Trop. J. Anim. Sci. 3 (1) 53 - 62 (2000)
ISSN: 1119 - 4308

INFLUENCE OF HOUSING CONDITIONS AND TYPE OF FINISHING FEEDS ON THE OXIDATIVE STABILITY OF BROILER-CHICKEN MUSCLES

G.E. ONIBI*, E.A.O. LASEINDE AND S. AKINYANDENU
Department of Animal Production and Health School of Agriculture and Agricultural Technology, Federal University of Technology, P.M.B. 704, Akure, Ondo State, Nigeria.

Target Audience: Broiler farmers; chicken processors; meat scientists; low-fat diet consumers.

ABSTRACT

Twenty-four Anak broiler chickens were used in a 2 x 2 factorial experiment to study the effect of rearing chickens in cages or on deep litter, and finishing them either on grower or finisher mash, for two weeks prior to slaughter, on muscle lipid content and extent of oxidation during cold storage. The cold storage treatments were 1, 4 and 8 days of refrigeration, and re-freezing of frozen muscle samples which had been thawed once. Lipid oxidation in muscles was measured using the thiobarbituric acid reactive substances (TBARS) test.

Chickens finished on finisher mash had higher eviscerated weight (P>0.05), belly fat depot (P>0.05) and muscle lipid content (P<0.001) than those on grower mash. These on average were: eviscerated weight; 75.23 vs. 75.08% live weight (LW), belly fat; 14.25 vs. 11.67 g/kg LW, and lipid content of breast; 5.65 vs 3.73%, thigh; 7.28 vs 5.64%. Muscles from chicken reared in cages had higher lipid content (P>0.05) than those reared on deep litter (averaged 5.1 vs. 4.28% for breast; 7.02 vs. 5.90% for thigh) and the thigh muscle contained higher lipid content than the breast muscle. Oxidative susceptibility of muscles increased with increasing lipid content (thigh > breast; cage > deep litter; finisher mash > grower mash). Muscle lipid oxidation also increased (P<0.001) with increasing length of refrigerated storage, and thawed and then re-frozen muscles oxidised more than those that were constantly frozen.

Keywords: Broiler chickens; Finishing feeds; Housing; Muscle lipids; Lipid oxidation.

DESCRIPTION OF PROBLEM

One of the indices of meat quality under close scrutiny by consumers, especially in the developed societies, is the quantity and nature of lipids in meat. High intake of saturated lipids has been associated with increased risk of cardiovascular diseases (1) and low fat diets are generally preferred to fatty diets. Similarly, consumer's acceptability of meat with high intra- and extra-muscular fat is low.

The conventional practice of raising broilers to slaughter weight is to finish them on finisher mash (2). This mash contains approximately 20% crude protein (CP) and 2700 Kcal metabolisable energy per kilogram (ME/kg) feed. Grower mash

*Corresponding author

on the other hand contains about 14% CP and 2400 Kcal ME/kg feed. (3) reported that feeding grower mash instead of finisher mash to broilers for two weeks prior to slaughter reduced abdominal fat depot.

High lipid content in poultry meat may adversely affect its quality during processing, marketing and storage. Unlike microbial deterioration, oxidation of meat lipids is not stopped by cold storage (4) and it has been shown to lead to loss of fresh meat colour, development of off flavour, changes in taste, texture and nutritive value, formation of potentially harmful lipid oxidation products and increased oxidative loss (5, 6, 7). Thus, any way that the rate of lipid oxidation in meat, especially chicken can be retarded, may be important in the less developed nations where meat is mostly displayed without refrigeration, and transportation of frozen meat is carried out in unrefrigerated trucks.

This work was undertaken to determine the lipid content and extent of lipid oxidation in thigh and breast muscles of broiler chickens kept in cages and on deep litter, and fed either grower mash or broiler finisher mash for two weeks prior to slaughter.

MATERIALS AND METHODS

Twenty-four Anak broiler chickens were obtained from a flock of experimental broilers fed broiler starter from a day-old to four weeks and broiler finisher between 4th and 7th weeks. These birds were reared on deep litter during the 7-week period. At the end of the 7th week, the broilers were weighed, tagged, and distributed into experimental cages and deep litter pens. The four treatments comprised of two feed types (grower and finisher feeds) and two housing conditions (cage and floor), representing a 2 x 2 factorial experimental design. Each treatment was replicated thrice with 10 birds/replicate. The broilers were fed and managed between 7 and 9 weeks of age. The broiler finisher mash was used as the conventional feed (Control) while the grower mash was the test feed to reduce fat deposit in the chickens. Table 1 shows the percentage composition and calculated analysis of the feeds.

At the end of the 9th week, 6 chickens (3 males and 3 females) per each of the 4 feeding/housing treatments were slaughtered and processed manually. Live and eviscerated weights, and weights of the abdominal fat of each chicken were obtained. Thigh and breast muscles were dissected from each of the chickens. Each part was divided into four, separately packed in cellophane bags and allocated to each of these four storage treatments:

A – Fresh muscles* collected immediately after slaughter and frozen.

B – Fresh muscles collected and refrigerated for 4 days before frozen storage.

C – Fresh muscles collected and refrigerated for 8 days before frozen storage.

D – Fresh muscles that was frozen immediately after slaughter, thawed after 15 days of storage (at room temperature for 1½ hours) and re-frozen.

*Muscles refer to thigh and breast muscles.

Treatment A represented fresh muscle while treatments B and C were to simulate the effect of refrigerated storage for 4 and 8 days respectively. Treatment D was used to study the effect of re-freezing that may occur during transportation.

Refrigeration temperature was set at approximately 4°C and this was monitored with a digital thermometer. This refrigerator was supported with a stand-by electric power generator.

All chemical analyses were carried out after 3 months of frozen storage. Moisture and lipid contents of muscle samples were determined according to the method of (8). Extent of muscle tissue lipid oxidation was determined using the modified extraction 2-thiobarbituric acid (TBA) method described by (9). Results were expressed as mg malonaldehyde (MDA)/kg muscle. Data were subjected to one-way analysis of variance (ANOVA) and 2 x 2 factorial analysis as appropriate, using the Minitab Statistical Package (v. 10.2, Minitab Inc., P.A., USA).

RESULTS AND DISCUSSION

Dietary Composition

The calculated analysis of the feeds (Table 1) showed that the grower mash contained 14.08% CP, 4.23% crude fat and 2509 Kcal/kg ME while the finisher mash contained 19.77% CP, 9.14% crude fat and 2829 Kcal/kg ME. Thus, the finisher mash had higher dietary protein, fat and energy contents than the grower mash.

Table 1. Composition of Experimental feeds (%)

Ingredients (%)	Starter	Finisher	Grower
Maize	51.0	40.0	46.0
Wheat offals	8.5	15.0	23.0
Palm kernel cake	15	15.0	25.0
Fish meal (65%)	7.4	4.0	1.0
Soyabean Meal	13	6.0	1.0
Groundnut cake	12	12.0	-
Oil	-	5.0	-
Salt	0.35	0.5	0.5
Bone Meal	1.7	1.7	2.7
Lysine	0.2	0.2	0.2
Methionine	0.4	0.4	0.4
Vitamin premix	0.25	0.2	0.4
	100	100	100
Calculated Analysis			
Crude Protein (%)	24.92	19.77	14.08
Crude fat (%)	4.75	9.14	4.23
ME (Kcal/kg)	2910.98	2828.55	2509.09

Carcass Traits

Table 2 shows the results of measured carcass traits of the broiler chickens. The eviscerated weight and the relative weight of the belly fat were not significantly influenced (P>0.05) by feed types (grower or finisher mash). However, chickens finished on finisher mash had on average higher eviscerated weight and abdominal fat contents than those finished on grower mash (eviscerated weight: 75.23 and 75.08% LW; belly fat: 14.25 and 11.67 g/kg LW, for chickens fed finisher and grower mash respectively). The higher eviscerated weight (P>0.05) of chickens on the finisher mash may be attributed to higher protein and energy contents of this feed which improved weight gain (3). These authors also reported that the higher energy level of the finisher mash compared with the grower mash led to higher belly fat content of broilers.

Table 2. Carcass traits of broiler chickens finished on grower and finisher mash

	Feed type				Statistical Significance		
	Grower Mash		Finisher mash				
Housing condition	Cage	Deep litter	Cage	Deep litter	Feed type	Housing condition	Interaction
Carcass Traits							
Eviscerated weight (%)	76.96 ±3.52	73.19 ±5.59	77.38 ±2.65	73.08 ±1.63	NS	**	NS
Belly fat (g/kg LW)	12.06 ±3.92	11.28 ±4.43	17.79 ±12.36	10.71 ±3.56	NS	NS	NS

n = 6

Mean ± SD

NS = Not significant (P>0.05)

** = P<0.01

Interaction = Interaction between feed type and housing condition.

LW = Live weight.

Housing condition (cage and deep litter) significantly influenced (P<0.01) the eviscerated weight. Broilers in cages had higher eviscerated weight (average of 77.17% LW) than those on deep litter (average of 73.14% LW). Similar result, although not significant (P>0.05) was obtained for the belly fat content with birds in cages having higher belly fat content than those on deep litter (averagely 14.93 vs 11.00 g/kg LW). The higher eviscerated weight of birds in cages may be due to better diversion of dietary nutrients towards body tissue growth and also less dissipation as heat during physical activity because of their movement restriction. Similar reasons too may be ascribed for the lower belly fat content of birds on deep litter which might not conserve energy to a greater extent (10).

The interaction between the feed type and housing condition showed no significant effect (P>0.05) for both eviscerated weight and belly fat content. This suggests that these two factors similarly influenced each of the measured parameters.

Moisture Content of Muscles

Results of the moisture contents of the breast and thigh muscles as influenced by feed type and housing condition are shown in Table 3. There was no significant (P>0.05) difference in muscle type, feed type, housing condition or interaction between feed type and housing condition. The values ranged between 73.18 ± 0.63 and 75.62 ± 2.85%, and was within the range of 65 and 76% reported for poultry meat by (11).

Table 3. Moisture content (%) content of muscles of broiler chickens finished on grower and finisher mash

	Feed type				Statistical Significance		
	Grower Mash		Finisher mash				
Housing condition	Cage	Deep litter	Cage	Deep litter	Feed type	Housing condition	Interaction
Muscle type							
Breast	73.66	74.87	74.77	75.62	NS	NS	NS
	±1.00	±1.50	±2.35	±2.85			
Thigh	73.60	75.13	73.18	74.01			
	±3.22	±1.61	±0.63	±1.24	NS	NS	NS
STAT. SIG.	NS	NS	NS	NS			

n = 3

Mean ± SD

NS = Not significant (P>0.05)

Interaction = Interaction between feed type and housing condition.

Stat. Sig. = Statistical significance.

Lipid Content of Muscles

Results of lipid content of the muscles are presented in Table 4. The thigh muscle contained higher total lipids than breast muscle but was only significant(P<0.05) for those fed finisher mash and reared on deep litter. This supports the report of (12, 13) that the thigh muscle contained higher lipid content than the breast muscle.

Feed type significantly influenced the lipid content of the breast (P<0.001) and thigh (P<0.05) muscles. Broilers finished on finisher mash had higher total muscle

Table 4. Lipid content (%) of muscles broiler chickens finished on grower and finisher mash.

Housing condition	Feed type				Statistical Significance		
	Grower Mash		Finisher mash				
	Cage	Deep litter	Cage	Deep litter	Feed type	Housing condition	Interaction
Muscle type							
Breast	4.12	3.33	6.08	5.22			
	±0.81	±0.32	±0.97	±0.29	***	NS	NS
Thigh	6.19	5.09	7.85	6.70			
	±1.28	±1.22	±1.11	±0.60	*	NS	NS
STAT. SIG.	NS	NS	NS	*			

n = 3

Mean ± SD

NS = Not significant (P>0.05)

* = P<0.05; *** = P<0.001

Interaction = Interaction between feed type and housing condition.

Stat. Sig.= Statistical significance.

lipid content than those finished on grower mash (averagely 5.65 vs 3.73% forbreast muscle; 7.28 vs 5.64% for thigh muscle). This may be attributed to higher lipid and energy contents of the finisher mash, leading to higher deposition of fat as reported by (14). Although there were no significant differences (P>0.05) due to housing condition or interaction between feed type and housing condition, it was observed that broilers raised in cages had higher muscle lipid contents than those raised on deep litter. Similar reasons attributed earlier for higher belly fat of birds reared in cages compared with those on deep litter may be opined.

Lipid Oxidation in Muscles

Results of lipid oxidation in the muscles are presented in Table 5. The storage treatments significantly influenced (P<0.001) extent of oxidation irrespective of housing conditions and feed type. Lipid oxidation was observed to increase in both breast and thigh muscles from fresh (Treatment A), through 4 days of refrigeration (Treatment B) to 8 days of refrigeration (Treatment C). Thawing and re-freezing (Treatment D) was found to increase lipid oxidation more than in Treatments A and B but not as much as in Treatment C. This increase in lipid oxidation with increasing length of refrigeration is in accordance with the reports of (7, 15) that deteriorative changes continue to occur during refrigerated storage of meat.

Lipid oxidation was significantly higher (P<0.001) in the thigh muscle than the breast muscle. However, there was no significant difference (P>0.05) in the interaction between storage treatment and muscle type. This showed that the

rate of lipid oxidation in both muscles were similar during cold storage. The higher oxidation in the thigh muscle than breast muscle may be attributed to its higher lipid content (Table 4). Thigh muscle has also been reported to contain higher content of pro-oxidants like iron than breast muscle (16). (17) reported that the amount of iron from the haeme pigment of muscle correlates well with the tendency of the muscle to oxidise.

Table 5. Lipid oxidation in the muscles of broiler chickens on grower and finisher mash.

		Feed type				Statistical Significance		
	Grower Mash		Finisher mash					
Storage treatment	Muscle type	Cage litter	Deep	Cage litter	Deep type	Feed condition	Housing	Interaction[1]
A	Breast	0.080 ±0.03	0.063 ±0.01	0.075 ±0.01	0.067 ±0.03	NS	NS	NS
	Thigh	0.129 ±0.04	0.138 ±0.03	0.158 ±0.02	0.151 ±0.04	NS	NS	NS
B	Breast	0.085 ±0.02	0.094 ±0.02	0.126 ±0.02	0.106 ±0.03	*	NS	NS
	Thigh	0.152 ±0.03	0.151 ±0.05	0.222 ±0.03	0.182 ±0.09	*	NS	NS
C	Breast	0.173 ±0.05	0.140 ±0.04	0.216 ±0.06	0.177 ±0.04	*	NS	NS
	Thigh	0.259 ±0.07	0.263 ±0.08	0.382 ±0.10	0.372 ±0.09	*	NS	NS
D	Breast	0.122 ±0.05	0.116 ±0.07	0.156 ±0.08	0.144 ±0.09	NS	NS	NS
	Thigh	0.252 ±0.04	0.247 ±0.03	0.287 ±0.02	0.267 ±0.04	*	NS	NS
Storage treatment			***	***	***	***		
Muscle type			***	***	***	***		
Interaction[2]			NS	NS	NS	NS		

n = 6

Mean ± SD NS = Not Significant (P>0.05) * = P<0.05; *** = P<0.001

[1]Interaction = Interaction between feed type and housing condition.

[2]Interaction = Interaction between muscle type and storage treatment.

The type of feed did not significantly affect (P>0.05) muscle lipid oxidation in the fresh sample (Treatment A). However, at days 4 and 8 of refrigerated storage (Treatments B and C respectively), oxidation of lipid in the muscles was significantly affected (P<0.05) by feed type. Throughout refrigeration (Treatments

A, B and C), breast and thigh muscles from chickens fed finisher mash oxidised more than those from chickens fed grower mash. This may be attributed to higher lipid content of muscles of chicken fed the finisher mash (Table 4). When muscles were thawed and re-frozen (Treatment D), breast muscle was not significantly influenced ($P>0.05$) but the thigh muscle was significantly affected ($P<0.05$) by feed type. Similar higher oxidation in muscles from chickens fed finisher mash compared with those fed grower mash was observed for refrigerated muscles and thus the same reasons may be attributed.

Housing condition, and interaction between feed type and housing condition did not significantly influence ($P>0.05$) lipid oxidation in the muscles. However, higher oxidation was observed to occur in breast and thigh muscles of chickens reared in cages than those reared on deep litter. The chickens reared in cages had higher belly fat (Table 2) and muscle lipid (Table 4) contents than those on deep litter and are therefore more liable to oxidation.

CONCLUSIONS AND APPLICATIONS

Conclusions

1. Finishing of broiler chickens on finisher mash compared with grower mash led to higher belly fat depot and muscle lipid content.
2. The higher lipid content resulted in higher susceptibility of the muscles from chickens finished on finisher mash to oxidative deterioration during refrigerated and frozen storage.
3. The thigh muscle contained more lipids than the breast muscle and was more liable to oxidation.
4. More oxidation occurred when frozen chickens were thawed and re-frozen compared with continuous frozen storage.

Applications

1. Reduction of the lipid content of meat from broiler chickens by dietary and housing manipulations would help to reduce human intake of fat, reduce the risk associated with atheriosclerosis, and ultimately lead to reduction in production of toxic oxidation products in the meat during cold storage.
2. Thigh muscle that is more susceptible to oxidation than breast muscle should be assigned shorter shelf-life during refrigerated and frozen storage.
3. The use of unrefrigerated trucks for transportation of frozen meat should be discouraged as thawing and re-freezing increases muscle lipid peroxidation.

REFERENCES

1. DHSS, 1984. Diet and cardiovascular disease: Committee on Medical Aspects of Food Policy 1984 report for the Department of Health and Social Security on Health and Social Subjects . No. 28, H.M. Stationary Office, London.
2. Laseinde, E.A.O., 1999. Broiler Production. Pages 27-28 in: Poultry Ventures: Prospects and Practice. ACKO Publishers, Akure, Nigeria.

3. **Laseinde, E.A.O, and O.T. Fakuade,** 1999. Effect of low energy finisher diet in eliminating abdominal fat depot in broiler chicken. Proc. of 4th Annual Conf. of Anim. Sci. Association of Nigeria. pp. 6-9

4. **Hamilton, R.J.,** 1989. The chemistry of rancidity in foods. Pages 1-21 in: Rancidity in Foods. J.C. Allen and R.J. Hamilton eds. 2nd ed. Elsevier Sci. Publ. Ltd. England

5. **Faustman, C., R.G. Cassens, D.M. Schaefer and K.K. Scheller,** 1989. Vitamin E supplementation of Holstein steer diet improves sirloin steak colour. J. Food Sci. 54: 485-486.

6. **Monahan, F. J., J.L Gray, A.M. Booren, E.R. Miller, D.J. Buckley, P.A. Morrisey, and E.A. Gomaa,** 1992. Influence of dietary treatment on lipid and cholesterol oxidation in pork. J. Agric. Food Chem. 40: 1310-1315.

7. **Onibi, G.E., J.R. Scaife, I. Murray, and V.R. Fowler,** 1998. Use of a-tocopherol acetate to improve fresh pig meat quality of full-fat rapeseed-fed pigs J. Am. Oil. Chem. Soc. 75 (2): 189-197.

8. **AOAC,** 1990. Official method of the Association of Official Analytical Chemists. K. Helrich ed. 15th ed., Virginia, USA.

9. **Salih, A.M., D.M. Smith, J.F. Prince, and L.E. Dawson,** 1987. Modified extraction 2-thiobarbituric acid method for measuring lipid oxidation in poultry. Poultry Sci. 66: 1483-1488.

10. **Cherry, T. and L.E. Jones,** 1982. Dietary cellulose, wheat bran, fish meal in relation to hepatic lipids, serum lipids and lipid excretion in laying hens. Poultry Sci. 61: 1873-1878.

11. **Ikeme, A. I.,** 1990. Marketing of meat in Nigeria. Meat Sci. and Tech. 1st ed. African Fep Publishers Ltd., Onisha, Nigeria.

12. **Igene. J., K. Yamauchi, A.M. Pearson, J.I. Gray, and S.D. Aust,** 1985. Evaluation of 2-thiobarbituric acid reactive substances in relation to warned over flavour development in cooked beef. J. Agric. Food Chem. 33: 366-367.

13. **Richardson, R.I.,** 1994. Vitamin E. in poultry meat. Poult. International 33: 28-29.

14. **Jenser, L.D.,** 1977. Calorie efficiency of fats versus carbohydrate for poultry and their use in formulation of their ration. Cornell Nutrition Service.

15. **Sklan, D., Z. Tenne, and P. Budowski,** 1983. The effect of dietary fat and tocopherol on lipolysis oxidation in turkey meat stored at different temperatures. Poultry Sci. 62: 207-2021.

16. **Kanner, J.I. F, Sofer, S. Harel, and L. Doll,** 1988. Antioxidant Activity of ceruloplasmin in muscle membrane and *in situ* lipid peroxidation J. Agric. Food. Chem. 36(3): 412-415.

17. Apte, S. and P.A. Morrissey, 1987. Effect of haemoglobin and ferritin on lipid oxidation in raw and cooked muscle systems. Food Chem. 25: 127-134.