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NATICK/TR-79/034

THE EFFECT OF RADURIZATION ON THE pH, FREE WATER, MEAT SWELLING AND VOLATILE ORGANIC COMPOUND CONCENTRATIONS OF STORED CHICKEN MEAT

IRRADIATED FOOD PRODUCTS GROUP
RADIATION PRESERVATION OF FOOD DIVISION

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The purpose of these experiments was to investigate rapid objective methods for determining shelf life of radurized chicken. They included pH, free water, meat swelling and chemical analysis of volatile compounds.

Fresh eviscerated broiler chickens were low dose, gamma-irradiated (2.5 kGy and 5.0 kGy) and stored at 1.6°C for up to 31 days. Samples were withdrawn at intervals for testing. The results suggest that radurized chicken could

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be differentiated from nonirradiated chicken by determining pH, free water or meat swelling; these methods will not however define the time when enzymatic degradation noticeably occurs. Volatile organic compound concentrations correlate with the observation of chicken meat deterioration but the test methods are complex.

Preface

These studies were undertaken as a research project by the Irradiated Food Products Group, Radiation Preservation of Food Division, Food Engineering Laboratory under Project 1L762724AH99DC.

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The Effect of Radurization on the pH, Free Water, Meat Swelling and Volatile Organic Compound Concentrations of Stored Chicken Meat

Introduction

Spoilage of stored fresh eviscerated chicken is not a specifically defined quality but is a gradual process. The chicken deterioration depends mainly on initial microbial population and storage temperature. The extent of deterioration has traditionally and quite satisfactorily been determined by the onset of putrid odors and skin sliminess which occur when the total plate counts (TPC) are greater than $10^{6.5}$ to 10^{8} microorganisms per square centimeter. The approximate shelf-life of fresh chicken is about 4 to 6 days stored at 4.4°C, 8 days at 1°C, and 10 days at -1°C (Elliot and Michener, 1961).[1]

The use of radurization to control microbial spoilage and increase the shelf-life of fresh chicken alters the normal spoilage pattern. Radurization destroys or inhibits the growth of the normal spoilage microorganisms and the putrifactive odors, and high TPC ($10^{6.5}$ to $10^{8}cm^{2}$) do not develop within 31 days (Howker et al., 1976,[2] Josephson et al., 1975[3]). However, an increasingly noticeable enzymatic deterioration of radurized chicken occurs after approximately 18 to 21 days in storage limiting the acceptability of the chicken (Howker et al. 1976[4]); therefore, the traditional off-odors or high TPC are not applicable as spoilage indicators.

[1] R.P. Elliot and H. D. Michener, 1961. Microbiological standards and handling codes for chilled and frozen foods. A review. Appl. Microbiol., 9:452

[2] J.J. Howker, R. S. Kahan, and E. Wierbicki, 1976. Radurization of fresh poultry. NATICK/TR-77/006, U.S. Army Res & Dev Command, Natick, MA 01760.

[3] E.S. Josephson, F. Heiligman, C. K. Wadsworth, J.J. Howker, and E. Wierbicki, 1975. Low dose irradiation at "Natick." Presented at the FAO/IAEA Advisory Group Meeting on Low Dose Irradiation of Agricultural Prod., Rio de Janeiro, Brazil.

[4] See Reference 2.

The purpose of these experiments was to investigate rapid objective methods for determining shelf-life of radurized chicken including pH, free water, meat swelling and chemical analysis of volatile compounds.

Materials and Methods

Fresh eviscerated chickens (0.9 to 1.4 kg) were transported in ice-packed insulated carriers from the Boston, MA area, USDA-inspected, poultry processors to the U.S. Army Natick Research and Development Command, Natick, MA within four hours post-slaughter. The chicken samples were individually packaged in 2-mil, medium-density, polyethylene bags and gamma-irradiated (Cobalt 60 source) at a dose rate of 9.2 Gy per second, within 24 hours after slaughter.

Salted chicken carcasses. In addition to other procedures, the Kosher processing of fresh chicken includes dry salt coating of the carcasses and holding for 30-45 minutes before final washing and cooling. This procedure reduces the spoilage bacterial population and increases the shelf-life (Howker et al., 1976)[5].

Eviscerated chicken carcasses were halved. One side was coated with salt (NaCl), held for 30 minutes, rinsed, soaked in ice water for one hour and drained. The matching side (control) was not salted but soaked in ice water for one hour and drained. The salted and control halves were stored at 1.6°C.

Radurized chicken carcasses. Chicken carcasses were halved, one side was irradiated at 5.0 kGy $\pm$ 10% at 2°C + 5°C and the alternate side used as a nonirradiated control. The radurized and control chicken halves were stored at 1.6°C.

[5] See Reference 2.

Radurized ground chicken meat. The leg and breast meats were detached from fresh chicken carcasses. All skin, gross fat and tendons were removed and the leg and breast meat separately ground through a 3.2-mm plate. The ground meat was packaged in 15.2 X 10.2-cm medium-density polyethylene bags. The samples were Co 60 irradiated at 5.0 kGy $\pm$ 10% at $2^{o}C \pm 5^{o}C$ then stored at $1.6^{o}C$ with the nonirradiated controls.

Water-Holding Capacity. Water-holding capacity of nondisintegrated and ground meat was determined by the press method of Wierbicki and Deatherage (1958).[6] Approximately 0.5-g meat samples (4 replicates) from the subcutaneous surface muscle of the breasts and legs of two chickens per storage withdrawal were dissected. The meat samples were pressed at 3.5 MPa for 1 minute.

Meat Swelling and pH. Meat swelling was determined by the method of Wierbicki et al., (1962, 1963).[7,8] pH measurements were made on the ground meat slurry used for meat swelling analysis. A Beckman Zeromatic pH meter was used.

[6] E. Wierbicki and F. E. Deatherage, 1958. Determination of water-holding capacity of fresh meats. J. Agr. Food Chem., 6:387.

[7] E. Wierbicki, M. G. Tiede, and R. C. Burrell, 1962 Die bestimmung der fleischquellung als methode zur untersuchung der wasserbindungskapazität von muskelproteinen mit geringem salthaltevermögen. Die Fleischwirtschaft, 10:948

[8] E. Wierbicki, M. G. Tiede, and R. C. Burrell, 1963. Die bestimmung der fleischquellung als methode zur untersuchung der wasserbindungskapazität von muskelproteinen mit geringem salthaltevermögen. II. Amwendung der quellungsmethodik. Die Fleischwirtschaft, 5: 396

Volatile Organic Compounds. Sixteen chickens were cut in half longitudinally along the breast bone. The halves were individually packaged in polyethylene bags and one-half of each chicken was irradiated using a Co-60 source at 2.5 kGy $\pm$ 20% at 0 to 2°C. The other half was held as a control. Both irradiated and control chicken were stored at 1.6°C.

Samples for chemical analysis of volatile compounds were prepared by deboning four chicken halves and grinding skin and muscle tissues through a 6.4-mm plate. The volatile compounds were collected and separated into two fractions on a volatility basis, using low-temperature, high-vacuum distillation techniques, Angelini, et al. (1967),[9] Merritt, et al. (1959).[10] The more volatile of the two fractions contained those compounds volatile in the temperature range of -196°C to -78°C. The less volatile of the two fractions contained those compounds volatile in the temperature range of -78°C to room temperature. The more volatile fraction was analyzed directly, whereas the less volatile fractions required extraction of the organic volatiles from copious amounts of water with diethylether followed by removal of the solvent at -78°C under high vacuum. The sample fractions of volatile constituents were then analyzed by combined wide-range temperature-programmed gas chromatography and time-of-flight mass spectrometry. The outputs from this analytical system provide a continuous and instantaneous display of the mass spectrometer output, a gas chromatographic trace, a digital printout of the area for each peak of the gas chromatogram, and oscillographic recordings of the mass spectrum of each peak of the gas chromatogram. This analytical instrument system provides simultaneously both qualitative and quantitative data.

[9] P. Angelini, D. A. Forss, M. L. Bazinet and C. Merritt Jr. 1967. Methods of isolation and identification of volatile compounds in lipids. J. Am. Oil Chem. Soc., 44:26.

[10] C. Merritt, Jr., S. R. Bresnick, M. L. Bazinet, J. T. Walsh and P. Angelini, 1959. Determination of volatile components of foodstuffs. Techniques and their application to studies of irradiated beef. J. Agr. Food Chem. 7:784.

Microbiology. The total plate count (TPC) was determined by swabbing 6.25-square-centimeter areas of the chicken carcass, diluting and surface streaking on Heart-Infusion agar. The plates were incubated at 21°C for 5 to 7 days.

Proximate Analysis. Moisture, protein, fat, salt,and ash were determined by the standard AOAC methods (1970).[11]

Experimental Results and Discussion

The effect of storage on pH, free water,and percent meat swelling of nonirradiated chicken carcasses. After approximately seven days of storage, the chicken carcasses developed putrid odors. There was no outstanding change in the pH, free water,or meat swelling at this seven-day storage time. However, the pH, free water and meat swelling measurements of chicken carcasses stored at 1.6°C changed with extended storage as expected. The pH and meat swelling measurements increased and the free water decreased (Figure 1). The leg meat data shows higher readings for all three factors than that of the breast meat but was similar in trend.

The effect of salting on the pH, free water,and meat swelling of stored chicken carcasses. The pH and meat swelling measurements increased while the free water decreased with storage time for both the control and salted chicken (Figure 2). The salting had no effect on the pH of the chicken, and both leg and breast meat were identical in pH. The salt process did affect the meat swelling and free water characteristics, however, resulting in greater swelling and less free water for the salted samples than for the nonsalted controls.

The salted chicken halves exhibited off odors after 10 days storage;

[11] AOAC, 1970. Official methods of analysis, 11th Ed. Assn. of Official Agric. Chemists, Washington, D.C.

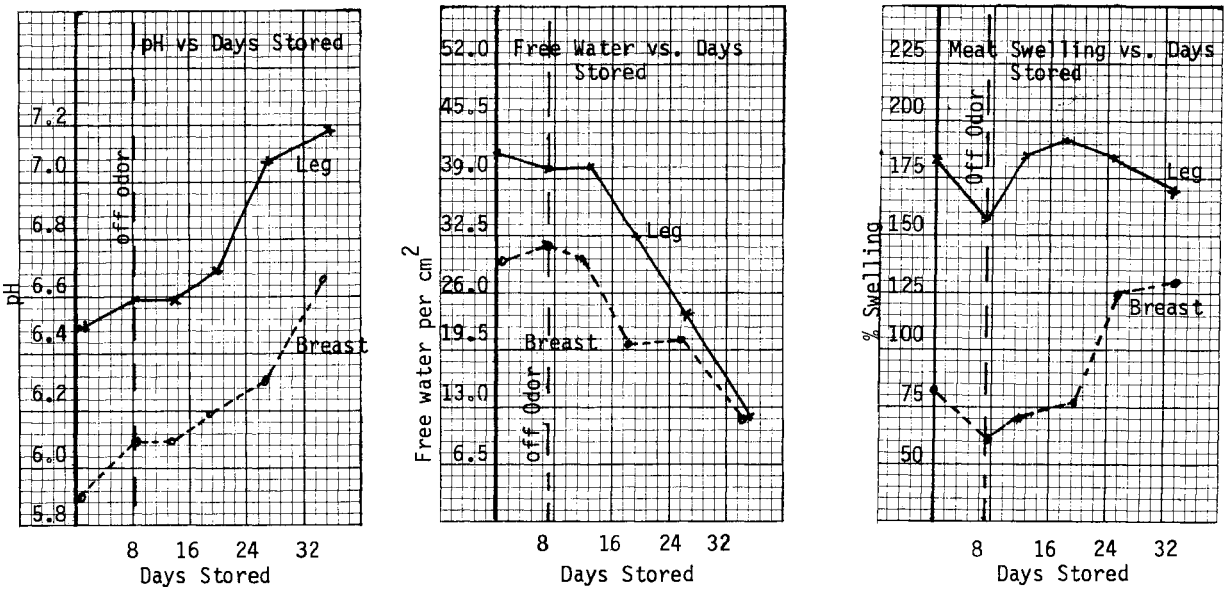

Figure 1. Ph, free water, and meat swelling of chicken meat stored at 1.6°C

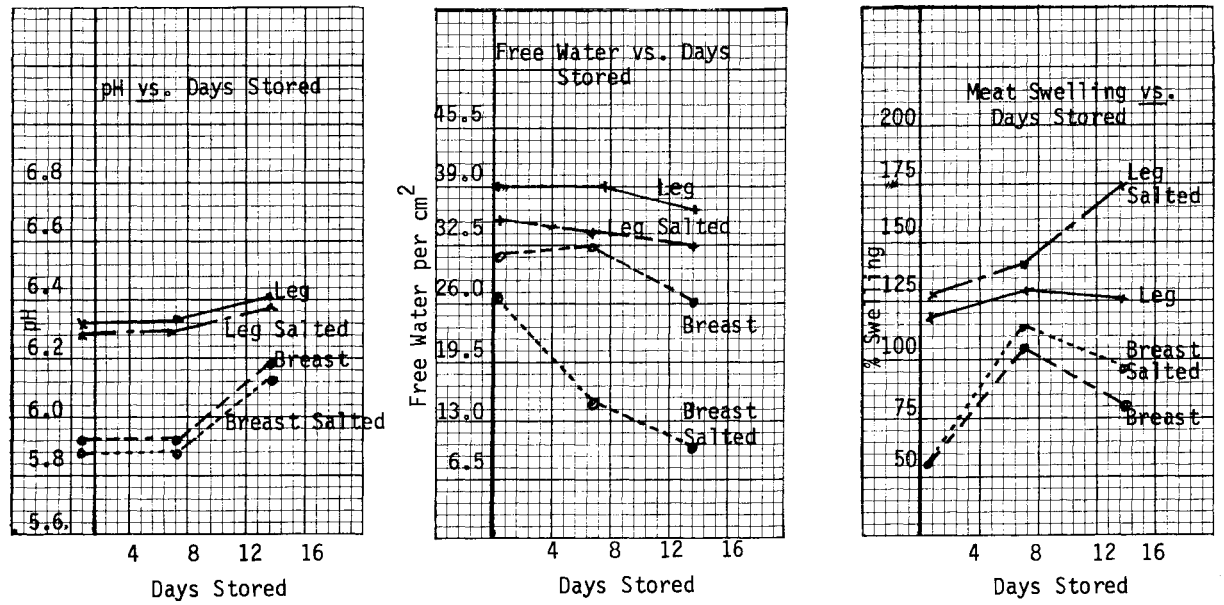

Figure 2. Effect of salt and pH, free water, and meat swelling of chicken meat stored at 1.6°C.

the nonsalted controls after 7 days. There were no changes in the pH, free water or meat swelling concurrent with the off odor development. This lack of change was expected as the off odors are the results of bacterial growth on the skin and not enzymatic meat breakdown.

Proximate analysis of the chicken meat shows that small quantities of salt are retained in the meat after soaking and rinsing procedures (Table 1).

Table 1

Proximate analysis of control and salted chicken meat stored at 1.6°C

		Protein		Nonprotein N.		NaCl		Ash		Fat		Moisture	
		Control	Salted	Control	Salted	Control	Salted	Control	Salted	Control	Salted	Control	Salted
Breast*	1 day	23.8	22.6	0.59	0.59	0.10	0.47	1.70	1.47	0.19	0.32	74.2	74.6
"	7 days	21.8	21.4	0.57	0.57	0.19	0.73	0.93	1.35	.23	0.19	75.2	75.1
"	14 "	22.4	22.2	0.60	0.60	0.14	0.67	0.90	1.35	.15	0.14	75.3	74.8
Leg*	1 day	20.5	19.7	0.42	0.41	0.19	0.38	1.14	1.33	1.89	2.19	76.2	76.1

* Mean of carcass

The effect of radurization on the pH, free water and meat swelling of stored chicken carcasses.

The pH of the nonirradiated chicken, both breast and leg meat, increased with storage time, after 21 days storage, the carcasses were discarded because of putrifaction (Figure 3). The pH of radurized carcasses increased up to 28 days in storage then declined. The pH of the radurized chicken meat was slightly more acid than the nonirradiated chicken meat.

The free water of the radurized breast and leg chicken meat was greater than the nonirradiated counterpart. As the storage period increased, there was a small decrease in free water of the radurized chicken. The free water of the nonirradiated chicken meat decreased markedly after 12 days storage.

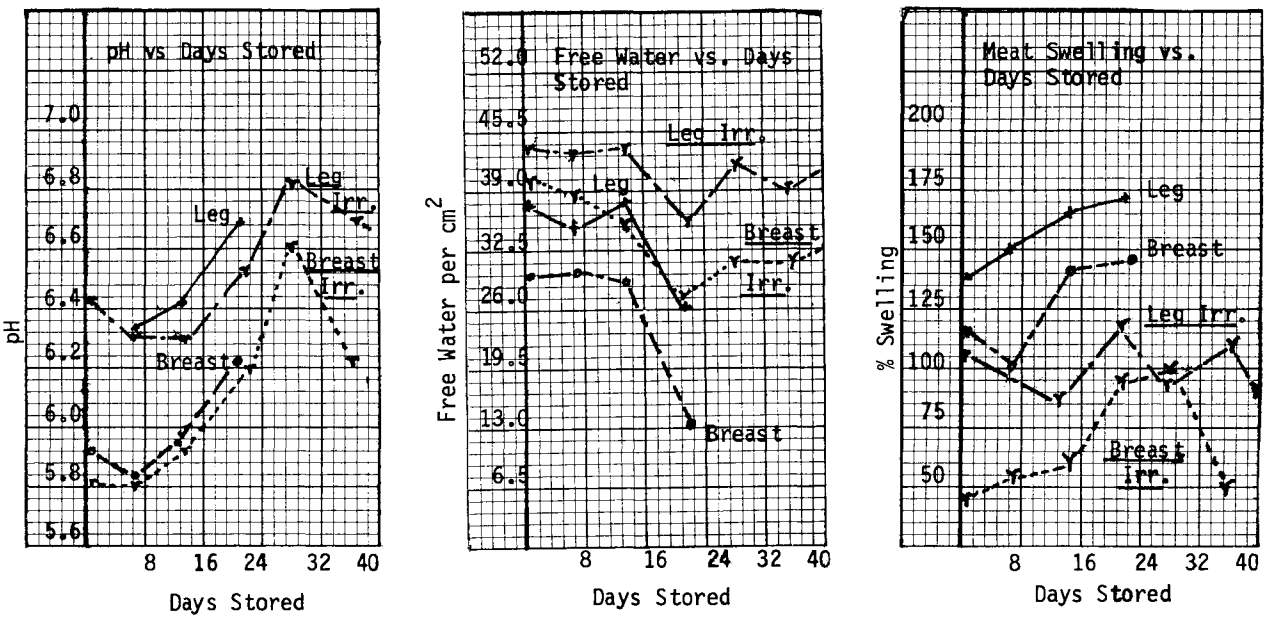

Figure 3. Effect of radurization (5.0 kGy) on pH, free water, and meat swelling of chicken meat stored at 1.6°C

The meat swelling of the radurized breast and leg chicken meat was less than the nonirradiated chicken. As the storage duration increased, the meat swelling of the nonirradiated chicken increased, the meat swelling of the radurized chicken increased until 26-34 days, then declined.

The pH, free water, and meat swelling of chicken were affected by the radurization process causing lower pH and meat swelling and greater free water content than the nonirradiated control. The optimum shelf life of

radurized chicken stored at 1.6°C is approximately 15 to 18 days (Howker et al., 1976)[12]. There was no pronounced change in these test data at the 18 to 21-day storage period that would indicate noticeable enzymatic degradation of the radurized chicken meat.

The effect of radurization on the pH, free water, meat swelling and total plate count of ground chicken meat.

The pH of the radurized and nonirradiated ground chicken meat was similar. There was little change in the pH of the ground leg muscle when stored 22 days; but the pH of the ground breast meat increased with extended storage (Fig. 4).

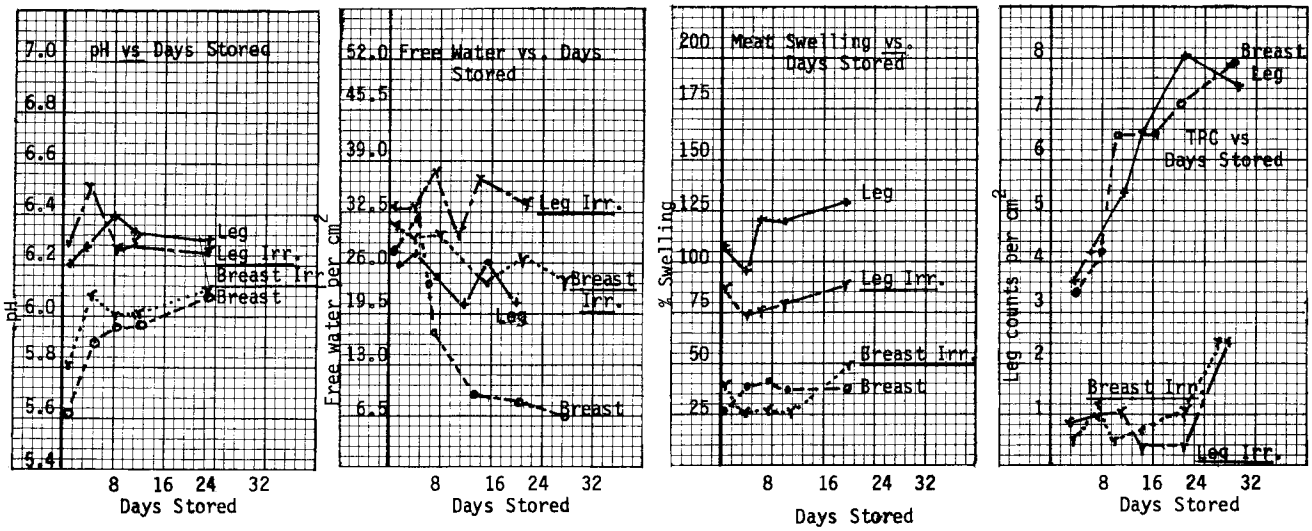

Figure 4. Effect of radurization (5.0 kGy) on pH, free water, meat swelling, and total plate count of ground chicken meat stored at 1.6°C.

The free water of the radurized ground chicken meat was greater than the nonirradiated meat and the meat swelling was less. The results for the ground and nonground meat are similar. The free water of the radurized ground meat decreased little during 21 days storage, but the nonirradiated ground meat free water decreased to a greater extent.

[12]See Reference 2.

The meat swelling of the nonirradiated ground meat was greater than the radurized meat. Both nonirradiated and radurized meat swelling increased slightly with storage time.

The total plate count of nonirradiated ground meat increased by 4 log cycles during storage; the radurized ground meat total plate count remained constant for 21 days, then increased by 2 log cycles in 7 days.

The radurized ground meat data are similar to the data of the nonground meat in that neither the pH, free water, meat swelling or total plate count indicates a change until after 18 to 21 days storage when the quality of the radurized meat becomes questionable. Therefore, these test methods are not useful as quality indicators for radurized poultry.

Volatile Organic Compounds. The classes of compounds found in both control and radurized chicken were: Hydrocarbons, aliphatic and aromatic; alcohols; ketones, aldehydes, and sulfur containing. Amines were found only in the decomposing control chicken meat. These control samples were also characterized by a marked increase in sulfur compounds with expended storage which was not the case with the irradiated samples. Control samples stored longer than fifteen days were not analyzed as these samples were spoiled.

The sum of the concentrations in ppb of the volatile compounds in the more volatile of the two fractions isolated from the samples is shown in Figure 5. The larger concentrations of volatile compounds observed initially in the radurized chicken samples is mainly due to the predominance of aliphatic hydrocarbons resulting from the irradiation process. There is a decrease in concentrations of volatiles for the first several days of storage for both control and radurized chicken meat. The decrease in concentration of volatiles of the control chicken meat correlates with the loss of fresh chicken odor (Table 2), and the later increase in volatile concentration

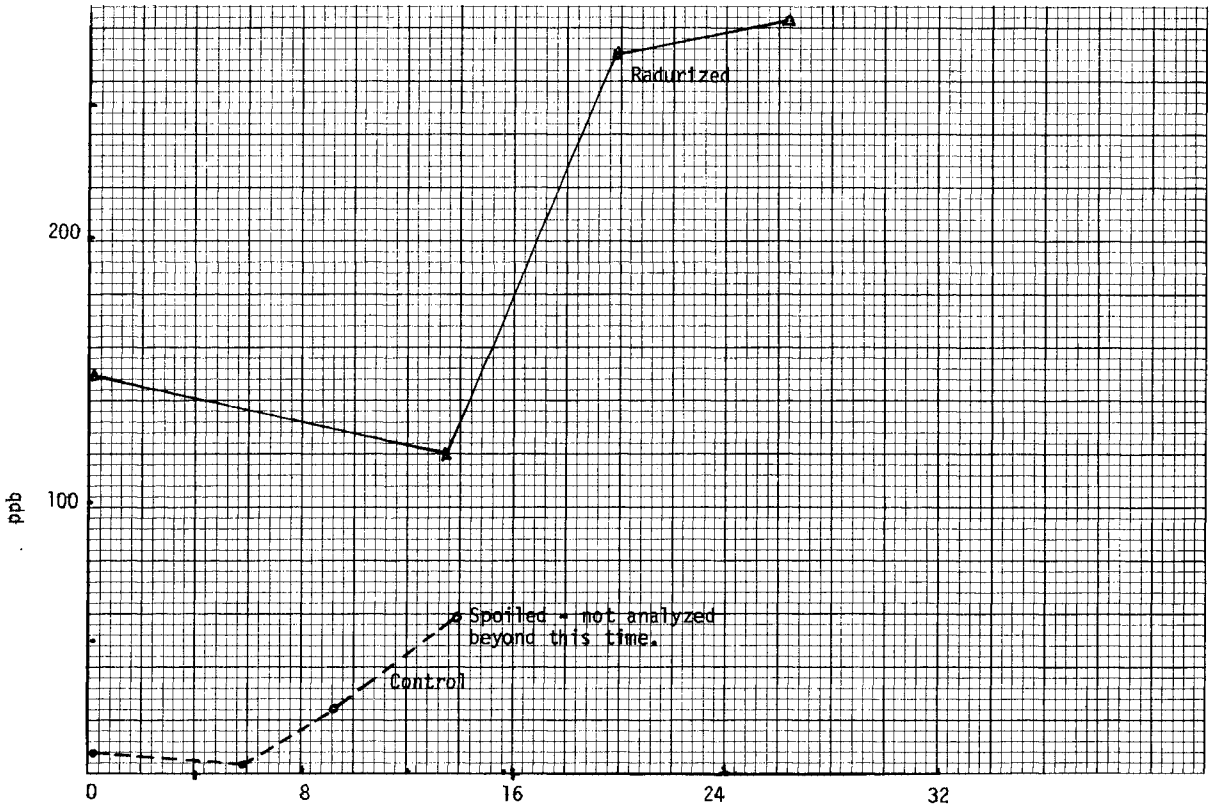

Figure 5 Total volatile organic compounds of more volatile fractions of radurized (2.5 kGy) and nonirradiated chicken meat stored at 1.6°C

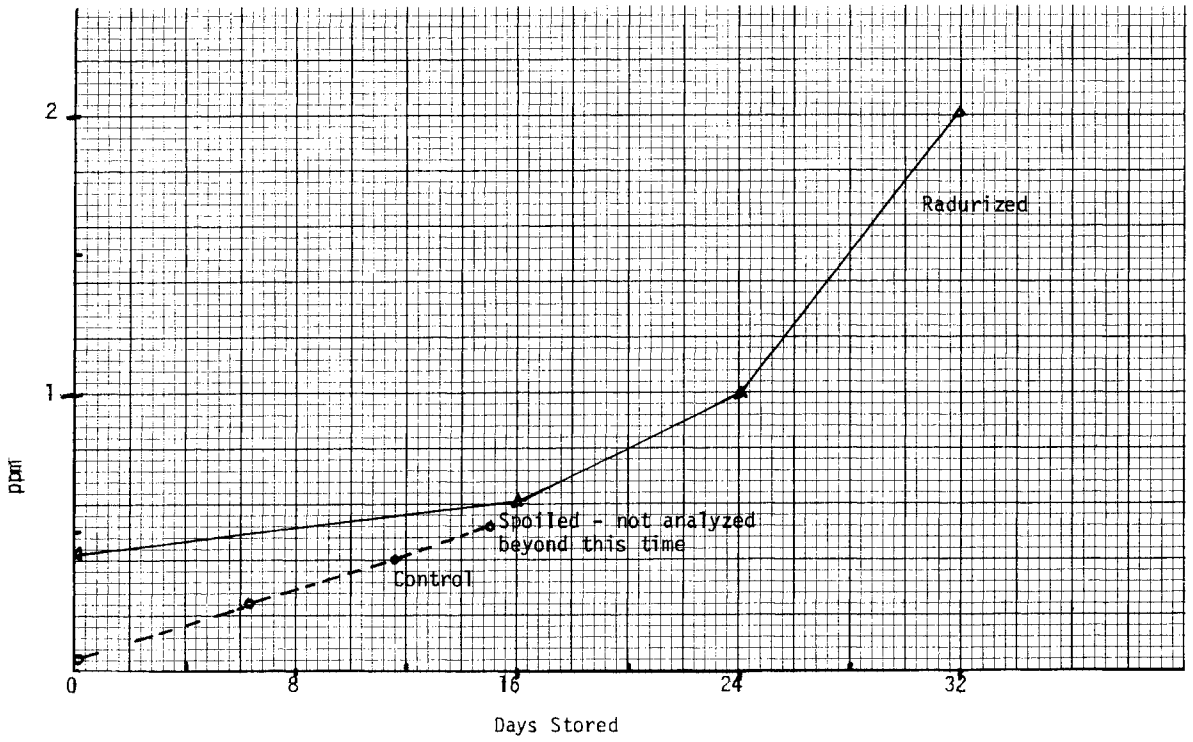

Figure 6 Total volatile organic compound concentration of radurized (2.5 kGy) and nonirradiated chicken meat stored at 1.6°C

Table 2

Odor profile of nonirradiated and radurized chicken* stored at 1.6°C.

Days Stored	Nonirradiated	Irradiation Dose 2.5 kGy	5.0 kGy
0 day	Fresh chicken	Slight irrad. odor	Irrad. odor
4	Fresh chicken	Fresh chicken odor	Slight irrad. odor
8	No odor	Fresh chicken odor	Fresh chicken odor
11	Slight off odor	Chicken odor	Chicken odor
15	Putrid	Slight chicken odor	Slight chicken odor
18	Putrid	Stale chicken odor	Stale chicken odor
22	Putrid	Stale chicken odor	Stale chicken odor
31	Putrid	Stale chicken (sour)	Stale chicken odor

* Examination of 6 carcasses

was in accord with the observed deterioration. There also was a decrease of radurized chicken meat volatile concentration which coincides with the early loss of irradiation odor. The later volatile concentration increase correlates with the observation of sample deterioration.

In general, the radurized samples contained a larger concentration of volatile compounds than did the controls (Figure 6). Although both control and radurized chicken meat showed an increase in concentration of volatile compounds with increasing storage time, they differed in the patterns of volatile compounds present. This is probably due to the fact that pseudomonas which are the bacteria mainly responsible for the production of sulfur compounds and resulting putrid spoilage odor are vitually destroyed by the irradiation treatment. However, other microorganisms normally present in the flora of fresh chicken, i.e. moraxella, remain viable after an irradiation treatment of 2.5 kGy (Freeman, et al., 1976)[13] and are mainly responsible for the nonputrid deterioration of the radurized chicken samples.

Because of the complexity of sample preparation, analysis and sophistication of the equipment, this technique as used in this study, would not be applicable as a quick test for deterioration of radurized chicken. However, it was observed in this study that the degree and type of deterioration and the loss of freshness in chicken stored at refrigeration temperatures could objectively be determined by chemical data obtained by proper selection and application of currently existing analytical techniques.

[13] L. R. Freeman, G. J. Silverman, P. Angelini, C. Merritt, Jr. and W. B. Esselen, 1976. Volatiles produced by microorganisms isolated from refrigerated chicken at spoilage. Appl. and Enviro. Microbiol., 32:222.

Conclusions

1. The pH, free water, and meat swelling data of stored chicken leg meat is different than that of breast meat.

2. Salt treatment (Kosher process) had no effect on the pH of stored chicken but decreased free water and increased the meat swelling.

3. Radurization decreased the pH and meat swelling and increased the free water of chicken meat. The pH, meat swelling and free water tests could be used to differentiate between radurized and nonirradiated chicken. The tests do not define the change in radurized chicken when enzymatic degradation is noticeable (18 to 21 days).

4. There is a marked difference in the patterns of volatile organic compounds found between the radurized chicken samples and the controls. These differences correspond well with the different types of spoilage odors and other sensory observations. Volatile organic compound concentrations correlate with the observations of chicken meat deterioration for both the radurized and control samples but considerable simplications of the analysis is required before it can be applied as a rapid objective test for deterioration of fresh and radurized chicken.

This document reports research undertaken at the US Army Natick Research and Development Command and has been assigned No. NATICK/TR-79/034 in the series of reports approved for publication.

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Wierbicki, E., M. G. Tiede, and R. C. Burrell, 1963. Die bestimmung der fleischquellung als methode zur untersuchung der wasserbindungskapazität von muskelproteinen mit geringem salthaltevermögen. II. Anwendung der quellungsmethodik. Die Fleischwirtschaft, 5:396.

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