Microbiological Load and Quality Characteristics of Irradiated Chicken Meat

Mahfouth Al-Bachir
Radiation Technology Dep. Syrian Atomic Energy Commission,
P O Box: 6091, Damascus, Syria,
E-mail: Scientific@aec.org.syy

ID # (2719)
Received: . 03/02/2013
In-revised: 03/03/2013
Corresponding Author:
Mahfouth Al-Bachir
E-mail: Scientific@aec.org.syy

KEYWORDS

Chicken meat, Gamma irradiation, Microbiological load, Sensory evaluation, Shelf life.

ABSTRACT

The present study was conducted to evaluate the combined effect of gamma irradiation and refrigeration on the microbiological, chemical and sensorial characteristics of raw chicken meat. Chicken meat was irradiated at doses of 0, 2, 4 and 6 kGy of gamma irradiation, and kept in a refrigerator (1-4^{o}C). General composition, microbial, chemical and sensory evaluation of chicken meat was done. Results showed that, all used doses of gamma irradiation reduced the total mesophilic aerobic plate counts (TPCs) and total coli forms of chicken meat. Shelf-life extension periods estimated on the basis of a limit of 6 log CFU/g for TPCs were 2, 4, 9, and more than 13 weeks for samples irradiated at 0, 2, 4, and 6 kGy, respectively. Irradiation had little or no effect on general composition (moisture, protein, and fat contents), total acidity, lipid peroxide and total volatile basic nitrogen. Sensory evaluation showed no significant differences between irradiated and non-irradiated chicken meats.

الحُمولة الميكروبية والخَصَائص النَوعية للحوم الفروج المُشـعَعَة

محفوظ البشير
قسم تكنولوجيا الإشعاع، الهيئة السورية للطاقة الذرية
ص ب 6091 دمشق، سوريا
بريد إلكتروني: Scientific@aec.org.syy

رقم المسودة: # (2719)
تاريخ إستلام المسودة: 2013/02/03
تاريخ المسودة المُعَدَلة: 2013/03/03
الباحث المُرَاسَل: محفوظ البشير
بريد إلكتروني:
Scientific@aec.org.syy

الكلمات الدالة

لحم فروج، أشعة غاما، حمولة ميكروبية، تقويم حسي، مدة غرض.

المُستلخص

نفذت هذه الدراسة بهدف تقويم التأثير المشترك لكل من أشعة غاما والتبريد في الخصائص الميكروبية والكيميائية والحسية للحم الفروج الطازج. عرض لحم الفروج للجرع 0 و2 و4 و6 كيلو غري من أشعة غاما، وحفظ في البراد (بدرجة حرارة تراوحت بين 1 و 4^{o}م). حددت المكونات العامة والحمولة الميكروبية والخصائص الكيميائية والحسية للحم الفروج. بينت النتائج، أن كل الجرع الإشعاعية المستخدمة من أشعة غاما قد خفض العدد الكلي للميكروبات النامية في وسط هوائي ومجموع الكوليفورم في لحم الفروج. لقد كانت مدد فترات العرض المحددة بقاعدة وصول الحمولة الميكروبية إلى 6 دورات لوغاريتمية لعدد الميكروبات في الغرام 2 و 4 و 9 وأكثر من 13 أسبوع للعينات المعرضة للجرع 0 و 2 و 4 و 6 كيلو غري على التتالي. لقد كان للتشعيع تأثير طفيف أو معدوم في المكونات العامة (محتوى الرطوبة والبروتين والدهن)، والحموضة الكلية، وأكسدة الدهون، والازوت القاعدي الطيار. ولم تظهر فروق معنوية في الخصائص الحسية بين لحم الفروج المعالج وغير المعالج بالأشعة.

Introduction

Microbiological contamination of meat is a concern, for both meat producers and consumers. In developed as well as developing countries, an increase in the incidence of food –borne diseases, especially of animal origin, has been noticed (Mayer-Miebach *et al.* 2005). Also, different methods for decreasing the microbial flora under a standard allowance for increasing the shelf-life and decontamination of microbial pathogens have been proposed. An alternative approach could be the use of medium dose irradiation to improve the microbiological safety and shelf-life of meat (Al-Bachir and Zeino, 2009).

Radiation processing of meat is recognized as a safe and effective method among the existing technologies for meat and meat products preservation (Al-Bachir, 2007). A number of investigators have shown that irradiation is effective in eliminating food borne pathogens associated with poultry (Lacroix, 2006). In addition, other researchers have investigated the effect of gamma irradiation on microbial, sensory, and nutritional qualities of chicken carcasses (Javanmard et al. 2006), and chicken *Kabab* (Al-Bachir *et al.* 2010). However, wide acceptability of radiation processed meat products will depend upon quality parameters, such as oxidative changes, color stability and organoleptic attributes, (*Sweetie et al.* 2006); (Al-Bachir *et al.* 2010). Chicken meat is considered one of the most important food of animal production in Syria. The production increased from 65000 tons in 1995 to 150000 tons in 2005 (Syrian Statistical Abstract, 1996; 2006). However, no information is available on safety and quality of chicken meat produced in Syria and using irradiation to improve its meat quality and storability. Therefore, the objective of this study was to evaluate the quality of chicken meat produced under local condition, and to investigate the effect of using gamma irradiation on shelf-life, sensory and chemical properties of chicken meat.

Materials and Methods

Materials

Chicken meat was obtained from a commercial supplier. Each carcass of chicken was transferred into polyethylene bags, each bag is considered as replicate. All bags were divided into four groups, one group as control and other three for treating with gamma irradiation.

Methods

(1) Irradiation and Analysis Performed after Processing

Samples from packed chicken meat were exposed to gamma radiation at doses of 0, 2, 4 and 6 kGy in a ^{60}CO package irradiator (dose rate 730 Gy/h). The irradiation was performed at room temperature (15–20°C). The absorbed dose was determined using alcoholic chlorobenzene dosimeter. Ethanol chlorobenzene is prepared in our lab by mixing 24 ml chlorobenzene, 4 ml distilled water, 0.04 ml acetone, 0.04 ml benzene to 100 ml ethanol. The absorbed dose is determined by the measurement of chloride ions or hydrogen ions by means Oscillotitrator (OK-302/2, Radelkisz, Budapest, Hungary) (Cserep *et al.* 1971). For each treatment, 20 bags of chicken meat were allocated and all were stored at 1–4°C temperature. Microbiological and chemical analyses were performed on controls and treated samples immediately after irradiation, and weekly throughout the storage period, which lasted 3 months. Sensory evaluation and proximate analysis were done within two days of irradiation.

(2) Microbiological Evaluation

Before irradiation and in order to determine the survival curves, the chicken meat was artificially inoculated by thoroughly mixing it with a pure culture of *Salmonella spp* and *Escherichia coli.* The used *Salmonella spp* and *E. coli* have been isolated in our lab from contaminated local food. The above mentioned strains were identified by biochemical identification test. The initial numbers of artificial contamination were 1.2×10^{7} and 2.0×10^{6} CFU g^{-1} for *Salmonella spp* and *E. coli* respectively. The survival curve was estimated from irradiation doses of 0.2, 0.4, 0.6, 0.8 and 1.0 kGy. The survival level of *Salmonella spp* was determined by plate counting on Xylose Lysine Desoxycholate Agar (XLD) (Biolife, 402206, Italy) and the survival level of *E. coli* was determined by plate counting on Eosin Methylene Blue Agar (EMBA) (Oxoid, CM 69, UK), after 2 days of incubation at 37°C.

Three replicates from each treatment, irradiated and non-irradiated were aseptically opened, and 10g of whole chicken meat were transferred to a sterilized glass bottle containing 90ml of sterile physiological water (9g kg^{-1}NaCl). The bottle was shaken to homogenize the sample. Further dilutions were made as far as 10^6 by (AOAC, 2010) method. The media used for the microbiological study were nutrient agar (Oxoid, CM 325, UK), for the total (mesophilic aerobic) plate counts (TPCs) (48 h incubation at 30°C). A cut-off value of 10^7 CFU g^{-1} for TPCs (Ayres, 1960), was used for the unacceptable samples, and no further analyses were carried out when those indicator values were exceeded. Total coliform were determined on Violet Red Bile Agar (VRBA) (Oxoid, CM 485, UK) at 37°C for 48 hrs.

(3) Chemical and Physical Analysis

Approximately 150g of chicken meat were blended for 15s in a laboratory blender, and the mixture was used in all the chemical analysis. Each sample was homogenized and analyzed in triplicates to determine moisture (drying for 6hrs at 105°C, and ashing for 4 hrs at 550°C), fat (as extractable component in Soxhlet apparatus, Glas-Col, U.S.A.), protein (as Kjeldahl nitrogen) using standard methods (AOAC, 2010). pH values of the solutions of chicken meat were determined using an HI 8521 pH meter (Hanna Instruments, Woonsocket, RI, USA).

The total acidity was obtained by a direct titration with (0.1 N) NaOH and phenolphthalein as an indicator (Egan *et al.* 1981). The total acidity was calculated as ml of (0.1 N) NaOH = 0.0090g lactic acid. Lipid peroxidation in terms of g iodine $100g^{-1}$ fat of chicken meat was determined by the modified method of (Buege and Aust,1978). Total volatile basic nitrogen (VBN) in the sample in term of mg VBN per kg chicken meat (ppm) was determined by the method of (Pearson, 1976).

(4) Sensory Evaluation

The sensorial criteria, especially the taste, flavor (odor), color and texture of the irradiated and non-irradiated chicken meat were evaluated within two days of irradiation. Each untrained panelist received four coded samples (one non-irradiated and three irradiated samples; one at each dose). All the chicken meat was tasted by 25 people. Before testing, all samples of chicken were fried in fat for 5 min. Each member independently evaluated the chicken meat for taste, flavor (odor), color and texture on a 5- point hedonic scale (1: extremely poor, 2: poor, 3: acceptable, 4: good, 5: excellent), according to (Al-Bachir *et al.* 2010).

(5) Statistical Analysis

The four treatments were distributed in a completely randomized design with three replicates. The data were subjected to the analysis of variance test (ANOVA) using the SUPERANOVA computer package (Abacus Concepts Inc, Berkeley, CA, USA; 1998). A separation test on treatment means was conducted using Fisher's least significant differences (LSD) methods (Snedecor and Cochran, 1988) at 95% confidence level.

Results and Discussion

(1) Effect of Gamma Irradiation on Characteristics of Chicken Meat

The average moister, protein, fat, ash, and pH value of the chicken meat is given in table 1. The mean chicken meat characteristics were: moisture 67.99±2.36%, protein 17.90±1.22%, fat 10.97±3.90%, ash 2.83±0.92%, and pH value 6.41±0.11%.

Table 1: Effect of Gamma Irradiation on Moisture, Crude Protein, Crude Fat, and Ash (%), and pH Value of Chicken Meat.

Treatment	0kGy	2kG	4kGy	6kGy	LSD5%
Moisture	67.99±2.36	70.16±4.03	66.38±1.22	69.28±1.40	04.73
Protein	17.90±1.22	19.71±0.56	19.19±0.50	20.65±1.16	01.73
Fat	10.97±3.90	07.53±2.20	09.85±0.65	09.94±2.29	04.79
Ash	02.83±0.92	03.65±0.81	09.04±1.14	03.58±0.40	01.62
pH	06.41±0.11	06.69±0.10	09.64±0.10	06.69±0.10	00.15

No significant differences in moisture and fat content of chicken meat were observed due to irradiation. However, gamma irradiation up to 4.5 kGy had no effect on the chemical composition of cooked meat components (Rady *et al.* 2005). Results of the proximate analysis of meat *Borak* showed that irradiation doses of 2, 4, and 6 kGy of gamma irradiation had no significant effect on moisture, protein, and pH value (Al-Bachir, 2007). However, the proximate analysis of chicken meat showed that protein content tend to be increased when the chicken meat was irradiated with 2, 4, and 6 kGy doses of gamma irradiation. The results of pH value were in agreement with total acidity values (table 3). Non-irradiated chicken samples showed lower pH values than irradiated samples, as from the first day of storage (see table 1).

(2) Effect of Gamma Irradiation on Microbiological Quality of Chicken Meat

Results of the microbiological tests in the preliminary studies with chicken meat are summarized in table 2. As with raw meats, non-irradiated chicken meat samples were found to be contaminated with relatively high initial counts of aerobic mesophilic bacteria, and coliform, as their mean log_{10} counts reached 6.02 and 5,38 CFU/g, respectively. This reflects possible cross contamination during slaughter which has a significant effect on the bacterial status of carcasses (Borch and Arinder, 2002).

Table 2. Effect of Gamma Irradiation on the Microbial Load of Chicken Meat Stored at 1-4^{0}C (log_{10} CFU/g)

Treatment	**0kGy**	**2kG**	**4kGy**	**6kGy**
Total Count (log_{10} CFU/g)				
00	6.02±0.20	3.72±0.35	1<	1<
01	6.45±0.21	5.36±0.12	1<	1<
02	7.78±0.34	5.83±0.16	1<	1<
03	Rejected	6.48±0.16	1<	1<
04	Rejected	7.04±0.12	1<	1<
05	Rejected	Rejected	2.63±2.28	1<
07	Rejected	Rejected	6.50±1.03	1<
09	Rejected	Rejected	Rejected	1<
11	Rejected	Rejected	Rejected	2.40±0.11
13	Rejected	Rejected	Rejected	2.72±0.90
Total Coli forms (log_{10} CFU/ g)				
00	5.38±0.08	1<	1<	1<
01	6.14±0.05	1<	1<	1<
02	6.61±0.02	1<	1<	1<
03	Rejected	1<	1<	1<
04	Rejected	1<	1<	1<
05	Rejected	1<	1<	1<
07	Rejected	1<	1<	1<

Data present in table 2, shows the effects of gamma irradiation at 2, 4, and 6 kGy on total aerobic plat counts (TPCs), and total coliform during storage under refrigeration conditions. The efficiency of irradiation on microbiological destruction of TPCs and total coliform was immediate, and the importance of the reduction TPCs and total coliform was proportional to the irradiation doses. At day 1, total counts were reduced by, 3 log unit for 3 kGy and 6 log units for 4 and 6 kGy in chicken meat. According to (Ayres,1960) formula, which used in our study as reference indicator, and according to the (Syrian National Standards, 2179/2000) approved this level as indicator for food products; control samples and samples irradiated with 2 and 4 kGy of chicken meat exceeded the acceptance limit of $10^7 g^{-1}$ TPCs after 2, 4, and 9 weeks of storage at 1–4°C. Samples irradiated at 6 kGy, however, remained acceptable, after more than 13 weeks of storage at 1–4°C. Microbiological Shelf-life extension periods was estimated to from less than two weeks on control to 4, 9, and more than 13 weeks for samples irradiated at 2, 4, and 6 kGy respectively. The decrease in TPCs and increase in shelf-life of chicken meat as a result of irradiation was in agreement with other studies (Spoto *et al.* 2000); (Mahrour *et al.* 2003); and (Al-Bachir *et al.* 2010). Previous work by (Katta et al.,1991) appeared that on irradiation dose of 2.0 kGy or more inactivated 99% of the microbial loads of chicken carcasses. (Javanmard *et al.,* 2006) reported that irradiation with doses of 3 or 5 kGy had significant effect ($p<0.05$) on the reduction of microbial loads of chicken meat.

The survival of *Salmonella spp*. and *E. coli* inoculated in chicken meats were inversely correlated to the irradiation dose. The dose of irradiation needed to decrease by 1 log CFU/g of *Salmonella spp*. and *E. coli* number in chicken meat were 270 and 345 Gy (D_{10} value) respectively. (Al-Bachir *et al.,* 2010) reported that D_{10} values of *Salmonella spp*. and *E coli* in chicken *Kabab* were 213 and 400 Gy respectively. In particular, it is encouraging that a radiation dose of 2.5 kGy was sufficient to eliminate inherent *Salmonella spp*. in chicken meat (Katta *et al.*, 1991). However, among the spices of bacteria in chicken meat the coliforms were most sensitive to gamma irradiation (Mantilla *et al.* 2009).

(3) Effect of Gamma Irradiation on Chemical Quality of Chicken Meat

(3.1) Total Acidity

The total acidity of the chicken meat is shown in table 3. Total acidity content, calculated as lactic acid, was 0.93±0.19%. The total acidity of chicken meat showed a dose dependent decrease on irradiation.

Table 3. Effect of Gamma Irradiation on Total Acidity (Lactic acid%) of Chicken Meat Stored at 1-4° C

Treatment	0kGy	2kG	4kGy	6kGy	LSD5%
Storage period/weeks					
00	0.93±0.19	0.84±0.11	0.77±0.08	0.66±0.17	0.27
01	0.92±0.03	1.11±0.04	0.96±0.11	0.82±0.10	0.15
02	1.04±0.13	1.18±0.03	1.12±0.13	0.92±0.07	0.18
03	Rejected	1.13±0.12	1.02±0.18	0.88±0.04	0.26
04	Rejected	1.58±0.23	1.22±0.13	1.07±0.14	0.34
05	Rejected	Rejected	1.23±0.14	1.04±0.20	0.39
07	Rejected	Rejected	1.32±0.36	1.62±0.33	0.79
09	Rejected	Rejected	Rejected	1.10±0.26	
11	Rejected	Rejected	Rejected	0.92±0.07	

However, refrigerated storage significantly increased ($p<0.05$) their total acidity contents in both irradiated and non-irradiated samples**.** These results concur with other researchers who have also reported a decrease in total acidity of radiation processed meat (Kanatt *et al.,* 1997), and chicken *Kabab* (Al-Bachir *et al.*, 2010). (Sweetie *et al.*, 2006) have reported that meat that are irradiated at a dose of 2.5 or 5.5 kGy show a higher free fatty acid content compared to non-irradiated control samples.

(3.2) Lipid Oxidation

Lipid oxidation was measured in term of g iodine/100g fat of chicken meat. The effect of various level of gamma irradiation on peroxide values is shown in table 4.

Table 4. Effect of Gamma Irradiation on Lipid Oxidation (g Iodine 100 g-1 fat) of Chicken Meat Stored at 1-4° C

Treatment	0kGy	2kG	4kGy	6kGy	LSD5%
Storage period/weeks					
00	0.009±0.001	0.009±0.002	0.007±0.002	0.009±0.001	0.003
01	0.003±0.0001	0.005±0.0002	0.103±0.003	0.005±0.001	0.006
02	0.003±0.0001	0.004±0.0004	0.004±0.0003	0.004±0.001	0.001
03	Rejected	0.002±0.0001	0.001±0.00005	0.003±0.0002	0.0004
04	Rejected	0.002±0.0002	0.002±0.0002	0.001±0.0002	0.00045
05	Rejected	Rejected	0.001±0.0001	0.001±0.0001	0.0003
07	Rejected	Rejected	0.002±0.0002	0.001±0.0001	0.0004
09	Rejected	Rejected	Rejected	0.101±0.008	
11	Rejected	Rejected	Rejected	0.0011±0.0004	

There was no significant ($p>0.05$) difference between irradiated and non-irradiated control groups. In irradiated groups, no significant ($p>0.05$) difference was found as irradiation dose level increased. These results agree with findings of (Javanmard *et al.,* 2006). The peroxide at low irradiation dose (<10 kGy) there was no significant change in any of the meat lipids (Hampson *et al.,* 1996) and meat *Borak* (Al-Bachir, 2007). In contrast, the addition of antioxidants was able to reduce lipid oxidation caused by the irradiation treatment of chicken meat (Brito *et al.,* 2011).

(3.3) Volatile Basic Nitrogen

Effects of gamma irradiation on VBN of chicken meat were compared (Table 5). Irradiation of chicken meat samples had no significant effect ($p<0.05$) on their VBN content. However, refrigerated storage significantly increased ($p<0.05$) their VBN contents in both irradiated and non-irradiated samples (table 5).

Table 5. Effect of Gamma Irradiation on Volatile Basic Nitrogen (ppm) of Chicken Meat Stored at 1-4° C

Treatment	0kGy	2kG	4kGy	6kGy	LSD5%
Storage period/weeks					
00	617.72±44.95	575.85±106.89	549.28±63.34	668.96±51.08	133.36
01	1116.93±73.22	1028.35±172.21	776.78±29.38	724.94±53.42	185.28
02	1116.57±233.07	1064.74±33.22	1028.51±56.10	947.42±133.45	260.18
03	Rejected	1152.99±89.45	1096.37±228.61	849.48±101.50	306.42
04	Rejected	1378.82±247.83	1093.36±64.57	1028.55±71.94	306.85
05	Rejected	Rejected	1134.61±71.58	1133.48±297.20	490.02
07	Rejected	Rejected	2125.69±630.56	2584.76±780.21	1608.05

These results agree with previous observations in chicken meat (Badr, 2004), and chicken *Kabab* (Al-Bachir *et al.,* 2010). (Rady *et al.,* 2002) reported that 4 and 6 kGy of gamma irradiation had no real effect on the total volatile basic nitrogen content of quail carcasses. The volatile basic nitrogen is related to protein breakdown (Egan *et al.,* 1981) and the observed increases through the storage periods may be attributed to the formation of ammonia or other basic compounds due to microbial activity (Badr, 2004).

(4) Effect of Gamma Irradiation on Sensory Quality of Chicken Meat

Table 6 illustrates the results of the initial sensory evaluations carried out for the chicken meat. It was found that immediately after irradiation the overall sensory scores of irradiated and non-irradiated samples were not significantly ($p<0.05$) different. Taste, flavor, texture, and color of irradiated samples were not different from its non-irradiated control and all the samples were acceptable.

Table 6: Effect of Gamma Irradiation on the Sensory Properties of Chicken Meat (5 points scale).

Treatment	0kGy	2kG	4kGy	6kGy	LSD5%
Storage period/weeks					
Taste	2.93±1.15	3.11±1.05	2.64±1.06	2.93±1.15	0.57
Flavor	3.14±1.04	3.25±0.89	3.14±0.97	2.89±1.2	0.55
Color	3.14±0.18	3.32±1.02	2.96±1.11	3.32±0.86	0.56
Texture	3.54±0.88	3.57±0.79	3.21±1.03	3.14±0.89	0.48

(Data represent a 5 point scale ranging from 1 "very bad" to 5"very good")

Our observation is in agreement with (Badr *et al.* ,2005); (Javanmard *et al.,* 2006),; and (Yosof *et al.*, 2009) who have reported that irradiation (3 kGy) did not affect the sensory attributes of the chicken meat. many investigators have studied the effect of gamma irradiation on the sensory characteristics of other meat and meat products. Most of them found no effect of gamma irradiation on sensory quality of tested meat and meat products (Badr *et al.,* 2004); (Al-Bachir *et al*., 2010).

Conclusion

It can be concluded from the results that gamma irradiation at pasteurization doses 4-6 kGy, in combination with refrigeration (1-4°C) could maintain the safety and quality of chicken meat. This combination technology can enhance the shelf-life of chicken meat without chemical and sensory quality changes. Thus, radiation processing could be used to the advantage of processors, retailers and consumers.

Acknowledgment

The author would like to express sincere appreciation to the Director General of the Atomic Energy Commission of Syria and the staff of the division of food irradiation.

References

AL-Bachir M; and **Zeinou R** (2009) Effect of Gamma Irradiation on Microbial Load and Quality Characteristics of Minced Camel Meat. *Meat Science,* **82** (1): 119-124. Available at: http://www.deepdyve.com/lp/elsevier/

AL-Bachir M (2007) Effect of Gamma Irradiation on the Microbial Load, Chemical, and Sensory Properties of *Borak*: Prepared Chilled Meals. *Acta Alimentaria,* **36** (1): 15-25. Available at: http://www.akademial.com/content/d362mx279382281/

AL-Bachir M; Farah S; and **Othman Y** (2010) Influence of Gamma Irradiation and Storage on The Microbial Load, Chemical, and Sensory Quality of Chicken Kabab. *Radiation Physics and Chemistry,* **79** (8): 900-905. Available at: http://www.sciencedirect.com/article/pii/S09806X10001477

AOAC (2010) *Official Methods of Analysis, 15th ed*. Association of Official Analytical Chemists, Washington DC, USA.

Ayres JC (1960) Relationship of Organisms of the Genus Pseudomonas to the Spoilage of Meat, Poultry and Eggs (The). *Journal of Applied Bacteriology,* **23** (3): 471-486. Available at: http://www.onlinelibrary.wiley.com/doi/10.1111/j.1365-

Badr HM; Rady AH; Abdeldaim MH; and **Khalaf H** (2005) Improving the Quality of Ready-to-eat Meals by Gamma Irradiation, Baked De-bond Chicken Meat with Potato Slices or Baked Fish and Cooked Rice. *Isotope and Radiation Research,* **37** (1): 55-75.

Badr HM (2004) Use of Irradiation to Control Food Borne Pathogens and Extend the Refrigerated Market Life of Rabbit Meat. *Meat Science,* **67** (4): 541-548. Available at: http://www.sciencedirect.com/article/pii/0309174003003280

Borch E; and **Arinder P** (2002) Bacteriological Safety Issues in Red Meat and Ready-to-eat Meat Products, as well as Control Measures. *Meat Science,* **62** (3): 381-390. Available at: http://www.sciencedirect.com/article/pii/0309174002001250

Brito PP; Azevedo H; Pomarico-Neto W; Roque CV; and **Brusqui AL** (2011) Effect of Antioxidants on Thiobarbituric Acid Reactive Substances of Mechanically De-boned Chicken Meat Irradiated with Ionizing Radiation: Cobalt-60 and Electron Beam Sources. *Proceedings of International Nuclear Atlantic Conference, Nuclear Energy New Jobs for Better Life*, *24-28 Oct. 2011*. Belo Horizonte, MG (Brazil). pp 6.

Buege JA; and **Aust SD** (1978) Microsomal Lipid Peroxidation. *In: Packer L; and Fleischer S (eds), Methods in Enzymology*. Academic Press, New York, USA. pp52-302.

Cserep G; Fejes P; Foldlak G; Gyorgy I; Horvath ZS; Jakab A; Stenger V; and **Wojnarovits L** (1971) *Chemical Dosimetry Course: A Laboratory and Institute of Isotopes of Hungarian Academy Sciences Budapest*, Hungarian Academy Sciences Budapest, Hungary. pp 27-32

Egan H; Kirk RS; and **Sawyer R** (1981) *Pearson's Chemical Analysis of Foods. 8th ed*. Longman Scientific & Technical, Edinburgh, Churchill Livingstone. UK. pp185-185.

Hampson JW; Fox JB; Lakritz L; and **Thayer DW** (1996) Effect of Low Dose Gamma Radiation on Lipids in Five Different Meats. *Meat Science* , **42** (3): 271-276. Available at: http://www.sciencedirect.com/article/pii/030917409500047x

Javanmard M; Rokni N; Bokaie S; and **Shahhosseini G** (2006) Effect of Gamma Irradiation and Frozen Storage on Microbial, Chemical and Sensory Quality of Chicken Meat in Iran. *Food Control,* **17** (6): 469-473. Available at: http://www.sciencedirect.com/article/pii/S0956713505000575

Kanatt SR; Paul P; Dsouza SF; and **Thomas P** (1997) Effect of Gamma Irradiation on the Lipid Peroxidation in Chicken, Lamb and Buffalo Meat During Chilled Storage. *Journal of Food Safety,* **17** (4): 283-294. Available at: http://www.onlinelibrary.wiley.com/doi/10.1111/j.1745-4565.1997.tb00195.x.

Katta SR; Rao DR; Sunki GR; and **Chawan CB** (1991) Effect of Gamma Irradiation of Whole Chicken Carcasses on Bacterial Loads and Fatty Acids. *Journal of Food Science,* **56** (2): 371-372. Available at: http://www.onlinelibrary.wiley.com/doi/10.1111/j.1365-2621.1991.tb05383.x.

Lacroix M (2006) The Influence of MAP Condition and Active Compounds on the Radiosesitation of *E. Coli* and *Salmonella* Typhi Present in Chicken Breast. *Radiation Physics and Chemistry*, **71** (1/2): 69-72. Available at: http://www.sciencedirect.com/article/pii/S0969806X04002488

Mahrour A; Lacroix M; Nketsa-Tabiri J; Calderon N; and **Gagnon M** (2003) Antioxidant Properties of Natural Substances in Irradiated Fresh Poultry. *Radiation Physics and Chemistry,* **52** (1): 77-80.

Mantilla SPS; Santos EB; Mano SB; and **Franco RM** (2009) Bacteriological Evaluation of Refrigerated Vacuum and Air Packed Chicken Fillets Treated with Irradiation*. In: Proceedings of International Nuclear Atlantic Conference: Innovations in Nuclear Technology for A Sustainable Future, 27th Sep. -2nd Oct. 2009*. Rio De Janeiro, Brazil. pp8.

Mayer-Miebach E; Stahl MR; Eschrig U; Deniaud L; Ehlermann DAE; and **Schuchmann HP** (2005) Inactivation of A Non-Pathogenic Strain of *E. Coli* by Ionizing Radiation. *Food Control,* **16** (8): 701-705. Available at: http://www.sciencedirect.com/article/pii/S0956713504001264

Pearson D (1976) Chemical Analysis of Foods, 7th Ed. (The). Churchill, Livingston, Edinburgh, UK. pp 386-386.

Rady AH; Badr HM; and **Abdel-Daiem MH** (2005) Improving the Quality of Ready-to-eat Meals by Gamma Irradiation: Cooked Meat Balls and Mashed Potatoes. *Isotope and Radiation Research,* **37** (1) 35-54.

Rady AH; Khalaf HH; Afifi EA; and **Nasr EH** (2002) Improving the Microbial Safety and Quality of Quail Carcasses by Gamma Irradiation. *Isotope and Radiation Research,* **34:** 305–313.

Snedecor G; and **Cochran W** (1988) *Statistical Methods*. The Iowa State University Press, Ames, Aiwa, USA. pp 221-221.

Spoto MHF; Alcard AR; Gurgel MSA; Blumer L; Walder JMM; and **Domarco RE** (2000) Gamma Irradiation in the Control of Pathogenic Bacteria in Refrigerated Ground Chicken Meat. *Scientia Agricola,* **57** (3): 389-394.
Available at: http://www.scielo.br/

Sweetie RK; Chander R; and **Sharma A** (2006) Effect of Radiation Processing of Lamb Meat on its Lipids. *Food Chemistry,* **97** (1): 80-86.
Available at: http://www.sciencedirect.com/article/pii/S0308814605002785

Syrian Statistical Abstract SSA (1996 & 2006) Central Bureau of Statistics. SSA, Office of the Prime Minister, Damascus, Syrian Arab Republic, pp 130 & pp 137.

Yusof SCM; Juri ML; Ali F; Abdulmajida S; Deraman M; Ahmad Ramli RA; Ahmad R; Harun Z; and **Babji AS** (2009) Acceptance of Gamma Irradiated Pre-Cooked Processed Chicken Meat Products (The). *Jurnal Sains Nuklear Malaysia,* **21**(1): 65-71.
Available at: http://www.gemilang.ukn/my/cgi-bin/chameleon/sessionid=