IOWA STATE UNIVERSITY
Digital Repository

Animal Science Publications | Animal Science

9-2002

Quality Characteristics of Irradiated Ready-to-Eat Breast Rolls from Turkeys Fed Conjugated Linoleic Acid

M. Du
Iowa State University

Dong U. Ahn
Iowa State University, duahn@iastate.edu

Aubrey Mendonca
Iowa State University, amendon@iastate.edu

I. V. Wesley
United States Department of Agriculture

Follow this and additional works at: http://lib.dr.iastate.edu/ans_pubs


Part of the Agriculture Commons, Meat Science Commons, and the Poultry or Avian Science Commons

The complete bibliographic information for this item can be found at http://lib.dr.iastate.edu/ans_pubs/76. For information on how to cite this item, please visit http://lib.dr.iastate.edu/howtocite.html.

This Article is brought to you for free and open access by the Animal Science at Iowa State University Digital Repository. It has been accepted for inclusion in Animal Science Publications by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

Quality Characteristics of Irradiated Ready-to-Eat Breast Rolls from Turkeys Fed Conjugated Linoleic Acid

Abstract

The objective of this study was to determine the effect of irradiation on the quality of ready-toeat (RTE) breast rolls from turkeys fed conjugated linoleic acid (CLA). The oxidative stability of RTE turkey rolls was improved by the dietary CLA treatment. Irradiation increased the production of acetaldehyde, 3-methyl-butanal, 2-methyl-butanal, and total volatiles in turkey rolls but had little effect on other aldehydes. Irradiation also produced new volatiles, including sulfur compounds, not detected in nonirradiated turkey breast rolls. We detected significantly higher amounts of alkanes with nine or higher carbons in irradiated samples than in nonirradiated samples. Irradiation increased the redness of RTE turkey breast rolls, but the degree of redness and the amount of total volatiles decreased with storage. CLA treatment lowered the redness (a*) and increased the lightness (L*) of RTE turkey breast rolls during the entire storage period. Sensory evaluation revealed that irradiation produced off-flavor, but CLA and irradiation did not influence the texture and juiciness of RTE turkey breast rolls. Consumers did not like the off-flavor but preferred the color induced by irradiation to nonirradiated RTE turkey breast rolls.

Keywords

turkey breast roll, irradiation, sensory characteristic, consumer test, conjugated linoleic acid

Disciplines

Agriculture | Animal Sciences | Meat Science | Poultry or Avian Science

Comments

This article is from *Poultry Science* 81 (2002): 1378, doi:10.1093/ps/81.9.1378.

Rights

Works produced by employees of the U.S. Government as part of their official duties are not copyrighted within the U.S. The content of this document is not copyrighted.

This article is available at Iowa State University Digital Repository: http://lib.dr.iastate.edu/ans_pubs/76

Quality Characteristics of Irradiated Ready-to-Eat Breast Rolls from Turkeys Fed Conjugated Linoleic Acid[1]

M. Du,* D. U. Ahn,*[,2] A. F. Mendonca,† and I. V. Wesley‡

*Department of Animal Science, and †Department of Food Science, Iowa State University, Ames, Iowa 50011-3150; and ‡Pre-Harvest Food Safety and Enteric Disease Unit, National Animal Disease Center, Ames, Iowa 50010

ABSTRACT The objective of this study was to determine the effect of irradiation on the quality of ready-to-eat (RTE) breast rolls from turkeys fed conjugated linoleic acid (CLA). The oxidative stability of RTE turkey rolls was improved by the dietary CLA treatment. Irradiation increased the production of acetaldehyde, 3-methyl-butanal, 2-methyl-butanal, and total volatiles in turkey rolls but had little effect on other aldehydes. Irradiation also produced new volatiles, including sulfur compounds, not detected in nonirradiated turkey breast rolls. We detected significantly higher amounts of alkanes with nine or higher carbons in irradiated samples than in nonirradiated samples. Irradiation increased the redness of RTE turkey breast rolls, but the degree of redness and the amount of total volatiles decreased with storage. CLA treatment lowered the redness (a*) and increased the lightness (L*) of RTE turkey breast rolls during the entire storage period. Sensory evaluation revealed that irradiation produced off-flavor, but CLA and irradiation did not influence the texture and juiciness of RTE turkey breast rolls. Consumers did not like the off-flavor but preferred the color induced by irradiation to nonirradiated RTE turkey breast rolls.

(*Key words*: turkey breast roll, irradiation, sensory characteristic, consumer test, conjugated linoleic acid)

2002 Poultry Science 81:1378–1384

Downloaded from http://ps.oxfordjournals.org/ at Iowa State University on May 11, 2015

INTRODUCTION

A multistate outbreak of food poisoning was associated with the consumption of delicatessen meats, including turkey products (Morbidity and Mortality Weekly Report, 1998). A popular delicatessen item is ready-to-eat (RTE) turkey roll, which is usually cooked to an internal temperature of 73 C, cooled, sliced, repackaged, and then refrigerated. Although *Listeria monocytogenes* can be killed during the cooking, a tremendous potential exists for postcooking contamination of the product during handling prior to final packaging. In addition, *L. monocytogenes* could survive the conditions (salt, refrigeration) provided by this product. Of the 12 product recalls during 1999, six were attributed to *L. monocytogenes* in delicatessen meats. An urgent need exists for postcook bactericidal interventions, such as bacteriocins or irradiation, to eliminate *L. monocytogenes* in RTE meats without negatively affecting their sensory characteristics.

Irradiation is an effective tool in inactivating foodborne pathogens. In light of recent outbreaks and product recalls due to pathogens in meat, the expanded application of irradiation technology in meat and meat products is important. However, irradiation is reported to induce off-odor, lipid oxidation, and color changes, which negatively affect consumer acceptance of meat (Nanke et al., 1998, 1999; Jo and Ahn, 2000; Ahn et al., 2000a). Irradiation off-odor is related to sulfur compounds, aldehydes, and alkanes formed from radiolysis of sulfur amino acids and fatty acids (Ahn et al., 2000a,b; Du et al., 2001). The color changes induced by irradiation are associated with CO production during irradiation (Nam and Ahn, 2002a,b).

Most studies related to irradiation impact on meat quality are based on fresh or unprocessed cooked meats; few reports are available on quality and consumer acceptance of irradiated RTE meat products. Irradiation of meat under vacuum can lessen these oxidative changes (Ahn et al., 1998), and addition of antioxidants has proven effective in lessening oxidative changes.

Dietary conjugated linoleic acid (CLA) reduces the proportion of polyunsaturated fatty acids in animal tissues (Du et al., 2000, 2001). Therefore, meats from animals fed CLA will be less susceptible to lipid oxidation, color changes, and volatile production than those from

©2002 Poultry Science Association, Inc.

Received for publication August 15, 2001.
Accepted for publication April 10, 2002.
[1]Journal Paper Number J-19508 of the Iowa Agriculture and Home Economics Experiment Station, Ames, IA 50011-3150. Project No. 3706, supported by the National Alliance of Food Safety.

[2]To whom correspondence should be addressed: duahn@iastate.edu.

Abbreviation Key: CLA = conjugated linoleic acid; GC = gas chromatograph; MS = mass spectrometry; RTE = ready-to-eat; TBARS, = 2-TBA-reactive substances; TCA = trichloroacetic acid.

animals fed a control diet. When considering the involvement of free radicals in lipid oxidation-dependent off-odor production, the use of dietary antioxidants to control off-odor production in meats by irradiation is highly reasonable (Patterson and Stevenson, 1995). The objective of this study was to determine the effect of dietary CLA and irradiation on volatiles, color, sensory characteristics, and consumer acceptance of RTE turkey rolls under vacuum packaging.

MATERIALS AND METHODS

Sample Preparation

Eighty 3-mo-old turkeys were allotted to four pens; two pens (20 birds/pen) were assigned to one of the dietary treatments containing 0% CLA from a commercial source,[3] and the other two pens were assigned to diets with 2% CLA[3] (60% CLA, mainly *cis*-9, *trans*-11, and *trans*-10, *cis*-12 CLA isomers). A corn-soybean meal basal diet was used, and the energy level was adjusted using soybean oil.

After 2 mo on the feeding trial, turkeys were slaughtered following the USDA guidelines. After 24 h of storage at 4 C, breast muscles were separated from the carcasses and used to make breast rolls. Breast meats were ground through a 15-mm plate two times and then mixed for 3 min with 1.5% NaCl, 0.5% polyphosphate, and 10% water. The mixture was stuffed into 150-mm collagen casings and then cooked in an 85 C smoke house with relative humility of 92% until the center temperature reached 74 C. After being cooled by a cold-water shower, the rolls were cut into 5 mm thick slices and individually packaged in vacuum bags[4] (nylon-polyethylene, 9.3 mL O_2/m_2 per 24 h at 0 C). Four replications were prepared.

Color Measurement

The surface colors of turkey rolls were measured in package with a Hunter LabScan colorimeter[5] and expressed as color L* (lightness), a* (redness), and b* (yellowness) values. The same packaging materials were used to cover white standard plates to eliminate the influence of packaging material on meat color.

Gas Measurement

Minced turkey roll (10 g) was put in a 24-mL screw-cap glass vial with a Teflon × fluorocarbon resin-silicone septum.[6] Each vial was microwaved for 10 s at full power (1,200 W) to release gas compounds from the meat sample. After 5 min of cooling at room temperature, headspace (200 μL) was withdrawn with an airtight syringe and injected into a gas chromatograph (GC).[7]

A Carboxen-1006 Plot column[8] (30 m × 0.32 mm i.d.) was used to analyze gas compounds produced by irradiation in turkey rolls. The initial oven temperature was 50 C and was increased to 160 C at 25 C/min. Helium was the carrier gas at a constant flow of 2.4 mL/min. A flame ionization detector equipped with a nickel catalyst[7] was used as a detector, and the temperatures of inlet, detector, and nickel catalyst were set at 250, 280, and 375 C, respectively. Detector air, hydrogen, and make-up gas (helium) flows were 400, 40, and 50 mL/min, respectively.

Gas compounds were identified by using standards and a GC-mass spectrometer (MS).[7] The area of each peak was integrated by Chemstation software.[7] To quantify the amounts of gases released, each peak area (pA × s) was converted to a gas concentration (ppm or %) contained in the headspace (14 mL) of 10-g meat samples, using the concentration of CO_2 in air (330 ppm).

2-TBA-Reactive Substances Measurement

Five grams of meat was weighed into a 50-mL test tube and homogenized with 15 mL of deionized distilled water (DDW) using a Polytron homogenizer[9] for 10 s at highest speed. One milliliter of the meat homogenate was transferred to a disposable test tube (3 × 100 mm), and 50 μL of butylated hydroxyanisole (7.2%) and 2 mL of TBA-trichloroacetic acid (15 m*M* TBA-15% TCA) were added. The mixture was vortexed and then incubated in a boiling water bath for 15 min to develop color. Then sample was cooled in cold water for 10 min, vortexed again, and centrifuged for 15 min at 2,500 × *g*. The absorbance of the resulting supernatant solution was determined at 531 nm against a blank containing 1 mL of deionized distilled water and 2 mL of TBA-TCA solution. The amounts of TBA-reactive substances (TBARS) were expressed as milligrams of malonaldehyde per kilogram of meat.

Volatile Analysis

A purge-and-trap dynamic headspace GC-MS system was used to identify and quantify the volatile compounds. One gram of minced RTE turkey roll was placed in a 40-mL sample vial, and the vial was flushed with helium gas (99.999%) for 5 s at 40 psi. After capping with a Teflon-lined, open-mouth cap, the vial was placed on a refrigerated (4 C) sample tray. The maximum sample holding time on the sample tray before determination of volatiles was less than 3 h to minimize oxidative changes (Ahn et al., 1999). Samples were heated to 40 C and purged with helium gas (40 mL/min) for 15 min. Volatiles were trapped with a Tenax trap column[10] at 20 C, desorbed for 2 min at 220 C, concentrated using

[3]Conlinco, Inc., Detroit Lakes, MN.
[4]Koch, Kansas City, MO.
[5]Hunter Laboratory, Inc., Reston, VA.
[6]I-Chem. Co., New Castle, DE.
[7]Hewlett Packard Co., Wilmington, DE.
[8]Supelco, Bellefonte, PA.
[9]Brinkman Instruments Inc., Westbury, NY.
[10]Tekmar-Dorham, Cincinnati, OH.

Downloaded from http://ps.oxfordjournals.org/ at Iowa State University on May 11, 2015

a cryofocusing unit at –80 C, and then desorbed into a GC column for 30 s at 220 C. A GC equipped with a mass selective detector[7] was used to separate, identify, and quantify the volatile compounds in irradiated samples. An HP-624 column (7.5 m, 250 μm i.d., 1.4 μm nominal),[7] an HP-1 column (52 m, 250 μm i.d., 0.25 μm nominal),[7] and an HP-Wax column (7.5 m, 250 (m i.d., 0.25 (m nominal)7 were combined using zero-volume connectors and used for volatile analysis. A ramped oven temperature was used: the initial oven temperature was set at 0 C for 2.5 min, and then increased to 10 C at 5 C/min, to 45 C at 10 C/min, to 110 C at 20 C/min, to 210 C at 10 C/min, and held for 2.5 min. Liquid nitrogen was used to cool the oven below ambient temperature. Helium was the carrier gas at constant pressure of 20.5 psi. The ionization potential of the MS was 70 eV; the scan range was between 18.1 and 350 m/z. The identification of volatiles was achieved by comparing mass spectral data with those of the Wiley library and authentic standards. The peak area was reported as the amount of volatiles released.

Sensory Evaluation by Trained Sensory Panel

Sixteen trained sensory panelists characterized sensory attributes of RTE turkey breast rolls. Panelists were selected based on interest, availability, and performance in screening tests conducted with samples similar to those being tested. Training sessions were conducted to allow panelists familiarize themselves with irradiation odor, the scales to be used, and the ranges of attribute intensity likely to be encountered during the study. Fifteen-centimeter linear horizontal scales, anchored with descriptors at opposite ends, were used to rate the stimuli of color (none to pink), aroma (weak to strong), off-flavor (weak to strong), hardness (soft to hard), and juiciness (dry to juicy) of RTE turkey rolls. The responses from the panelists were expressed in numerical values ranging from 0 to 15. All samples presented to panelists were labeled with random three-digit numbers.

Consumer Test

For consumer acceptance test, each pack of turkey rolls from different dietary treatments was labeled with a different, random, three-digit number. Consumers were selected based on the frequency of poultry meat consumption and willingness to participate in test. After reading an informed consent form, consumers who agreed to participate were asked to indicate their preferences of the color, flavor, and overall acceptance of turkey rolls on seven-point hedonic scales (where 1 = dislike strongly to 7 = like strongly).

Statistical Analyses

Data were processed by the general linear model of SAS software (SAS Institute Inc., 2000). Mean values and standard errors of the means are reported, and the differences in the mean values were compared by the Student-Newman-Keuls' multiple-range test.

RESULTS AND DISCUSSION

TBARS Values

Table 1 shows the TBARS values of breast rolls. At 0 d of storage, irradiation with up to 2.5 kGy did not influence the TBARS of RTE turkey breast rolls. However, after 3 and 7 d of storage, there were differences in the TBARS of RTE rolls. At Day 3, the TBARS of RTE rolls from the control diet that received 2.5 kGy irradiation were significantly lower than those that received 0 or 1.5 kGy irradiation. At Day 7, the TBARS of rolls from the CLA diet that received 2.5 kGy was significantly lower than that of control diet. The reason for reduced TBARS values in RTE rolls irradiated at 2.5 kGy could have been due to the increased oxidation-reduction (redox) potential of RTE breast rolls immediately after irradiation. Nam et al. (2002a,b) showed that irradiation significantly reduced the redox potential of meat, which was confirmed by Du et al (2002). However, irradiation initiates lipid oxidation by generating free radicals and, thus, accelerates oxidation. Therefore, the net effect of irradiation on lipid oxidation, whether preventing or accelerating it, will be dependent upon the balance between the decrease in redox potential and the initiation of lipid oxidation by irradiation.

Lipid oxidation in RTE turkey rolls did not proceed because of low oxygen availability under vacuum conditions, and thus, decreased TBARS of irradiated meat was the net effect of irradiation. We have observed similar results in vacuum-packaged irradiated meats. RTE turkey rolls from dietary CLA treatments had lower TBARS than those from control diet (Table 1) and were consistent with our previous report (Du et al., 2000). The main reason for the improved oxidative stability could have been due to the decreased proportion of unsaturated fatty acids in meat by the dietary CLA (Du et al., 2001).

Volatile Profiles

Irradiation had significant influence on numerous volatiles, mainly sulfur compounds, aldehydes, and alkanes (Tables 2 and 3). Dimethyl sulfide, carbon disulfide, dimethyl disulfide, and dimethyl trisulfide were the sulfur compounds detected in irradiated RTE turkey rolls. The amounts of all those sulfur compounds increased as the irradiation dose increased. Due to the low threshold for odor detection for sulfur compounds, even small amounts of these sulfur compounds are important in irradiation off-odor (Ahn et al., 2000a,b). Irradiation also greatly increased acetaldehyde, 3-methyl-butanal, and 2-methyl-butanal. Whereas 3-methyl-butanal and 2-methyl-butanal were from the radiolysis of leucine and isoleucine, the source of acetaldehyde is not clear yet (Jo and Ahn, 2000). Other aldehydes, including propanal,

Downloaded from http://ps.oxfordjournals.org/ at Iowa State University on May 11, 2015

TABLE 1. The 2-TBA-reactive substances (TBARS) values of turkey rolls under vacuum packaging[1]

Storage	Dietary treatment	0 kGy	1.5 kGy	2.5 kGy	SEM
		(mg MDA/kg meat)			
0 d	0% CLA	0.83	0.74^{x}	0.78^{x}	0.04
	2% CLA	0.67	0.65^{y}	0.60^{y}	0.03
	SEM	0.05	0.02	0.02	
3 d	0% CLA	0.74	0.78	0.75^{x}	0.04
	2% CLA	0.67^{a}	0.67^{a}	0.57^{by}	0.02
	SEM	0.03	0.05	0.02	
7 d	0% CLA	0.89^{ax}	0.93^{ax}	0.75^{b}	0.04
	2% CLA	0.69^{y}	0.69^{y}	0.62	0.03
	SEM	0.04	0.04	0.03	

[a,b]Means within a row with no common superscript differ significantly ($P < 0.05$); n = 4.
[x-y]Means within a column with no common superscript differ significantly ($P < 0.05$); n = 4.
[1]CLA = conjugated linoleic acid; MDA = malondialdehyde.

butanal, and hexanal, were less influenced by irradiation. Many of alkanes were detected in the volatiles of RTE turkey rolls. The amounts of alkanes with longer than nine carbons increased, but most of the smaller alkanes with less than nine carbons were not influenced by irradiation. The significance of alkanes on irradiation odor is not clear.

No significant differences in volatiles between the RTE rolls from turkeys fed 0% CLA and 2% CLA were found in most of the volatile compounds detected. However, the content of acetaldehyde was higher in 2% CLA turkey rolls than that in 0% CLA, although this was not statistically significant. In the study of chicken rolls, we found that acetaldehyde might be related to metal-like odor after irradiation (Du et al., 2002). In the chicken study, however, much higher amounts of acetaldehyde were detected, and sensory panelists identified a much stronger and obvious metal-like odor after irradiation.

After 7 d of storage, the overall contents of volatiles decreased, whereas the general volatile profiles were not changed. The decrease in volatile content during storage under vacuum conditions is reasonable because small

TABLE 2. The volatile profile of turkey rolls at 0 d of storage under vacuum packaging[1]

	0% CLA				2% CLA			
Volatile	0 kGy	1.5 kGy	2.5 kGy	SEM	0 kGy	1.5 kGy	2.5 kGy	SEM
Butane	109	130	208	39	83^{b}	160^{a}	179^{a}	12
Acetaldehyde	174^{c}	$1,155^{b}$	$2,697^{a}$	264	207^{c}	$2,107^{b}$	$3,172^{a}$	91
Methane thiol	0^{c}	990^{b}	$2,512^{a}$	152	0^{c}	502^{b}	$1,032^{a}$	81
Pentane	4,316	3,474	4,477	621	2,496	2,486	2,909	212
Propanal	378	125	445	161	84^{b}	95^{b}	159^{a}	13
Dimethyl sulfide	1,382	1,379	1,695	253	984	624	1,165	216
Carbon disulfide	73^{ab}	92^{a}	0^{b}	24	0	0	31	18
2-Methyl-propanal	128^{c}	566^{b}	$1,238^{a}$	41	97^{c}	546^{b}	828^{a}	35
Hexane	1,003	483	704	336	761^{b}	825^{b}	$1,331^{a}$	114
Butanal	212	21	138	110	136^{b}	201^{a}	240^{a}	19
Methyl cyclopentane	93	0	70	56	0	0	0	0
3-Methyl-butanal	294^{c}	$1,147^{b}$	$2,498^{a}$	91	229^{c}	$1,095^{b}$	$1,726^{a}$	38
2-Methyl-butanal	169^{c}	902^{b}	$2,072^{a}$	69	130^{c}	871^{b}	$1,408^{a}$	44
Heptane	480	391	597	99	470^{b}	615^{ab}	754^{a}	73
Pentanal	1,893	548	942	729	917^{b}	$1,031^{ab}$	$1,284^{a}$	83
Dimethyl disulfide	456^{c}	$2,781^{b}$	$4,587^{a}$	155	503^{c}	$2,456^{b}$	$3,938^{a}$	222
Toluene	71^{c}	931^{b}	$1,935^{a}$	66	88^{c}	$1,057^{b}$	$1,682^{a}$	43
Octane	2,293	2,395	2,956	333	4,055	2,031	4,437	740
2-Octene	153	105	179	20	585	115	839	238
Hexanal	5,004	3,271	4,831	832	4,104	3,677	4,392	339
Benzene	69^{b}	125^{b}	219^{a}	25	107^{b}	95^{b}	191^{a}	22
Nonane	179^{b}	268^{a}	329^{a}	28	137^{b}	232^{a}	244^{a}	26
Heptanal	0	0	0	0	0	0	0	0
Decane	$1,022^{b}$	$2,063^{ab}$	$3,213^{a}$	550	$1,020^{b}$	$1,493^{a}$	$1,565^{a}$	108
2-Methyl decane	414^{b}	$1,269^{ab}$	$1,968^{a}$	330	569^{b}	$1,396^{a}$	$1,459^{a}$	110
Nonadecane	$1,006^{b}$	$1,941^{ab}$	$2,919^{a}$	465	$1,213^{b}$	$1,737^{ab}$	$2,214^{a}$	237
Dimethyl trisulfide	211^{c}	870^{b}	$1,568^{a}$	138	0^{c}	903^{b}	$1,310^{a}$	99
Dimethyl decane	$1,363^{b}$	$3,567^{ab}$	$5,541^{a}$	1,269	$1,806^{a}$	$2,186^{b}$	$2,575^{b}$	398
Dodeecane	2,982	5,059	5,532	976	2,834	3,674	3,433	1,089
Total	26,785	37,717	58,960	8,459	$25,399^{b}$	$32,310^{b}$	$46,116^{a}$	2,234

[a-c]Means within a row of same category with no common superscript differ significantly ($P < 0.05$), n = 5.
[1]CLA = conjugated linoleic acid.

Downloaded from http://ps.oxfordjournals.org/ at Iowa State University on May 11, 2015

TABLE 3. The volatile profile of turkey rolls at 7 d of storage under vacuum packaging[1]

	0% CLA				2% CLA			
Volatile	0 kGy	1.5 kGy	2.5 kGy	SEM	0 kGy	1.5 kGy	2.5 kGy	SEM
Butane	24^{c}	85^{b}	130^{a}	11	95	125	155	17
Acetaldehyde	498	921	975	172	0^{c}	1,687^{a}	1,021^{b}	173
Methane thiol	0^{c}	757^{b}	1,545^{a}	147	0^{c}	550^{b}	842^{a}	91
Pentane	2,903	2,861	2,807	309	2,295	2,458	2,017	307
Propanal	181	122	125	26	23^{b}	239^{a}	103^{b}	30
Dimethyl sulfide	838	1,036	880	56	989	1,160	1,164	201
Carbon disulfide	0^{b}	0^{b}	66^{a}	17	57	37	0	25
2-Methyl-propanal	156^{c}	469^{b}	730^{a}	31	0^{c}	494^{b}	638^{a}	29
Hexane	355	375	405	23	564	975	870	150
Butanal	34	0	0	12	66	192	183	38
Methyl cyclopentane	63^{a}	0^{b}	0^{b}	15	0	30	27	23
3-Methyl-butanal	469^{c}	911^{b}	1,406^{a}	61	149^{c}	989^{b}	1,306^{a}	43
2-Methyl-butanal	240^{c}	802^{b}	1,294^{a}	49	102^{b}	232^{b}	1,143^{a}	65
Heptane	305	336	400	35	419	592	554	78
Pentanal	536	496	493	37	652^{b}	1,348^{a}	926^{ab}	148
Dimethyl disulfide	251^{c}	2,235^{b}	3,003^{a}	127	284^{c}	1,365^{b}	2,434^{a}	210
Toluene	22^{c}	789^{b}	1,297^{a}	44	68^{c}	834^{b}	1,290^{a}	51
Octane	1,863	1,691	1,620	127	3,016	3,946	2,277	809
2-Octene	99	91	90	5	629	918	474	241
Hexanal	3,830	3,594	3,107	409	2,862	4,070	2,524	486
Benzene	16^{b}	57^{ab}	101^{a}	19	80	147	149	20
Nonane	139	143	189	15	58^{b}	136^{a}	165^{a}	15
Heptanal	0	0	0	0	0	0	0	0
Decane	867	721	1,151	186	771	739	824	121
2-Methyl decane	562	464	716	108	486^{b}	422^{b}	699^{a}	66
Nonadecane	958	798	1,216	162	729	776	1,060	319
Dimethyl trisulfide	147^{b}	482^{a}	633^{a}	63	0^{c}	328^{b}	502^{a}	32
Dimethyl decane	1,045	873	1,510	343	439^{b}	412^{b}	2,151^{a}	193
Dodecane	2,941	2,354	3,764	661	3,082^{b}	2,347^{b}	4,950^{a}	491
Total	20,144^{b}	24,158^{b}	30,331^{a}	1,662	18,867^{b}	28,643^{a}	31,258^{a}	2,530

$^{a\text{-}c}$Means within a row of same category with no common superscript differ significantly ($P < 0.05$); n = 5.

[1]CLA = conjugated linoleic acid.

TABLE 4. Color of turkey rolls at 0 d of storage under vacuum packaging[1]

Storage	Hunter color	Dietary treatment	0 kGy	1.5 kGy	2.5 kGy	SEM
0 d	L*	0% CLA	78.04	78.94	78.87	0.54
		2% CLA	78.70	78.64	78.45	0.32
		SEM	0.50	0.20	0.54	
	a*	0% CLA	8.95^{bx}	11.90^{ax}	12.17^{a}	0.16
		2% CLA	8.53^{by}	11.50^{ay}	11.77^{a}	0.19
		SEM	0.12	0.08	0.27	
	b*	0% CLA	14.30^{a}	12.71^{b}	12.16^{c}	0.17
		2% CLA	13.92^{a}	12.41^{b}	12.31^{b}	0.20
		SEM	0.19	0.11	0.24	
3 d	L*	0% CLA	78.81	79.22	78.87^{y}	0.34
		2% CLA	79.42	79.93	79.89^{x}	0.23
		SEM	0.26	0.31	0.30	
	a*	0% CLA	8.36^{cx}	11.45^{b}	12.84^{ax}	0.31
		2% CLA	7.67^{by}	10.70^{a}	11.34^{ay}	0.40
		SEM	0.22	0.47	0.33	
	b*	0% CLA	14.06^{ax}	11.90^{b}	11.79^{b}	0.13
		2% CLA	13.55^{ay}	12.34^{b}	11.34^{c}	0.24
		SEM	0.17	0.22	0.18	
7 d	L*	0% CLA	80.90	79.64^{y}	79.83	2.41
		2% CLA	81.45	82.08^{x}	81.54	0.54
		SEM	0.56	0.59	0.92	
	a*	0% CLA	7.66^{cx}	10.05^{bx}	11.05^{ax}	0.18
		2% CLA	7.20^{cy}	9.03^{by}	10.00^{ay}	0.16
		SEM	0.10	0.19	0.19	
	b*	0% CLA	15.34^{a}	13.31^{b}	12.51^{b}	0.44
		2% CLA	14.04	13.85	12.75	0.48
		SEM	0.43	0.39	0.55	

$^{a\text{-}c}$Means within a row with no common superscript differ significantly ($P < 0.05$); n = 8.

$^{x\text{-}y}$Means within a column of same category with no common superscript differ significantly ($P < 0.05$); n = 8.

[1]CLA = conjugated linoleic acid.

Downloaded from http://ps.oxfordjournals.org/ at Iowa State University on May 11, 2015

TABLE 5. The sensory evaluation results of turkey rolls by trained sensory panels[1]

Sensory characteristic	Dietary treatment	Irradiation dose			
		0 kGy	1.5 kGy	2.5 kGy	SEM
Color	0% CLA	5.2[b]	8.2[a]	9.8[a]	0.6
	2% CLA	5.1[c]	7.8[b]	10.4[a]	0.7
	SEM	0.7	0.6	0.6	
Aroma	0% CLA	7.6	8.1	8.9	0.9
	2% CLA	6.9	7.5	8.5	1.0
	SEM	1.0	1.0	0.9	
Off-odor	0% CLA	3.7[b]	8.1[a]	9.8[a]	0.7
	2% CLA	3.4[c]	7.7[b]	9.9[a]	0.7
	SEM	0.5	0.7	0.9	
Texture	0% CLA	7.4	7.5	7.8	0.7
	2% CLA	7.2	7.8	9.1	0.6
	SEM	0.7	0.6	0.6	
Juiciness	0% CLA	7.9	6.9	7.4	0.7
	2% CLA	7.5	6.9	6.0	0.6
	SEM	0.6	0.7	0.7	

[a-c]Means within a row with no common superscript differ significantly ($P < 0.05$); n = 16.

[1]CLA = conjugated linoleic acid.

volatiles may escape through packaging material or react with other components in meat and become nonvolatile.

Color Measurement

Dietary CLA did not influence the L* values of turkey rolls at 0 d of storage. At 3 and 7 d of storage, however, the L* values of turkey rolls from turkeys fed 2% CLA were higher than those of control (Table 4). Irradiation did not affect on the L* values of turkey rolls. Irradiation increased the a* values of RTE turkey rolls, which was in agreement with previous reports (Du et al., 2000). One interesting finding here was that the redness of irradiated and nonirradiated turkey rolls from the dietary CLA treatments was lower than that of the controls before and after irradiation and remained low throughout storage. The reason for the decreased redness after CLA feeding was not clear but could be related to the reduced CO production in rolls from turkeys fed CLA. The production of CO in meats from broilers fed with CLA was lower than that of the control (Du et al., 2002). During storage, L* and b* values of turkey rolls were unchanged, but a* values decreased with storage time. The b* values significantly decreased as the irradiation dosage increased, regardless of dietary CLA treatments.

Sensory and Consumer Acceptance Analyses

The sensory evaluation results are shown in Table 5. The pink color of turkey roll increased as the irradiation dose increased, and was in agreement with the Hunter color measurement (Table 4). There was no difference in color between 0 and 2% CLA treatments. The cooked meat aroma of RTE turkey rolls became stronger as the irradiation dose increased but was not statistically significant. The off-flavor of turkey rolls increased significantly after irradiation, indicating that off-flavor was induced by irradiation. Patterson and Stevens (1995) detected off-odor in irradiated chicken, which agreed with our result. Dietary CLA had no significant effects on the aroma and off-flavor of RTE turkey rolls before or after irradiation. The texture and juiciness were not significantly influenced by irradiation and CLA treatments, although hardness of turkey roll slightly increased and

TABLE 6. Consumer test of turkey rolls[1]

Attribute	Dietary treatment	0 kGy	1.5 kGy	2.5 kGy	SEM
Flavor	0% CLA	4.9[a]	4.2[bx]	3.8b[x]	0.2
	2% CLA	5.2[a]	3.5[by]	3.3b[y]	0.2
	SEM	0.2	0.2	0.2	
Color	0% CLA	4.0[b]	5.1[a]	5.2[ax]	0.2
	2% CLA	4.1[b]	4.8[a]	4.7[ay]	0.2
	SEM	0.2	0.2	0.2	
Overall	0% CLA	4.8[a]	4.5[abx]	4.1[bx]	0.2
	2% CLA	4.9[a]	3.8[by]	3.4[by]	0.2
	SEM	0.2	0.2	0.2	

[a,b]Means within a row with no common superscript differ significantly ($P < 0.05$); n = 66.

[x-y]Means within a column of same category with no common superscript differ significantly ($P < 0.05$); n = 66.

[1]CLA = conjugated linoleic acid.

Downloaded from http://ps.oxfordjournals.org/ at Iowa State University on May 11, 2015

juiciness decreased as the irradiation dose and CLA level increased.

The increase in toughness as CLA level increased was in agreement with the results from chicken rolls (Du et al., 2002), and this change in texture could be caused by increased protein content in muscle with dietary CLA (Du et al., 2002; Park et al., 1997). The reason for the irradiation-induced changes in texture could be due to the cross-linking of amino acids during irradiation (Vachon et al., 2000).

Consumer acceptance of irradiated turkey rolls showed that as the irradiation dose increased, the acceptability of flavor decreased (Table 6). After irradiation, the acceptability of turkey rolls from turkeys fed 2% dietary CLA was lower than those of 0% CLA, indicating that dietary CLA treatment had a negative effect on the flavor of turkey rolls after irradiation. The reason could be related to greater production of certain volatiles induced by irradiation. Acetaldehyde could be one of the volatiles related to the negative, metal-like, off-odor in irradiated meats (Tables 2 and 3).

Consumers preferred the color of irradiated turkey rolls, with an acceptability of irradiated samples being significantly higher than that of nonirradiated samples (Table 6). The overall acceptance of irradiated samples was significantly lower than that of nonirradiated samples (Table 6). The overall acceptance of RTE rolls from turkeys fed 0% CLA was greater than that from 2% CLA after irradiation. Thus, dietary CLA had a negative effect on the flavor of irradiated RTE turkey rolls.

REFERENCES

Ahn, D. U., C. Jo, M. Du, D. G. Olson, and K. C. Nam. 2000a. Quality characteristics of pork patties irradiated and stored in different packaging and storage conditions. Meat Sci. 56:203–209.

Ahn, D. U., C. Jo, and D. G. Olson. 1999. Volatile Profiles of raw and cooked turkey thigh as affected by purge temperature and holding time before purge. J. Food Sci. 64:230–233.

Ahn, D. U., C. Jo, and D. G. Olson. 2000b. Analysis of volatile components and the sensory characteristics of irradiated raw pork. Meat Sci. 54:209–215.

Ahn, D. U., D. G. Olson, J. I., Lee, C. Jo, X. Chen, and C. Wu. 1998. Packaging and irradiation effects on lipid oxidation and volatiles in pork patties. J. Food Sci. 63:15–19.

Du, M., D. U. Ahn, K. C. Nam, and J. L. Sell. 2000. Volatile profiles and lipid oxidation of irradiated raw chicken meat patties from laying hens fed with diets containing conjugated linoleic acid. Meat Sci. 56:387–395.

Du, M., D. U. Ahn, K. C. Nam, and J. L. Sell. 2001. Volatile profiles and lipid oxidation of irradiated cooked chicken meat patties from laying hens fed with diets containing conjugated linoleic acid. Poult. Sci. 80:235–241.

Du, M., K. C. Nam, S. J. Hur, H. Ismail, Y. H. Kim, and D. U. Ahn. 2002. Quality characteristics of irradiated chicken breast rolls from broilers fed different levels of conjugated linoleic acid. Meat Sci. (in press).

Jo, C., and D. U. Ahn. 2000. Production of volatile compounds from irradiated oil emulsion containing amino acids or proteins. J. Food Sci. 65:612–616.

Millar, S. J., B. W. Moss, and M. H. Stevenson. 2000. The effect of ionising radiation on the colour of leg and breast of poultry meat. Meat Sci. 55:361–370.

Morbidity and Mortality Weekly Report. 1998. Multistate outbreak of listeriosis in the United States Morbid. Mortal. Weekly Rep. 47:1085–1086.

Nam, K. C. and D. U. Ahn. 2002a. Carbon monoxide-heme pigment complexes are responsible for the pink color in irradiated raw turkey breast meat. Meat Sci. 60:25–33.

Nam, K. C. and D. U. Ahn. 2002b. Mechanisms of pink color formation in irradiated precooked turkey breast. J. Food Sci. 67:600–607.

Nanke, K. E., J. G. Sebranek, and D. G. Olson. 1998. Color characteristics of irradiated vacuum-packaged pork, beef, and turkey. J. Food Sci. 63:1001–1006.

Nanke, K. E., J. G. Sebranek, and D. G. Olson. 1999. Color characteristics of irradiated aerobically packaged pork, beef, and turkey. J. Food Sci. 64:272–278.

Park, Y., K. J. Albright, W. Liu, J. M. Storkson, M. E. Cook, and M. W. Pariza. 1997. Effect of conjugated linoleic acid on body composition in mice. Lipids 32:853–858.

Patterson, R. L., and M. H. Stevenson. 1995. Irradiation-induced off-odour in chicken and its possible control. Br. Poult. Sci. 36:425–441.

SAS Institute Inc. 2000. SAS User's Guide. SAS Institute Inc., Cary, NC.

Vachon, C., H. L. Yu, R. Yefsah, R. Alain, D. St. Gelais, and M. Lacroix. 2000. Mechanical and structural properties of milk protein edible films cross-linked by heating and gamma-irradiation. J. Agric. Food Chem. 48:3202–3209.

Downloaded from http://ps.oxfordjournals.org/ at Iowa State University on May 11, 2015