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Chemical Properties of Chicken Muscles and Skin as Affected by Gamma Irradiation and Refrigerated Storage

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Abstract: This investigation aims to ascertain the effects of gamma irradiation at doses of 1.5 and 3.0 kGy, which approved for microbial decontamination of poultry, followed by refrigerated storage on the chemical properties of chicken muscles and skin. Non-irradiated and irradiated breast muscle, leg muscle, breast skin and leg skin were analyzed for proximate composition, amino acids and water & salt soluble proteins, whereas their lipids were analyzed for lipid characteristics, stability at 100°C and fatty acid profiles. Gamma irradiation had no remarkable effects on proximate composition, amino acids and protein solubility of muscles and skin, however, slightly decreased the total unsaturated fatty acids of lipids. Moreover, irradiation treatments slightly increased the acid value of lipids, while markedly increased their peroxide value and reduced their stability as determined by rancimat. Refrigerated storage induced no appreciable changes in macronutrients and protein solubility, while increased the acid value and peroxide value of lipids which were within the acceptable levels. Irradiation and storage did not appreciably affect the iodine value of lipids.

Key words: chicken, irradiation, amino acids, solubility, lipid, stability, fatty acids

Introduction

World poultry meat consumption is of significant economic importance in more than 50 countries worldwide, including Egypt, being on an upward trend for many years and will undoubtedly continue in an upward trend (Roenigk, 1999). Because of its high meat yield, low shrinkage during cooking, ease of cooking & serving and low cost, chicken appears more frequently than any other animal as a source of meat in the diet of people throughout the world and broilers dominated the world poultry consumption picture, contributing about 70% to the world poultry market (Roenigk, 1999). Practically, all poultry is now sold in the ready-to-cook forms which may be as whole carcass, quartered or disjointed and deboned meat, and most broiler chicken is sold in the fresh state.

Bacterial contamination of poultry carcasses during processing is undesirable and unavoidable. Chickens naturally can carry a variety of pathogenic bacteria into the processing plant leading to transmission of these bacteria to the retail product. Therefore, poultry are acknowledged as being a potential reservoir of foodborne pathogens, particularly species of Campylobacter and Salmonella, and its meat can act as a source of these organisms and other pathogens for human infection (Uyttendaele *et al.*, 1999; Whyte *et al.* 2001 and Yang *et al.*, 2001).

The application of meat irradiation can virtually eliminate foodborne pathogens and showed the only good practicable means to ensure the safety of poultry products making them free from Salmonella and other pathogens (Andrews *et al.*, 1998 and Kaferstein and Moy 1993). Relatively low doses of ionizing radiation can be used for treatment of poultry and the regulations permitting poultry irradiation to control foodborne pathogens has been approved in many countries. The minimum dose of ionizing radiation approved for treatment of poultry is 1.5 kGy, while the maximum dose is 3.0 kGy (FDA, 1990; FSIS, 1992 and IAEA, 1998). However, radiation pasteurized products are neither sterile nor shelf – stable and must be properly refrigerated, cooked and served.

It is well documented that only small effects upon the nutritional value of the macronutrients in food are expected from the use of ionizing energy, because of the small amount of energy involved. Nevertheless, experimental investigations are necessary to determine the effects that actually do occur and especially to check the response of different classes of nutrients (IAEA, 1993). Therefore, the purpose of this investigation was to study the effects of such approved doses of gamma irradiation and subsequent refrigerated storage on the chemical properties of chicken muscles and their corresponding skin.

Materials and Methods

Materials: Chicken carcasses, having an average weight of 1.5 kg after removing the necks and coccycal regions(tails), were obtained from 7 weeks old broilers after slaughter in a commercial slaughterhous. Carcasses were then cut into four quarters and packaged individually in polyethylene pouches. Some of pouches were taken as a control non-irradiated samples, while the rest were immediately transported in an ice chest for irradiation treatment .

Irradiation of samples: Samples of packaged chicken parts were subjected to gamma irradiation at doses of 1.5 and 3.0 kGy using a Cobalt-60 source located at the National Center for Radiation Research and Technology, Nasr

City, Cairo, Egypt .

Storage: Irradiated and non-irradiated chicken parts were refrigerated stored at 4 ± 1°C until withdrawn for sampling and chemical analysis which was focused on breast and leg muscles and their corresponding skin. Storage of samples was terminated when the signs of decomposition became apparent.

Sampling and preparation of samples for analysis: For chemical analysis, samples of irradiated and non-irradiated chicken breast and leg parts were taken. Skin was carefully removed from breast and leg parts, while the muscles were trimmed free of all visible fat and hand deboned. Then each of the observed muscles and their skin was ground individually for uniformity of the sample and chemically analyzed. Chemical analyses were performed using triplicate samples per treatment and the results were recorded as the mean ± standard deviation for proximate composition, soluble proteins, lipid characteristics and oxidative stability. Meanwhile, for quantitative determination of amino acids and the determination of fatty acid profiles, hydrolysis procedures or the preparation of fatty acid methyl esters was carried out individually for each replicate of samples then, the observed hydrolyzates (for amino acids) or methyl esters (for fatty acids) for sample replicates per treatment were mixed will and analyzed as one sample.

Chemical analysis

Proximate composition: Moisture, total protein and ash were determined according to AOAC approved methods (AOAC, 1995), while total lipids were extracted from muscles and skin with chloroform / methanol (2:1) and determined according to the method of Folch, *et al.* (1957).

Water and salt soluble protein: Water and salt soluble proteins were extracted according to the procedures described by Yang & Froning (1992) and modified by Bonifer & Froning (1996), while the extracted proteins were determined by the Kjeldahle method (AOAC, 1995) .

Quantitative determination of amino acids: Quantitative determination of the total amino acids was carried out according to the method described by Pellet & Young (1980) and using high performance amino acid analyzer for the separation of amino acids.Tryptophan was determined colorimetrically according to the method described by Opienska-Blauth, *et al.* (1963).

Lipid characteristics: Acid value and peroxide value were determined according to standard AOCS analytical methods (|AOCS, 1998), while iodine value (Hannas) was determined according to AOAC (1995/ Official methods.

Oxidative stability at 100° C: Oxidative stability of the extracted lipids was determined using Motrohn rancimat 979 as described by Hasenhuttl and Wan (1992). Determinations were performed on 3.0 g lipid at 100°C with an air flow of 20 L/h.

Fatty acid profiles: Fatty acids of lipids extracted from chicken muscles and skin were converted to their methyl esters (Anon, 1966) and the analysis of fatty acid methyl esters was accomplished using a PYE Unicam gas chromatograph (Model 4550) equipped with flam ionization detector. The fractionation of fatty acid methyl esters was conducted using coild glass column (1.6 m x 4 mm) packed with cromosorb C and coated with 10% polyethylene glycol adipate (PEGA). The oven temperature was 180°C, while the temperatures of injector and detector were 250°C and 300°C, respectively. The hydrogen, nitrogen and air flow rates were 33, 30 and 300 m l/ min, respectively. The peak areas and retention times were measured using Spectra Physics 4719 integrator.

Results and Discussion

Proximate composition: The proximate chemical composition of non-irradiated chicken breast muscle, leg muscle, breast skin and leg skin showed that their moisture contents were 74.011, 74.012, 40.076, and 38.810%, whereas their contents from total protein, total lipids and ash (on dry weight basis) were found to be 89.632, 4.698, 5.670; 83.241, 12.153, 4.606; 18.079, 81.171, 0.750 and 15.612, 83.570 & 0.818%, respectively (Table 1). These results indicate that the proximate chemical composition differ from other published results (Bonifer and Forning, 1996 and Rhee *et al.*, 1996) which may reflect compositional variation from birds of different ages and dietary. It is also apparent that breast muscles had a much lower fat content and higher protein content than leg muscle. Numerous studies also found that chicken breast had the lowest fat content (Alasnier *et al.*, 2002 and Pikul and Kummerow, 1990). Neither gamma irradiation nor subsequent refrigerated storage (data not shown) could appreciably influence the contents of macronutrints for both chicken muscles and skin. Similar observations were previously reported by other workers (Alasnier *et al.*, 2000; El-Mongy, 1990 and Giroux and lacroix, 1998).

Table 1: Proximate composition of non-irradiated and irradiated chicken muscles and skin

Components	Percentage (Mean ± SD) in chicken muscle and its corresponding skin/Irradiation dose (kGy)											
	Breast muscle			Leg muscle			Breast skin			Leg skin		
	0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0
Moisture	74.011 ± 0.096	73.974 ± 0.207	73.868 ± 0.143	74.012 ± 0.112	73.990 ± 0.133	73.999 ± 0.135	40.076 ± 0.191	41.007 ± 0.240	40.650 ± 0.350	38.810 ± 0.095	38.747 ±0.093	39.021 ± 0.119
Protein*	89.632 ± 0.074	89.645 0.108	89.676 ± 0.095	83.241 ± 0.123	83.241 ± 0.153	83.243 ± 0.137	18.079 ± 0.073	18.104 ± 0.105	18.088 ± 0.089	15.612 ± 0.113	15.703 ± 0.069	15.587 ± 0.096
Lipids*	4.698 ± 0.055	4.670 ± 0.091	4.620 ± 0.055	12.153 ± 0.101	12.132n 0.124	12.126 ± 0.100	81.171 ± 0.072	81.144 ± 0.103	81.158 ± 0.088	83.570 ± 0.111	83.478 ± 0.071	83.595 ± 0.098
Ash*	5.670 ± 0.035	5.685 ± 0.017	5.704 ± 0.057	4.606 ± 0.028	4.627 ± 0.028	4.631 ± 0.037	0.750 ± 0.001	0.752 ± 0.003	0.754 ± 0.002	0.818 ± 0.002	0.819 ± 0.002	0.818 ± 0.002

a: On dry weight basis.

Table 2: Total amino acids of chicken muscles and skin as affected by gamma irradiation

Amino acids	Amount (g/100g protein) in chicken muscle and its corresponding skin/Irradiation dose (kGy)											
	Breast muscle			Leg muscle			Breast skin					
	0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0
Aspartic	8.724	8.719	8.721	8.780	8.788	8.784	8.200	8.200	8.207	8.163	8.165	8.162
Threonine	4.133	4.130	4.130	4.088	4.079	4.083	2.944	2.941	2.944	2.953	2.952	2.955
Serine	4.010	4.016	4.014	4.221	4.220	4.220	0.254	0.254	0.254	0.251	0.251	0.250
Glutamic	13.988	13.990	13.986	13.853	13.849	13.850	10.940	10.944	10.944	10.941	10.939	10.943
Proline	4.137	4.140	4.142	4.171	4.168	4.167	8.080	8.083	8.083	8.076	8.074	8.076
Glycine	6.000	6.022	6.020	6.133	6.130	6.131	12.588	12.582	12.582	12.591	12.589	12.590
Alanine	5.870	5.867	5.868	5.769	5.770	5.768	6.690	6.687	6.687	6.686	6.688	6.688
Valine	4.808	4.800	4.802	4.634	4.634	4.631	3.733	3.737	3.373	3.733	3.733	3.740
Methionine	5.314	5.315	5.315	5.311	5.307	5.310	2.344	2.341	2.341	2.345	2.346	2.344
Isolecucine	4.623	4.620	4.625	4.522	4.518	4.516	3.040	3.044	3.044	3.039	3.041	3.040
Leucine	7.375	7.381	7.380	7.313	7.316	7.315	5.383	5.380	5.380	5.383	5.382	5.380
Tyrosine	3.500	3.509	3.505	3.511	3.500	3.508	1.911	1.911	1.911	1.911	1.915	1.911
Phenylalanine	3.676	3.660	3.659	3.660	3.658	3.651	2.859	2.853	2.851	2.862	2.862	2.866
Lysine	9.017	9.000	9.000	8.906	8.911	8.911	5.388	5.390	5.370	5.384	5.384	5.381
Histidine	4.211	4.220	4.222	4.400	4.381	4.388	2.600	2.610	2.608	2.606	2.603	2.603
Arginine	6.188	6.183	6.186	6.212	6.210	6.210	6.860	6.860	6.862	6.862	6.862	6.857
Tryptophane	1.221	1.220	1.222	1.205	1.200	1.203	0.799	0.800	0.799	0.798	0.797	0.799
Total	96.795	96.792	96.797	96.689	96.639	96.646	84.613	84.617	84.610	84.587	84.583	84.585

Amino acids: The total amino acids were quantitatively determined in non-irradiated and irradiated chicken muscles and skin (Table 2).It is clearly seen that the total amino acids represented 96.795, 96.689, 84.613 and 84.587 (g/100g protein) in non-irradiated breast muscle, leg muscle, breast skin and leg skin, respectively. Both chicken muscles and their skin contained the same 17 amino acids that could be identified, however, some variations in their amounts were observed. Breast and leg muscles contained greater amounts of threonine, serine, glutamic, methionine, tyrosine, lysine and histidine, whereas their corresponding skin contained greater amounts of proline, glycine and alanine. Similar observations were reported by Abd El-Wahed (1986). The same data reveal that the amounts of individual amino acids showed no remarkable changes due to gamma irradiation. El-Mongy (1990) arrivate at similar results.

Water and salt soluble protein: Table (3) illustrates that water soluble protein amounted to 31.610, 32.203, 12.222 and 12.232 g/100 g protein, while the amounts of salt soluble protein were found to be 55.206, 57.225, 10.606 and 10.608 g/100g protein in non-irradiated breast muscle, leg muscle, breast skin and leg skin samples, respectively. These results are in well agreement with those reported by Pearson & Young (1989) who stated that sarcoplasmic and myofibrillar proteins comprise about 30-35 and 55-60 % of the total muscle protein, respectively, and were similar to those obtained by Bonifer & Froning (1996) for chicken skin. Gamma irradiation had no observable effects on protein solubility for chicken muscles and their skin. This is in accordance with the findings of previous investigations for protein solubility of Indian mackerel (Venugopal *et al.*, 1988) and beef (Kim *et al.*, 1999). Refrigerated storage had no remarkable effects on protein solubility of non-irradiated and irradiated breast and leg skin. However, slight decreases were observed for water soluble proteins within the first 4 days of refrigeration for all breast and leg muscles undertaken. Regarding extractability of salt soluble proteins from chicken

Table 3: Effects of gamma irradiation and refrigerated storage on water and salt soluble protein in chicken muscles and skin

Soluble protein fraction	Storage (days)	Amount (Mean ± SD g/100g protein) in muscle and its corresponding skin / Irradiation dose(kGy)											
		Breast muscle			Leg muscle			Breast skin			Leg skin		
		0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0
Water soluble	0	31.610 ±0.076	31.612 ±0.073	31.628 ±0.063	32.303 ±0.023	32.295 ±0.078	32.300 ±0.095	12.222 ±0.030	12.239 ±0.005	12.244 ±0.031	12.232 ±0.012	12.225 ±0.033	12.239 ±0.005
	2	31.481 ±0.017	31.481 ±0.082	31.519 ±0.073	32.104 ±0.004	32.163 ±0.033	32.116 ±0.088	12.218 ±0.036	12.232 ±0.012	12.242 ±0.036	12.252 ±0.032	12.255 ±0.039	12.245 ±0.059
	4	31.216 ±0.011	31.197 ±0.019	31.240 ±0.057	32.084 ±0.082	31.916 ±0.109	31.948 ±0.103	12.223 ±0.028	12.233 ±0.041	12.238 ±0.003	12.232 ±0.012	12.244 ±0.031	12.223 ±0.015
	6	31.216 ±0.015	31.223 ±0.023	31.234 ±0.041	31.943 ±0.057	31.819 ±0.126	31.865 ±0.072	12.236 ±0.022	12.236 ±0.017	12.235 ±0.035	12.222 ±0.030	12.238 ±0.002	12.239 ±0.021
	8	31.202 ±0.023	31.190 ±0.020	31.196 ±0.021	31.834 ±0.060	31.790 ±0.119	31.953 ±0.104	12.232 ±0.013	12.241 ±0.015	12.245 ±0.059	12.238 ±0.007	12.236 ±0.017	12.238 ±0.041
	10	R	31.197 ±0.019	31.240 ±0.057	R	31.916 ±0.082	31.998 ±0.111	R	12.239 ±0.021	12.236 ±0.016	R	12.235 ±0.035	12.245 ±0.029
	12	-	31.228 ±0.039	31.201 ±0.030	-	32.033 ±0.069	31.944 ±0.088	-	12.238 ±0.041	12.247 ±0.054	-	12.233 ±0.041	12.218 ±0.036
	14	-	31.195 ±0.019	31.201 ±0.055	-	31.802 ±0.108	31.848 ±0.147	-	12.255 ±0.039	12.252 ±0.032	-	12.244 ±0.030	12.233 ±0.041
	16	-	R	31.227 ±0.033	-	R	31.910 ±0.134	-	R	12.223 ±0.017	-	R	12.223 ±0.015
	18	-	-	31.201 ±0.055	-	-	32.036 ±0.083	-	-	12.232 ±0.032	-	-	12.252 ±0.032
	20	-	-	31.204 ±0.019	-	-	31.932 ±0.065	-	-	12.247 ±0.054	-	-	12.245 ±0.027
	22	-	-	31.213 ±0.053	-	-	31.925 ±0.095	-	-	12.244 ±0.031	-	-	12.222 ±0.030
	24	-	-	31.186 ±0.020	-	-	31.833 ±0.058	-	-	12.238 ±0.002	-	-	12.238 ±0.003
	26	-	-	R	-	-	R	-	-	R	-	-	R
Salt soluble	0	55.206 ±0.114	55.237 ±0.066	55.252 ±0.139	57.225 ±0.106	57.171 ±0.157	57.211 ±0.109	10.606 ±0.136	10.610 ±0.125	10.601 ±0.109	10.608 ±0.111	10.595 ±0.098	10.600 ±0.078
	2	57.931 ±0.143	57.957 ±0.151	57.896 ±0.186	54.738 ±0.153	54.685 ±0.152	54.690 ±0.190	10.588 ±0.106	10.587 ±0.105	10.633 ±0.065	10.619 ±0.063	10.623 ±0.069	10.613 ±0.058
	4	57.851 ±0.148	57.803 ±0.122	57.821 ±0.191	54.750 ±0.116	54.734 ±0.146	54.728 ±0.247	10.601 ±0.094	10.633 ±0.068	10.597 ±0.083	10.599 ±0.077	10.609 ±0.069	10.621 ±0.045
	6	57.830 ±0.073	57.810 ±0.073	57.826 ±0.183	54.783 ±0.190	54.716 ±0.194	54.734 ±0.152	10.604 ±0.117	10.600 ±0.102	10.628 ±0.063	10.623 ±0.058	10.614 ±0.094	10.618 ±0.096
	8	57.700 ±0.145	57.805 ±0.098	57.778 ±0.158	54.624 ±0.227	54.781 ±0.202	54.693 ±0.181	10.588 ±0.089	10.641 ±0.080	10.610 ±0.021	10.591 ±0.104	10.626 ±0.053	10.597 ±0.112
	10	R	57.770 ±0.068	57.851 ±0.220	R	54.722 ±0.150	54.678 ±0.190	R	10.626 ±0.052	10.601 ±0.094	R	10.624 ±0.082	10.600 ±0.078
	12	-	57.746 ±0.082	57.710 ±0.131	-	54.724 ±0.253	54.707 ±0.037	-	10.596 ±0.100	10.601 ±0.082	-	10.630 ±0.061	10.609 ±0.067
	14	-	57.755 ±0.116	57.780 ±0.192	-	54.728 ±0.164	54.731 ±0.186	-	10.595 ±0.040	10.627 ±0.075	-	10.621 ±0.051	10.621 ±0.048
	16	-	R	57.766 ±0.125	-	R	54.749 ±0.226	-	R	10.624 ±0.049	-	R	10.621 ±0.045
	18	-	-	57.835 ±0.229	-	-	54.688 ±0.215	-	-	10.631 ±0.063	-	-	10.595 ±0.098
	20	-	-	57.750 ±0.116	-	-	54.709 ±0.083	-	-	10.626 ±0.051	-	-	10.624 ±0.082
	22	-	-	57.765 ±0.128	-	-	54.673 ±0.161	-	-	10.639 ±0.064	-	-	10.626 ±0.047
	24	-	-	57.760 ±0.122	-	-	54.683 ±0.204	-	-	10.623 ±0.067	-	-	10.609 ±0.067
	26	-	-	R	-	-	R	-	-	R	-	-	R

R : Spoiled and rejected.

muscles, it is noticeable that salt soluble proteins of non-irradiated and irradiated breast muscles were more soluble and extractable after 2 days of storage than on day zero, which was in contrast for leg muscles, then storage had no apparent effects on the extractability of salt soluble proteins from both breast and leg muscles. The obtained results are very similar to those obtained by Xiong & Brekk (1991) as they also found that myofibrillar proteins from postrigor (24 h postmortem) chicken berast muscles were more soluble and much more readily extracted than from prerigor chicken breast muscles, while myofibrillar proteins in chicken leg muscles were more extractable than those in postrigor chicken leg muscles. This could be explained by the fact that in chicken breast muscle, which is composed of a preponderance of fast-twitch white fibers, some possible solubility constraints, including proteins in Z-disks, are removed by muscle endogenous proteases, presumably calpain, during rigor mortis development, but the Z-line structure in chicken leg muscle changed very little during the first 2 days of postmortem storage (Xiong, 1997).

Lipid characteristics: It is apparently seen in Table (4) that the initial acid value of lipids extracted from non-irradiated leg muscles was higher than that of lipids extracted from non-irradiated breast muscle, breast skin and leg skin being 0.533, 0.312, 0.383 and 0.341, respectively. However, the initial peroxide value of lipids extracted

Table 4: Lipid characteristics of chicken muscles and skin as affected by gamma irradiation and refrigerated storage

Determination	Storage (days)	Values (Mean ± SD) for Lipids of chicken muscle and its corresponding skin / Irradiation dose(kGy)											
		Breast muscle			Leg muscle			Breast skin			Leg skin		
		0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0	0.0	1.5	3.0
Acid value	0	0.312 ±0.006	0.323 ±0.010	0.336 ±0.003	0.533 ±0.003	0.554 ±0.004	0.575 ±0.004	0.383 ±0.005	0.397 ±0.003	0.413 ±0.003	0.341 ±0.004	0.351 ±0.004	0.364 ±0.003
	2	0.424 ±0.012	0.421 ±0.009	0.423 ±0.004	0.735 ±0.005	0.719 ±0.005	0.725 ±0.006	0.529 ±0.009	0.508 ±0.009	0.520 ±0.003	0.467 ±0.004	0.446 ±0.004	0.452 ±0.003
	4	0.555 ±0.014	0.534 ±0.019	0.505 ±0.002	0.956 ±0.007	0.905 ±0.005	0.867 ±0.022	0.716 ±0.056	0.639 ±0.016	0.606 ±0.004	0.603 ±0.003	0.557 ±0.003	0.531 ±0.003
	6	0.708 ±0.012	0.642 ±0.017	0.583 ±0.010	1.209 ±0.008	1.096 ±0.005	0.999 ±0.009	0.882 ±0.019	0.782 ±0.016	0.698 ±0.005	0.755 ±0.006	0.667 ±0.008	0.619 ±0.006
	8	0.839 ±0.061	0.744 ±0.022	0.651 ±0.018	1.437 ±0.004	1.248 ±0.056	1.124 ±0.006	1.021 ±0.019	0.882 ±0.025	0.765 ±0.007	0.906 ±0.006	0.776 ±0.004	0.682 ±0.012
	10	R	0.823 ±0.030	0.723 ±0.013	R	1.428 ±0.025	1.264 ±0.033	R	0.990 ±0.030	0.848 ±0.008	R	0.871 ±0.002	0.747 ±0.004
	12	-	0.935 ±0.018	0.779 ±0.013	-	1.593 ±0.007	1.337 ±0.004	-	1.089 ±0.010	0.893 ±0.027	-	0.958 ±0.008	0.801 ±0.003
	14	-	1.026 ±0.050	0.844 ±0.021	-	1.752 ±0.032	1.435 ±0.033	-	1.187 ±0.009	0.969 ±0.008	-	1.029 ±0.012	0.846 ±0.007
	16	-	R	0.885 ±0.007	-	R	1.484 ±0.015	-	R	1.013 ±0.013	-	R	0.870 ±0.010
	18	-	-	0.905 ±0.005	-	-	1.507 ±0.006	-	-	1.113 ±0.014	-	-	0.898 ±0.010
	20	-	-	0.978 ±0.011	-	-	1.573 ±0.048	-	-	1.170 ±0.009	-	-	0.966 ±0.030
	22	-	-	0.990 ±0.007	-	-	1.651 ±0.026	-	-	1.218 ±0.006	-	-	1.029 ±0.015
	24	-	-	1.034 ±0.016	-	-	1.717 ±0.019	-	-	1.306 ±0.006	-	-	1.180 ±0.060
	26	-	-	R	-	-	R	-	-	R	-	-	R
Peroxide value	0	0.524 ±0.003	0.589 ±0.053	0.723 ±0.005	0.486 ±0.003	0.606 ±0.006	0.681 ±0.004	0.412 ±0.005	0.496 ±0.005	0.555 ±0.002	0.401 ±0.004	0.469 ±0.003	0.523 ±0.004
(meq/kg lipid)	2	0.544 ±0.002	0.726 ±0.006	0.803 ±0.003	0.527 ±0.009	0.655 ±0.006	0.748 ±0.004	0.437 ±0.004	0.534 ±0.003	0.606 ±0.003	0.429 ±0.004	0.505 ±0.003	0.568 ±0.002
	4	0.622 ±0.008	0.835 ±0.006	0.925 ±0.006	0.575 ±0.006	0.743 ±0.004	0.853 ±0.007	0.477 ±0.007	0.588 ±0.006	0.672 ±0.004	0.464 ±0.003	0.552 ±0.003	0.622 ±0.003
	6	0.743 ±0.013	0.991 ±0.003	1.114 ±0.005	0.661 ±0.003	0.852 ±0.006	0.990 ±0.010	0.531 ±0.002	0.657 ±0.009	0.762 ±0.003	0.508 ±0.002	0.611 ±0.003	0.691 ±0.003
	8	0.895 ±0.008	1.185 ±0.007	1.333 ±0.004	0.766 ±0.004	0.994 ±0.007	1.159 ±0.003	0.590 ±0.003	0.756 ±0.005	0.866 ±0.004	0.567 ±0.003	0.682 ±0.003	0.773 ±0.006
	10	R	1.408 ±0.009	1.273 ±0.008	R	1.181 ±0.021	1.356 ±0.053	R	0.862 ±0.005	0.993 ±0.005	R	0.774 ±0.003	0.883 ±0.003
	12	-	1.682 ±0.018	1.875 ±0.022	-	1.403 ±0.014	1.609 ±0.018	-	0.982 ±0.008	1.096 ±0.006	-	0.882 ±0.002	1.008 ±0.002
	14	-	2.003 ±0.012	2.192 ±0.089	-	1.666 ±0.044	1.901 ±0.039	-	1.147 ±0.006	1.272 ±0.003	-	1.016 ±0.004	1.158 ±0.002
	16	-	R	2.246 ±0.014	-	R	1.948 ±0.012	-	R	1.300 ±0.007	-	R	1.161 ±0.003
	18	-	-	2.372 ±0.012	-	-	2.065 ±0.035	-	-	1.413 ±0.004	-	-	1.174 ±0.004
	20	-	-	2.292 ±0.008	-	-	2.216 ±0.062	-	-	1.467 ±0.004	-	-	1.167 ±0.002
	22	-	-	2.373 ±0.054	-	-	2.345 ±0.039	-	-	1.562 ±0.004	-	-	1.182 ±0.004
	24	-	-	2.546 ±0.052	-	-	2.434 ±0.032	-	-	1.703 ±0.004	-	-	1.219 ±0.003
	26	-	-	R	-	-	R	-	-	R	-	-	R

Iodine value													
	0	72.466 ±0.009	72.502 ±0.022	72.497 ±0.016	71.500 ±0.049	71.511 ±0.013	71.564 ±0.021	70.745 ±0.074	70.720 ±0.012	70.745 ±0.050	70.675 ±0.044	70.605 ±0.025	70.658 ±0.067
	2	72.363 ±0.003	72.457 ±0.049	72.413 ±0.047	71.295 ±0.038	71.413 ±0.043	71.353 ±0.077	70.585 ±0.030	70.700 ±0.017	70.693 ±0.016	70.602 ±0.010	70.586 ±0.020	70.600 ±0.016
	4	72.390 ±0.010	72.424 ±0.048	72.288 ±0.012	71.416 ±0.034	71.305 ±0.041	71.371 ±0.045	70.625 ±0.015	70.586 ±0.024	70.594 ±0.021	70.601 ±0.013	70.523 ±0.044	70.632 ±0.009
	6	72.401 ±0.010	72.348 ±0.072	72.404 ±0.012	71.322 ±0.062	71.341 ±0.067	71.402 ±0.012	70.695 ±0.020	70.663 ±0.046	70.605 ±0.049	70.522 ±0.048	70.571 ±0.051	70.623 ±0.069
	8	72.272 ±0.008	72.313 ±0.086	72.353 ±0.022	71.392 ±0.043	71.400 ±0.019	71.278 ±0.079	70.641 ±0.070	70.605 ±0.031	70.590 ±0.019	70.570 ±0.048	70.603 ±0.016	70.701 ±0.020
	10	R	72.185 ±0.030	72.397 ±0.008	R	71.363 ±0.057	71.356 ±0.091	R	70.586 ±0.065	70.601 ±0.011	R	70.611 ±0.011	70.600 ±0.012
	12	-	72.259 ±0.062	72.255 ±0.079	-	71.272 ±0.060	71.400 ±0.011	-	70.590 ±0.020	70.550 ±0.011	-	70.597 ±0.064	70.665 ±0.051
	14	-	72.348 ±0.057	72.401 ±0.032	-	71.310 ±0.056	71.284 ±0.049	-	70.643 ±0.058	70.662 ±0.035	-	70.528 ±0.032	70.571 ±0.061
	16	-	R	72.340 ±0.062	-	R	71.400 ±0.008	-	R	70.606 ±0.023	-	R	70.545 ±0.058
	18	-	-	72.290 ±0.041	-	-	71.351 ±0.074	-	-	70.586 ±0.022	-	-	70.603 ±0.026
	20	-	-	72.257 ±0.084	-	-	71.337 ±0.037	-	-	70.596 ±0.022	-	-	70.708 ±0.007
	22	-	-	72.400 ±0.059	-	-	71.367 ±0.047	-	-	70.592 ±0.017	-	-	70.570 ±0.074
	24	-	-	72.400 ±0.012	-	-	71.380 ±0.018	-	-	70.658 ±0.038	-	-	70.600 ±0.012
	26	-	-	R	-	-	R	-	-	R	-	-	R

R: Spoiled and rejected.

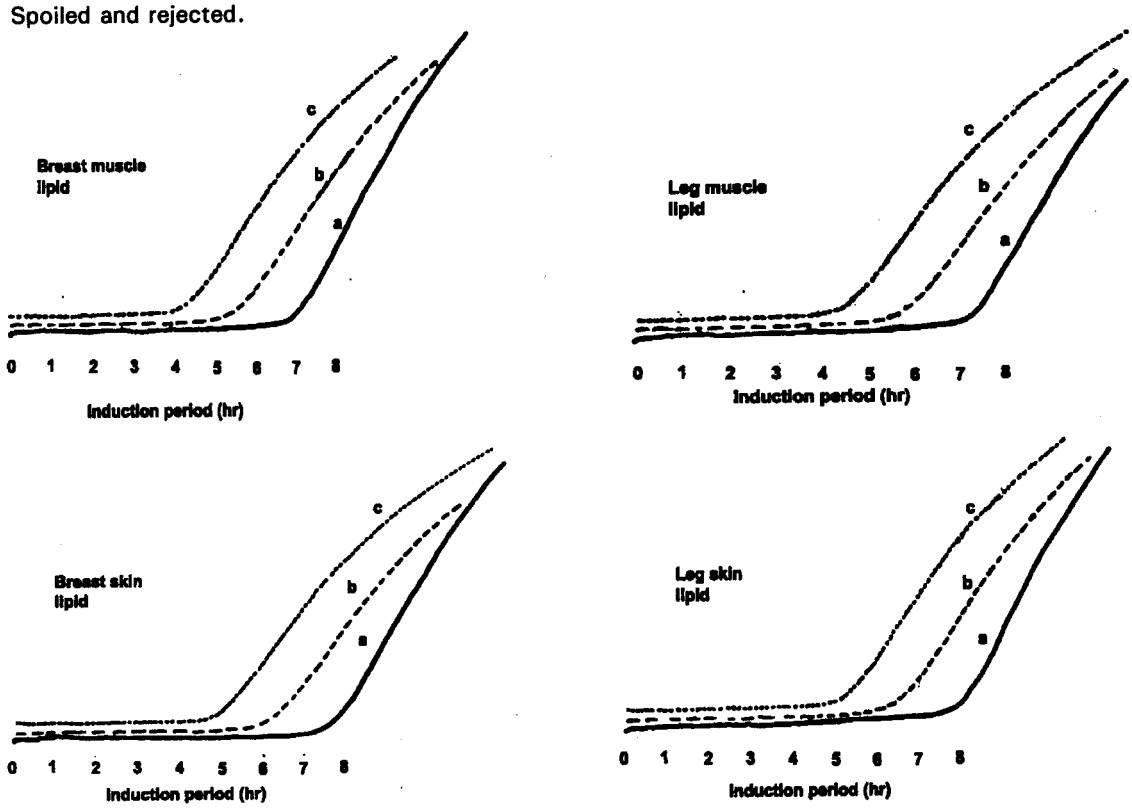

Fig. 1: Induction period (hr) of lipids spearated from non-irradiated and irradiated chicken muscles and skin
a: 0 kGy b: 1.5 kGy c: 3.0 kGy

from non-irradiated chicken muscles was higher than that of their skin lipids and breast muscle lipids showed the highest initial peroxide value being 0.524 meq / kg lipid, while reached 0.486, 0.412 and 0.401 meq / kg lipid in lipids of leg muscle, breast skin and leg skin, respectively. These data are in well agreement with those of previous studies which indicated that thigh muscle lipids contained significantly more free fatty acid amounts and less thiobarbituric acid reactive substances than breast muscle lipids at all times of refrigerated storage (Alasnier *et al.*, 2000) and the concentrations of malonaldhyde were higher in muscle lipids than in their skin lipids, while lipids oxidized faster in breast than in leg muscles which could be attributed to the large phospholipid fraction in breast lipids (Gray *et al.*, 1996 and Pikul and Niewiarowicz, 1990).

Gamma irradiation slightly increased the acid value and markedly increased the peroxide value of lipids of both muscles and their skin. The observed increases in the acid value may be due to the effects of irradiation on the ester bonds and liberation of free fatty acids (Rady and Schwartz, 1991), while the increased peroxide value may be attributed to the high unsaturation of lipids where unsaturated fatty acids are more readily oxidized than are the saturated acids. Table (4) further shows that refrigerated storage also markedly affected the acid and peroxide values of lipids of non-irradiated and irradiated muscles and skin. The rate of lipolysis was relatively higher in lipids of control samples, whereas the rate of oxidation was higher in lipids of irradiated samples. However, all values were within the acceptable levels. A positive correlation between oxidation of chicken fats and irradiation was also apparent post treatment and during storage in the findings of Kanatt, *et al.* (1998).

From the same Table, the results also indicate that the iodine value was 72.466, 71.500, 70.745 and 70.675 for lipids of non-irradiated breast muscle, leg muscle, breast skin and leg skin, respectively. The observed values were within the range of 63-80 reported by Mountney (1966) for chicken fat and showed no remarkable changes neither due to irradiation nor storage. Similar observations were reported by Hampson, *et al.* (1996) for turkey's breast and leg muscle lipid.

Oxidative stability of lipids at 100° C: The results illustrated by Fig. 1 show the effects of irradiation on stability of chicken muscles and skin lipids at 100°C as determined by rancimat. The induction period (hr) were found to be 6.65 ± 0.02, 6.94 ± 0.03, 7.62 ± 0.02 and 7.80 ± 0.03 hr for lipids extracted from non-irradiated breast muscle, leg muscle, breast skin and leg skin, respectively, indicating that breast muscle lipids had the lowest induction period. This may be attributed to the lower ratios of vitamin E to phospholipids and to polyunsaturated fatty acids in breast than in leg muscles as illustrated by Alasnier *et al.*, (2000) and Gray *et al.*, (1996). Irradiation of chicken parts at doses of 1.5 and 3.0 kGy decreased their lipid stability as the induction periods decreased to 5.26 ± 0.03, 5.49 ± 0.04, 6.23 ± 0.03, 6.41 ± 0.02 and 3.63 ± 0.09, 3.89 ± 0.05, 4.71 ± 0.04 and 4.98 ± 0.02 hr for lipids of breast muscle, leg muscle, breast skin and leg skin irradiated at 1.5 and 3 kGy, respectively. The decrement of lipid stability may be due to their high level of unsaturation (as will be shown in Table 5) which may be accompanied by low levels of natural antioxidants that in turn may be affected by irradiation. It was reported that, although poultry meat contained relatively higher levels of unsaturated fatty acids, the levels of natural antioxidants such as tochopherol were low (Ajuyah *et al.*, 1993).

Fatty acid profiles: Gas chromatographic analysis showed that the total saturated fatty acids amounted to 33.23, 34.66, 34.02 and 34.71%, while the total unsaturated fatty acids reached 66.77, 65.34, 65.98 and 65.29% of total fatty acids for lipids of non-irradiated breast muscle, leg muscle, breast skin, and leg skin, respectively (Table 5). In all separated lipids, palmitic and stearic acids were the major saturated fatty acids, whereas oleic, linoleic and palmetoleic acids constituted the major unsaturated fatty acids, respectively. The present findings agree will with those of numerous previous studies which showed that chicken lipids exhibited a higher degree of unsaturation (Lee and Foglia, 2000; Pikul and Niewarowicz, 1990 and Rhee *et al.*, 1996) and oleic, linoleic and palmetoleic were the major unsaturated fatty acids, while palmitic and stearic were the major saturated fatty acids (Lee and Foglia, 2000). Gamma irradiation induced slight decreases in the total unsaturated fatty acids leading to corresponding slight increases in the total saturated fatty acids for all separated lipids under investigation. In earlier studies, only negligible changes in fatty acid profiles were observed for the neutral lipids of muscles and for fatty acyl residues of skin lipids upon irradiation at 2-5°C (Maxwell and Rady, 1989).

In conclusion, it is well apparent that gamma irradiation at doses approved for treating poultry could not induce changes that adversely affect the chemical properties of chicken muscles and their corresponding skin. Although the elevated peroxide value and reduced fat stability were the only noticeable effects, the highest observed peroxide value was still, however, within the beginning of the acceptable levels, whereas the resultant stability was much higher than the period in which chicken would be distributed and stored.

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