending doses of gamma irradiation markedly increased their TBA values (O.D at 538 nm) as compared to values of control samples. Moreover, the values of TBA showed another gradual increases during cold storage of irradiated and non-irradiated amples (table 9). These results agree with the findings of Lacroix et al., (2004). The increase in TBA values for irradiated samples may be mainly attributed to the indirect effects of irradiation through the liberation of free radicals upon radiolysis of water which enhance the oxidation of lipids (Nawar, 1972), while cooked meat is highly susceptible to oxidation (Ahn et al., 1999).

Table (6): Effects of gamma irradiation and cold storage (4±1°C) on food borne pathogens in cooked rice.

Microbial determinations	Storage (days)	Irradiation dose (KGy) 0.0	1.5	3.0	4.5
Staphylococcus aureus (cfu/g)	0	$4.7x10^2$	3.0x10	Nil	Nil
	3	$5.9x10^2$	$1.4x10^2$	Nil	Nil
	6	$7.2x10^2$	$2.3x10^2$	Nil	Nil
	9	R2	$3.4x10^2$	Nil	Nil
	12		R2	Nil	Nil
	15			R2	Nil
	18				R2
Enterococcus faecalis (cfu/g)	0	$3.5x10^4$	$1.7x10^3$	Nil	Nil
	3	$5.4x10^4$	$2.6x10^3$	Nil	Nil
	6	$7.6x10^4$	$4.9x10^3$	Nil	Nil
	9	R2	$6.2x10^3$	Nil	Nil
	12		R2	Nil	Nil
	15			R2	Nil
	18				R2
Presence of *Salmonella*	0	Nil	Nil	Nil	Nil
	3	N.D	N.D	N.D	N.D
	6	-	-	-	-
	9	R2	-	-	-
	12		R2	-	-
	15			R2	-
	18				R2

R2: Rejected due to the deterioration of odor , N.D: Not determined.

Enterococcus faecalis, while the organism was completely eliminated in samples irradiated at dose of 3 or 4.5 KGy as it was not detected post treatments and during storage.

- *Salmonella* and *Vibrio sp.* :

Salmonella was not detected in all irradiated and non-irradiated samples of ready-to-eat meals under investigation. Moreover, samples of irradiated and non-irradiated baked fish showed no viable counts for *Vibrio* sp. Therefore, samples were not further examined for these micro-organisms during storage. Similar results were observed by Patterson et al., (1998). The absence of *Salmonella* and *Vibrio* sp. in ready-to-eat samples undertaken may be due to the care that taken to avoid cross contamination during their preparation (or the absence of *Vibrio* sp. in the raw fish). It is well known that cross-contamination (from raw to cooked foods) is one of the most important causes of the presence of *Salmonella* in the cooked foods.

In general, there are no standards or specifications for such ready-to-eat meals and the published guidelines for their microbiological quality are widely differed. In control non-irradiated samples under investigation, the observed counts for some food borne pathogenic bacteria may be relatively low. However, these counts did not agree, for instance, with the safety requirements of the European Airlines (AEA, 1996). The observed results clearly indicate that irradiation at dose of 3 KGy appeared to be the optimum for improving the quality of such ready-to-eat meals to agree with any safety requirements.

Chemical properties :

1- Proximate composition :

The moisture contents in samples of non-irradiated baked chicken meat, baked fish and cooked rice were 68.93, 70.34 and 60.43%, respectively, while their contents from total lipids, crude protein, ash and total carbohydrates amounted to 11.84, 9.87 and 9.97%, 80.53, 85.60 and 4.57%, 5.24, 4.41 and 2.19% and 2.39, 0.12 and 22.27%, respectively, on dry weight basis. Irradiation treatments of samples undertaken at the different applied doses had no measurable effects on their proximate chemical composition (table 7). Similar findings were observed by Badr (1998).

2- pH

Gamma irradiation at the ascending applied doses induced no real changes in the pH value of baked chicken meat, baked fish and cooked rice samples. However, cold storage induced gradual slight decreases in the pH value for both irradiated and non-irradiated samples (table 8). The observed decreases in the pH of samples during their storage may be due to the formation of acid compounds that may be attributed to the activity of lactic acid bacteria. The radio-resistance of some strains of lactic acid bacteria was documented (ICMSF, 1980).

3- Thiobarbituric acid (TBA) of the baked muscle samples :

Exposing samples of baked chicken and fish meat to the ascending doses of gamma irradiation markedly increased their TBA values (O.D at 538 nm) as compared to values of control samples. Moreover, the values of TBA showed another gradual increases during cold storage of irradiated and non-irradiated amples (table 9). These results agree with the findings of Lacroix et al., (2004). The increase in TBA values for irradiated samples may be mainly attributed to the indirect effects of irradiation through the liberation of free radicals upon radiolysis of water which enhance the oxidation of lipids (Nawar, 1972), while cooked meat is highly susceptible to oxidation (Ahn et al., 1999).

Table (7): Chemical composition of irradiated and non-irradiated baked de-boned chicken meat, baked fish and cooked rice.

Components	Percentages/Irradiation dose (KGy)											
	Baked de-boned chicken meat				Baked fish				Cooked rice			
	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5
Moisture	68.93	69.17	68.97	69.15	70.34	70.26	70.77	70.56	60.43	60.24	60.37	60.35
Total lipids*	11.84	11.72	11.68	11.75	9.87	9.93	9.57	9.96	9.97	10.09	9.99	10.12
Crude protein*	80.53	80.68	80.72	80.65	85.60	85.59	85.87	85.57	4.57	4.66	4.63	4.64
Ash content*	5.24	5.27	5.22	5.26	4.41	4.37	4.43	4.35	2.19	2.23	2.24	2.21
Total carbohydrates*	2.39	2.33	2.38	2.34	0.12	0.11	0.13	0.12	22.27	83.02	83.14	83.03

* *Calculated on dry weight*

Table (8): Effects of gamma irradiation and cold storage (4±1°C) on pH-value of baked de-boned chicken meat, baked fish and cooked rice.

Meal component	Storage (days)	pH-value/ Irradiation dose (KGy)			
		0.0	1.5	3.0	4.5
Baked de-boned chicken meat	0	6.19	6.05	6.02	5.95
	3	6.07	6.05	6.02	5.95
	6	5.97	6.00	6.02	5.90
	9	5.94	5.94	5.96	5.87
	12	R2	5.81	5.87	5.80
	15		5.73	5.79	5.78
	18		R2	5.64	5.72
	21			R2	5.66
	24				5.59
	27				5.54
	30				5.48
	33				5.40
	36				R2
Baked fish	0	5.75	5.75	5.75	5.75
	3	5.59	5.63	5.68	5.70
	6	R3	5.54	5.52	5.69
	9		5.39	5.45	5.57
	12		5.18	5.32	5.42
	15		R2	5.24	5.34
	18			5.02	5.22
	21			R2	5.13
	24				5.07
	27				5.03
	30				R2
Cooked rice	0	5.53	5.53	5.53	5.53
	3	5.42	5.47	5.50	5.52
	6	5.37	5.38	5.42	5.45
	9	R2	5.35	5.33	5.38
	12		R2	5.24	5.28
	15			R2	5.17
	18				R2

R2: Rejected due to the deterioration of odor.
R3: Rejected due to increasing the total bacterial count to mcre than $1x10^7$ cfu/g.

Table (9): Changes in thiobarbituric acid (as optical density at 538 nm) during cold storage (4±1°C) of irradiated and non-irradiated baked de-boned chicken meat and baked fish.

Meal muscle component	Storage (days)	TBA/ Irradiation dose (KGy)			
		0.0	1.5	3.0	4.5
Baked de-boned chicken meat	0	0.012	0.014	0.024	0.029
	3	0.015	0.018	0.031	0.036
	6	0.023	0.022	0.037	0.045
	9	0.028	0.031	0.044	0.054
	12	R2	0.036	0.049	0.060
	15		0.046	0.055	0.064
	18		R2	0.060	0.071
	21			R2	0.079
	24				0.086
	27				0.094
	30				0.096
	33				0.103
	36				R2
Baked fish	0	0.028	0.029	0.044	0.053
	3	0.035	0.033	0.048	0.056
	6	R3	0.038	0.052	0.060
	9		0.045	0.056	0.066
	12		0.049	0.060	0.071
	15		R2	0.063	0.075
	18			0.067	0.082
	21			R2	0.086
	24				0.092
	27				0.098
	30				R2

R2: Rejected due to the deterioration of odor.
R3: Rejected due to increasing the total bacterial count to more than $1x10^7$ cfu/g.

Sensory properties :

Sensory evaluation is still the best means in determining the acceptability of any food product and being the final guide to assure its acceptability. Irradiation of ready-to-eat samples under investigation could not affect their appearance as irradiated and non-irradiated samples and showed similar high scores of preference for their appearance. In addition, cold storage had no adverse effects on the appearance of all samples including those rejected due to either the deterioration of odor or increasing their total bacterial count to more than $1x10^7$ cfu/g (table 10). Similar results were observed by Stevenson et al., (1995).

Table (10): Sensory attributes for appearance and odor of baked de-boned chicken meat with potato slices, baked fish and cooked rice as affected by gamma irradiation and cold storage (4±1°C).

Meal component	Storage (days)	Mean of scores/ Irradiation dose (KGy)							
		Appearance				Odor			
		0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5
Baked de-boned chicken meat with potato slices	0	8.4	8.3	8.3	8.3	8.3	8.3	7.8	7.9
	3	8.4	8.3	8.3	8.3	7.5	8.2	7.8	7.8
	6	8.2	8.3	8.3	8.3	6.8	8.2	7.8	7.8
	9	7.8	8.2	8.2	8.3	6.5	7.6	7.6	7.6
	12	7.5 R2	8.2	8.2	8.3	3.2 R2	7.5	7.6	7.6
	15		7.9	8.7	8.2		6.7	6.9	7.6
	18		7.3 R2	7.6	8.2		3.1 R2	6.8	7.5
	21			7.2 R2	8.2			3.3 R2	7.5
	24				8.2				7.3
	27				7.8				6.9
	30				7.8				6.8
	33				7.6				6.5
	36				7.4 R2				3.2 R2
Baked fish	0	8.7	8.5	8.5	7.9	8.9	8.7	7.8	7.6
	3	8.7	8.5	8.5	7.7	8.7	8.7	7.8	7.5
	6	8.5 R3	8.5	8.5	7.6	8.5 R3	8.5	7.5	7.5
	9		8.2	8.5	7.6		8.5	7.5	7.3
	12		7.9	8.2	7.4		7.6	7.5	7.3
	15		7.5 R2	8.2	7.4		3.1 R2	7.3	7.3
	18			7.8	7.3			6.5	7.3
	21			7.6 R2	7.3			3.2 R2	7.2
	24				7.6				7.2
	27				7.6				7.2
	30				7.3 R2				3.2 R2
Cooked rice	0	8.9	8.3	7.9	7.9	8.7	7.9	7.8	7.8
	3	8.9	8.3	7.9	7.9	8.7	7.6	7.5	7.6
	6	8.7	8.3	7.9	7.9	8.5	7.5	7.4	7.6
	9	8.5 R2	7.8	7.6	7.9	3.2 R2	7.5	7.3	7.4
	12		7.3 R2	7.5	7.6		3.4 R2	7.3	7.4
	15			7.2 R2	7.6			3.2 R2	7.2
	18				7.4 R2				3.2 R2

R2: Rejected due to the deterioration of odor.
R3: Rejected due to increasing the total bacterial count to more than $1x10^7$ cfu/g.

Table (11): Effects of gamma irradiation on the taste of baked de-boned chicken meat with potato slices, baked fish and cooked rice.

Meal Component	Mean of scores / Irradiation dose (KGy)			
	0.0	1.5	3.0	4.5
Baked de-boned chicken meat with potato slices	8.7	8.5	8.4	8.3
Baked fish	8.8	8.6	8.5	8.5
Cooked rice	8.6	8.3	8.1	7.9

Table (10) shows that exposing ready-to-eat meals to gamma irradiation had no adverse effects on the odor of samples as recorded by the panelists. These results agree with other findings of Anon (1995) and Bari et al., (2000). Upon cold storage, samples of non-irradiated baked chicken meat with potatoes showed similar high scores till the detection of sour off odor and their rejection on day 12 of storage. Irradiation of samples at doses of 1.5, 3 and 4.5 KGy could retard their rejection due to the same reason after 18, 21 and 36 days, respectively. Samples of non-irradiated baked fish were scored as very good samples till their rejection due to increasing their total bacterial count to more than $1x10^7$ cfu/g on day 6 of storage, however, the rejected samples were still showed very good scores for odor. Meanwhile, baked fish samples that received the ascending doses of irradiation showed similar high scores for their odor till their rejection due to the sour odor on days 15, 21 and 30 of storage. Regarding cooked rice, non-irradiated samples as well as those irradiated at 1.5, 3 and 4.5 KGy showed similar high scores for their odor till the detection of the sour odor and their rejection on days 9, 12, 15 and 18 of cold storage. The sour odor may be attributed to the activity of *Micrococcus, Lactobacillus* and *Microbacterium* species (Banwart, 1981).

On the other hand, non-irradiated ready-to-eat samples as well as those exposed to gamma irradiation showed similar high scores of acceptability for their taste indicating that irradiation treatments had no adverse effects on the taste of the prepared ready-to-eat meals (table 11).

CONCLUSION

It could be concluded that the application of gamma irradiation at dose of 3 KGy can be an effective mean for eliminating the harmful bacteria in samples of ready-to-eat meals leading to the improvement of their quality with the extension of their cold storability without any adverse changes in the acceptability of their chemical or sensory properties.

REFERENCES

AEA, Association of European Airlines, Routine microbiological standards for aircraft ready food, In: Hygiene Guidelines, p. 9-13, Brussels, Belgium (1996).

Ahn, D.U., Olson, D.G., Jo, C. L. and Jin, S.K., J. Food Sci., 64 (2), 226-229 (1999).

Anon, Food Irradiation Newsletter, 19 (2), International Atomic Energy Agency, Vienna (1995).

AOAC, Association of Official Analytical Chemists, Official Methods of Analysis, 17th ed., AOAC International, Maryland, USA (2000).

APHA, Compendium of Methods for the Microbiological Examination of Foods, 3rd ed., American Public Health Association, Washington D.C (1992).

Ayçiçek, H., Sarimehmetoçu, B. and Çakiroçu, S., Food Cont., 15, 379-384 (2004).

Badr, H.M., Studies on some irradiated food products, Ph. D. Thesis, Fac. of Agric., Zagazig Univ., Egypt (1998).

Badr, H.M., Meat Sci., 67, 541-548 (2004).

Banwart, G.L., Basic Food Microbiology, A bridged text book, AVI Publishing Company, Inc., Westport (1981).

Barakat, R.K., Griffiths, M.W. and Harris, L.J., Int. J. Food Micrbiol., 62, 83-94 (2000).

Bari, M.L., Sabina, Y., Kusunoki, H. and Uemura, T., J. Food Prot., 63 (1), 56-62 (2000).

Bergdoll, M.S., Staphylococcal food poisoning, Cliver, D.O. (ed.). Food borne diseases, Academic Press, San Diego, p. 85-106 (1990).

Carballo, J., Moto, N., Barreto, G. and Jimenez, F., Meat Sci., 41, 301-313 (1995).

Dubois, M., Smith, F., Gilles, K.A., Hamilton, J.K. and Robers, P.A., Anal. Chem., 28 (3), 350-356 (1956).

Egan, H., Kirk, R.S. and Sawyer, R., Pearson's chemical analysis of foods, 8th ed., Churchill Livingstone, Edinburg (1981).

Eleftheriadou, M., Varnava, A., Metta, M., Nikolaou, A. and Akkelidou, D., Food Microbiol., 19, 463-471 (2002).

Fang, T.J., Wei, Q., Liao, C., Hung, M. and Wang, T.H., Int. J. Food Microbiol., 80, 241-250 (2003).

Grant, LR. and Patterson, M.F., Food Microbiol., 9, 95-103 (1992).

Herbert, D., Phipps. P.J. and Strange, R.E., Determination of total carbohydrates, Methods in Microbiology, p. 209-244 (1971).

Hilliam, M. and Boyle, C., World of Ingredients, May/June, 8-9, 11 (1996).

IAEA, Microbiological specification and testing methods for irradiated foods, Tech. Rep. Ser. No. 104, International Atomic Energy Agency, Vienna (1970).

ICMSF, International Commission on Microbiological Specifications for Foods, Microbial ecology of foods, Vol. l, Factors affecting life and death of microorganisms, Academic Press, New York (1980).

IOS, International Organization for Standardization, Microbiology: General guidance for enumeration microorganisms, IOS - 4833 (1978).

Jablonski, L.M. and Boach, G.A., *Staphylococcus aureus*, Doyle, M.P., Beuchat, L.R. and Montville, T.J. (eds.), Food microbiology: Fundamentals and frontiers, ASM press, Washington D.C, p. 353-375 (1997).

Jackson, T.C., Acuff, G.R. and Dickson, J.S., Meat, Poultry and Seafood, Doyle, M.P., Beuchat, L.R. and Montivlle, T.J. (eds), Food Microbiology, Fundamentals and Frontiers, ASM Press, Washington, D.C., p. 83-100 (2001).

Käferstein, F.K., World Health Stat., Q. 50 (1-2), 3-4 (1997).

Koburger, J.A. and Marth, E.H., Yeasts and molds, Speck, M. (ed.), Compendium of methods for the microbiological examination of foods. 2nd ed., APHA, Washington D.C., p. 197-202 (1984).

Lacroix, M., Ouattara, B., Saucier, L., Giroux, M. and Smoragiewicz, W., Radiat. Phys. Chem., 71 (1-2), 73-77 (2004).

Lee, J.V., Vibrio, Aeromonas and Plesiomonas. Parker, M.T. and Duerden, B.I. (eds), Principles of bacteriology, virology and immunity, vol. 2, Systematic bacteriology, Edward Arnold, London, 8th ed., p. 513-530 (1990).

Lee, J.W., Park, K.S., Kim, J.G., Oh, S.H., Lee, Y.S., Kim, J.H. and Byun, M.W., Radiat. Phys. Chem., 72 (1), 49-56 (2005).

Motarjemi, Y., Kaferstein, F., Moy, G., Miyagawa, S. and Miyag, K., Food Cont., 7, 77-85 (1997).

Nawar, W. W., Rad. Res. Rev., 3, 327-232 (1972).

O'Leary, E., Gormley, T.R., Butler, F. and Shilton, N., Lebensmittel Wissenschaft und Technologie, 33, 217-224 (2000).

Oxoid, The Oxoid Manual of Culture Media, Ingredients and Other Laboratories Services, 5th ed., Oxoid Limited, Hampshire, England (1982).

Oxoid, The Oxoid Manual, 8th ed., Oxoid Limited, Hampshire, England (1998).

Patterson, M.F., Stevenson, M.H., Grant, LR., McAteer, N.J. and Stewart, E.M., Combination process for food irradiation, Proceedings of the Final Research Co-ordination Meeting, IAEA, Vienna, Austria, p. 159-179 (1998).

Pearson, A.M. and Gillett, T.A., Processed meats, 3rd ed., Chapman and Hall, New York (1996).

Redmond, G.A., Gormley, T.R. and Butler, F., Innovative Food Sci. Emerg. Tech., 5, 65-72 (2004).

Roberts, D., Hooper, W. and Greenwood, M., Practical Food Microbiology, PHLS, London (1995).

Roybka, S., Food Res. Int., 34 (5), 449-455 (2001).

Satin, M., Meat Sci., 62, 277-283 (2002).

Stevenson, M.H., Stewart, E.M. and McAtter, N.J., Radiat. Phys. Chem., 46 (4-6), 785-788 (1995).

Tarladgis, B.G., Watts, B.M. and Younathan, M.T., J. Am. Oil Chem. Soc., 37, 44-48 (1960).

Tatini, S.R., Hoover, D.G. and Lachica, R.V.F., Methods for the isolation and enumeration of *Staphylococcus aureus*, Speck, M. (ed.), Compendium of methods for the microbiological examination of foods, 2nd ed., APHA, Washington D.C., p. 41 I-427 (1984).

Todd, E.C., Epidemiology and globalization of food borne disease, Labbe, R.G. and Garcla, S. (eds.), Guide to food borne pathogens, Wiely lnterscience, New York, p. 1-22 (2001).

Wierbicki, E., Food Irradiation Processing, IAEA, Vienna, Austria, p. 79-99 (1985).