Improvement of Broiler Meat Quality

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ABSTRACT

The consumer demands for quality of meats has become diverse in recent years. The present paper describes mainly the technology to improve the broiler meat quality with special reference to reducing fat contents in edible meats which is the heart of the quality constraints. Abdominal fat deposition in broilers was reduced by feeding of medium-chain triglycerides(MCT), suggesting MCT feeding is useful to produce broiler meat with low fat content. A phase feeding system to aim at improving meat quality that is mainly comprised with partial replacement of dietary protein into phase during 4~6 weeks increased edible meat yields and reduced abdominal fat deposition and fat contents in breast and thigh meats. Whiteness of fat tissue was intensified by feeding beef tallow or lard in place of yellow grease. Feeding Phaffia yeast containing astaxanthin increased redness of breast and thigh meats and improved visual appearance of meats which may be preferential for consumers. Feeding fish oil reduced abdominal fat deposition and increased EPA and DHA contents of fat tissues. These procedures could be used for manipulation of meat quality to meet consumer demands.

(Key words: broiler, meat quality, fat deposition, nutritional control)

INTRODUCTION

The increase of world population in 40 years from 1990 to 2030 has been forecast to attain approximately 3.6 billion at a rate of 90 million a year(Brown, 1994). Supply of food enough for world population including forecast population increase has been requested for now and future. However, the recent trend that expansion of crop land has become stagnant shows a decrease in crop production per capita. In addition to the above phenomena, the improvement in food habits in the world may prompt the consumption of animal food, i.e. milk, meats and eggs.

Animal protein foods contribute more than 30% of total energy intake and 50% of total protein intake in the developed countries. World meat production in 1993 amounted to 179 million tons and meat consumption per capita was about 32kg. In the world meat market, 29.4 million tons of chicken meats was produced in 1993 and consumption of chicken meats tended to increase as compared to beef consumption.

Chicken meat has been respected as excellent and cheap protein food well-balanced in the amino acid profile as well as low-fat and low calorie meat. In a recent progress in eating habits and consumer's consciousness of nutrition-health interrelationship, consumer demand for the quality has been diversed as the demand of "Taste" rises. It is very hard to meet the diversed demands of the consumer in the current broiler production system emphasizing production efficiency. It is, therefore, imperative to develop broiler production system focusing on high quality meat.

According to an investigation of consumer demands, factors obstructing chicken meat consumption have been classified as excessive fat, freshness and color of meat and fat as well as the safety. Among these factors, excessive fat in meats or fat deposition plays the basic and major role in problems of chicken meat quality since the excessive fat is concerned with the most of quality problems and the frequent occurrence of metabolic disorders.

1. Growth of broiler chickens

The broiler industry has been concerned with the efficient production of chicken meat at low cost. This aim has been approached through both genetic selection toward achieving a large body size and innovation in nutrition and management to support the genetic improvement. growth curves of male broilers for 30 weeks fitted properly with Gompertz function(Akiba, 1988) and the asymptotic final body weight was estimated at 6.8kg whcih is 1.3kg more than that of broilers 10 years before. Marketing body weight(about 8 weeks of age) of broilers in Japan averages about 3.2kg in male and 2.8kg in female, the age at inflection is 49 day of age which is 13 days earlier than the broilers 10 years before. It is suggested that broilers have been improved to achieve the larger body size at maturity and simultaneously become precocious. Most of broiler breeding company anticipates that growth of broilers keeps increase at a rate of 70~90 g iper year.

2. Quality problems of chicken meat

There are several aspects in quality problems of broiler chicken meats. From a scientific view point, the problems may be classified into chemical, physical, microbiological and sensory quality. Safety as food is essentially principal requirement. In the broiler industry, excess fat deposition, oxidation of fats, color of meats and fats, hemorrhages, teared skin, bone breakage, fatty livers, freshness, and bacterial contamination have been regarded as the major concerns. Visual appearance and sensory aspects are of important quality for consumers.

3. Chemical composition of broiler meat and its nutritional value

Chemical composition of broilers changes with age, characterized by gradual increase of the fat content but maintaining the protein content. Broiler meat is also characterized by well balanced amino acid profile, high vitamin content, and relatively high protein content against the energy content.

4. Fat deposition in broilers

An excessive fat deposition of rapidly growing broilers has been a great concern resulting in a tremendous financial loss in the broiler industry, since the depot fat and adhering fat on edible meats might be discarded as a garbage or processed as a component of poultry byproduct of low economical value. Most importantly, the excessive fat in broiler meats is against the preference of consumers for low-fat and low-calorie meats. The problem would be emphasized particularly in Japan compared to European and Asian countries since producers in Japan have used to market chickens at around 8 weeks of age to get a larger meat size which inevitably associated with an excessive fat production (Akiba et al., 1986).

Along with an increase in growth rate of broilers, the fatness has been emphasized. Abdominal fat content as % body weight at market(8 weeks) ascended at 0.07 and 0.11% a year for male and female chickens, respectively during latest 25 years in Japan, suggesting the development of fatness in the latest strains of broilers(Akiba, 1988). Growth curve fitted with the Gompertz function of carcass lipid deposition in male broiler chickens subjected to feeding for 30 weeks with experimental diets containing high protein(CP 23%) or low protein (CP 15%) diet which were formulated isocallorically(3200 kcal /kg) are illustrated in Figure 1. The carcass lipids were lower in chickens fed high protein diet than their counterparts kept on low protein diet during 9 weeks posthatch and increased extensively beyond 4 weeks of age approaching their asymptotes(1.17kg for high protein diet and 1.55kg for low protein diet). Abdominal fat weight comprised of almost one-fifth of the carcass lipids and followed the pattern found in the growth of carcass lipids. It is, therefore, suggested that fatness in broilers was substantial but under the dietary manipulations.

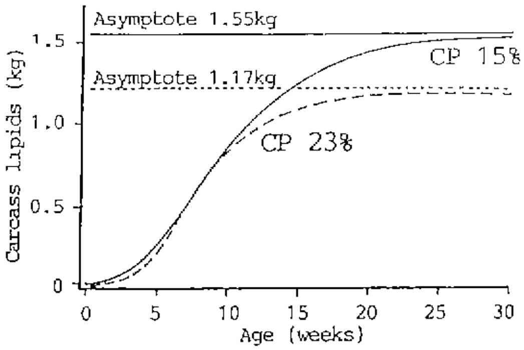

Figure 1. Growth curve of carcass lipids in male broiler chickens subjected to high or low protein diet.

Besides abdominal adipose tissues, considerable amount of adipose tissue was detected on the thigh, neck, breast, back and etc. in broilers(Nir et al., 1988). The amount of fat tissues in edible thigh and breast meats are, of course, crucial for consumer's perception. The subcutaneous fat in both breast and thigh meats increased as chickens grew and amounted to 45g (2.4% of body weight), indicating relatively large amount of fat in the edible meats and awaiting the nutritional manipulation to reduce them alike abdominal fat. We have observed significant positive correlationships between abdominal fat weight and subcutaneous fat weight in thigh or breast meats at marketing age of broilers(Akiba, 1992). Since it is confirmed that abdominal fat weight substantially correlates with carcass fat weight, it seems likely that abdominal fat weight represents carcass fatness and fat contents in the edible meat as well in broiler chickens.

5. Lipid metabolism in chickens

Considerable knowledge on avian lipid metabolism have been accumulated during latest 30 years. The understanding of lipid metabolism peculiar in avian species which are different from mammals(Annison, 1971; Leveille et al., 1975); the chick is able to utilize relatively large amount of dietary fat, lipoproteins, synthesized in the intestinal epithelium are transported via the portal system, liver is the main site for fatty acid synthesis and adipose tissues mainly function in the storage of fat; has evoked further studies on metabolic disorders confined in the lipid metabolism.

Accumulation of fat in animals is determined by hypertrophy and hyperplasia of adipose cells. Following the first report by Hood(1982), cellular growth of abdominal fat pad in broiler-type chickens have been published(March et al., 1984; Cherry et al., 1984). However, cellularity of adipose tissues of heavy-type broilers with much depot fat has been little studied.

Cellularity of abdominal tissues during growth was determined using the method of Lavau et al. (1977) in male and female broilers of heavy-type commercial strain(Akiba, 1988). Abdominal fat weight averaged 75g and 110g at 8 and 10 weeks of age in both male and female chickens. As shown in Figure 2, the number of adipocytes increased extensively until 6(males) or 8(females) weeks of age followed by the small increase thereafter, while no significant increases in volume of the adipocytes were observed during 4 weeks after hatching and then increased drastically. These growth patterns of adipocytes found in the heavy-type broilers appear quite different from those reported by Hood(1982) that the adipocyte number increased until 14 weeks of age in light-type broilers. It is, therefore, likely that adipocyte hyperplasia precedes extensively after hatching and attains to the plateau at an early age as growth rate of broilers improved.

6. Production of low-fat broiler meats (Control of adiposity)

We have observed in several experiments aiming at nutritional control of lipid metabolism that abdominal fat content correlated negatively with edible meat yield. Positive correlations were obtained between fat contents in breast and thigh meats and abdominal fat content. It is, therefore, established that reducing fat deposition possibly decreases fat content of edible breast and thigh meats, consequently increasing production of edible meat with less fat.

The fatness in broilers might partly be a

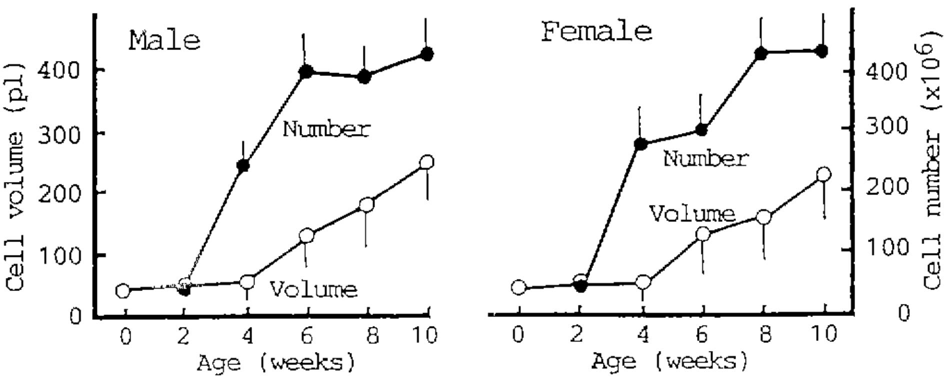

Figure 2. Cellularily of abdominal adippose tissue in broiler chickens.

consequence of genetic improvement toward a large body size and/or an increase in feed intake and could be manipulated by dietary factors as well as genetics, sexes, ages, environments(Lin et al., 1980; Summers and Leeson, 1979; Akiba et al., 1986). Of nutritional factors, the manipulation by dietary protein and amino acid contents, energy : protein ratio and dietary protein and fat sources has been greatly exploited(Donaldson, 1957; Summers and Leeson, 1979; Akiba et al., 1987; Jensen, 1991, Akiba et al., 1995).

Excessive deposition of fat in animals may be ascribed to some defects in lipid metabolism. It is likely that normalizing lipid metabolism results in retardation of fatness of broilers. Hepatic lipogenesis is inhibited by feeding unsaturated fatty acids-rich fats in chickens(Leveille et al., 1975; Donaldson, 1985). Increasing fat content in isoenergetically formulated diets decreased carcass fat content in broiler chickens(Alao and Balnave, 1984). Adiposity of broilers has been reported to be modified by fat sources(Edwards et al., 1973; Alao and Balnave, 1984).

We have noted that abdominal fat content at 56 days of age in chickens fed chicken oil and corn oil tended to decrease, but not significantly, as compared to yellow grease(Akiba et al., 1995). Pan et al. (1979) noted abdominjal fat in female broilers fed soybean oil was smaller than that fed tallow, alike our results. The descending trend in abdominal fat content by feeding corn oil and chicken oil in our experiment seemed to be mainly dependent upon decrease in the adipose cell volume in female chickens. Bourgeois et al. (1983) also demonstrated in mice that feeding lard increased both cell size and cell volume of the adipose tissue, while feeding soybean oil increased only the cell size. However in chickens, less information is available in effects of dietary fat sources on growth of the adipose cells.

Medium-chain triglycerides(MCT) are composed of saturated fatty acids moieties of six to 12 carbon atoms and the effects on lipid metabolism have received considerable attention in recent years(Akiba et al., 1993). The MCT is metabolized quite differently from long-chain triglycerides(LCT) in that MCT is easily digested even in short supply of bile acids, MCT is efficiently oxidized in tissues, and MCT increases lipolysis(Bach and Babayan, 1982). Geliebter et al. (1983) observed that feeding MCT to rats reduced carcass fat deposition.

In our experiments with broiler chicks, MCT was included in place of YG at 4% in isocaloric and isonitrogenous diets and fed for 4 or 8 weeks from a day of age. Body weight gains during 4 and 8 weeks posthatch were reduced to a small extent by feeding C10C8-TG(Table 1). Feed

Table 1. Effects of feeding medium-chain triglycerides(MCT) on performance, edible meat yield and fat deposition in chickens

Treatment	Feed intake (kg)	Body weight gain(kg)	Feed conversiton	Edible meat yield(kg)	Abdominal fat content (% BW)	Subcutaneous fat content (mg/cm²)
Control	5.54[a]	2.50[a]	2.22[a]	0.89[a]	3.69[a]	220[a]
MCT(0~4 wk)	5.32[b]	2.43[b]	2.19[a]	0.91[a]	3.09[b]	169[b]
MCT(0~8 wk)	5.26[b]	2.44[b]	2.15[b]	0.90[a]	3.20[ab]	158[b]

Means with different superscripts in columns are significantly different($p<0.05$).

conversion ration during 4 and 8 weeks, yield of edible meats were improved by feeding MCT. Feeding MCT reduced abdominal fat contents at 4 and 8 week of age and subcutaneous fat content of breast meats at 8 week. These data show that MCT might be provided as an efficient fat source to improve feed efficiency, edible meat yields and fatness in broilers, even though MCT may slightly reduce body weight gain, probably because of low palatability of the fats for young chicks. Thus, MCT modifies lipid metabolism and fatness of chickens.

Observation of the time-course changes of abdominal fat deposition up to marketing age after hatching shows that growth rate of fat tissues maximized during 4 to 6 week of age while amount of daily depot fat was largely comparable between phases 4~6 week and 6~8 week in broiler chickens. These findings may lead a hypothesis that the period from 4 to 6 week is substantial in the accumulation rate of fats and thereby being properly subjected to nutritional control.

As stated in the previous section, dietary protein is a possible nutrient to reduce fat deposition in broilers although the cost is essentially high. The phase feeding system with changing dietary CP content has been effectively employed in the broiler and egg production. In experiments with broiler chickens, we introduced a phase feeding system aiming at improvement of carcass quality with no increase in total dietary protein input up to marketing age., In this system, a part of the dietary protein fed during 1 to 4 weeks(phase-1) was allocated to phase-2 (from 4 to 6 week) when the fat growth was substantial.

Body weight, edible meat yield and abdominal fat content of female broilers at 8 weeks of age are shown in Table 2. No significant differences were ovserved in body weight except treatment 4 where dietary CP in phase-2 was increased to 23%. Feed conversion ratio tended to be improved by increasing CP in phase-2 in place of phase-1. Edible meat yield was significantly higher in chickens with treatment 2. Abdominal fat content was decreased by the allocation of part of dietary CP from phase-1 to phase-2 and supplementation with feather meal(FeM, supplemented at 3% in diet). The significant decrease was observed in treatment 6. A significant positive correlation was demonstrated between abdominal fat content and edible meat yield.

These results showed that phase feeding system with allocation of dietary CP with the aim of improving meat quality yielded expected results. Performance during the 8 weeks was

Table 2. Performance, edible meat yield and abdominal fat content in chickens on a phase feeding

	Dietary CP(%)			Body weight	Edible meat	Abdominal fat	
	Phase-1	Phase-2	Phase-3	(kg)	yields (kg)	(g)	(%BW)
1	22	18	18	2.92^{ab}	1.07^{bc}	98.3^{a}	3.25^{a}
2	19	20	18	2.97^{a}	1.11^{a}	95.0^{a}	3.10^{a}
3	19	20	18+FeM	2.90^{ab}	1.09^{ab}	90.1^{ab}	3.00^{a}
4	16	23	18	2.84^{b}	1.04^{c}	84.5^{abc}	2.89^{a}
5	16	23	18+FeM	2.89^{ab}	1.07^{bc}	83.7^{bc}	2.81^{ab}
6	22	23	18+FeM	2.95^{a}	1.09^{ab}	72.6^{c}	2.40^{b}

Means with different superscripts in columns are significantly different($P<0.05$).

not reduced while body weight at 4 weeks of age was lowered when dietary CP in phase-1 was partly replaced into phase-2. This is ascribed to compensatory growth due to high CP diet during phase-2 as previously reported by Cabel and Waldroup(1990). The abdominal fat content was largely reduced by feeding a high CP diet in phase-2 by replacing CP from phase-1, in particular the decrease was rather pronounced in treatments with 23% CP diets during phase-2. Total CP intake was not different in all treatments except in the groups supplemented with feather meal. It is therefore probable that the phase feeding system employed in the present study works to reduce fat deposition and improve the yield of low-fat meats with no increase in dietary CP intake, thereby not increasing the feed cost.

7. Dietary manipulation of chicken meat color

The recent trend in consumption of meats of native chickens of country chickens seems to reflect consumer demand for tasty meats with good appearance. In a prospect the future strategy to expand the consumption of chicken meats, manipulation of visual appearance of meats must be explored experimentally.

The meat color depends mostly on hemoglobin and myoglobin contents. Among those, the myoglobin contributes 80~90% of meat pigments because the hemoglobin decreases rapidly postmortem. Myoglobin content and total pigment concentrations in broiler meats are very low than beef and horse meat. However, less information is available on the manipulation of chicken meat color although some papers describe that the meat color is modified by stress prior to slaughter and processing in the slaughter house.

We have advanced several experiments in order to manipulate broiler meat color by dietary means(Akiba et al., 1994 and 1996). Phaffia yeast with red pigments, containing high concentration of astaxanthin was introduced to manipulate broiler meat color in our experiments. The astaxanthin is a natural carotenoid commonly included in lobsters and crabs in sea ocean and has been recently clarified to accompany antioxidant and antitumor activities and to modify immune functions.

In our experiments, phaffia yeast was included in the finishing diet for about 1 to 3 weeks prior to marketing at concentrations to give 10 to 30 ppm in the astaxanthin content. Our results showed that phaffia yeast extensively improved visual meat color(redness) and intensified a^* value on color meter of edible meats with no changes of the performance (Table 3). The astaxanthin concentration of breast and thigh meats in the yeast-fed chickens was averaged 0.02~0.5 mg /100g. It is, hence, suggested that phaffia yeast containing astaxanthin is an useful feed ingredient which improves meat color and meets consumer demands aiming at the health intention.

8. Dietary manipulation of fat color

Color of fat tissues in chicken meats is one of the criteria to promote purchasing meats as well as meat color itself. Yellow grease has been commonly used as the major fat sources for broiler diets. Fat color of the meats might be visual concern of consumers. Experiement was conducted to obtain changes in fat color and the fatty acid composition in chickens fed beef tallow, lard or chicken oil in place of yellow grease(Matsushita et al., 1998). Three week old broiler chickens were fed ad libitum on the experimental diets which were different in fat sources. Beef tallow(BT), lard(L) or poultry

Table 3. Effects of feeding Phaffia yeast containing astaxanthin on color of edible meats in chickens

Treatment	Astaxanthin in diet(ppm)	Feeding duration	a*value	
			Thigh	Breast
1 Control	0	−	7.47[b]	0.63[b]
2 + Yeast	10	3 to 8 week	8.79[a]	1.49[a]
3 + Yeast	20	5 to 8 week	8.59[a]	1.83[a]
4 + Yeast	30	7 to 8 week	7.57[b]	1.53[a]

Means with different superscripts in columns are significantly different($P<0.05$).

Table 4. Effects of dietary fat sources on weight, color and fatty acid composition of abdominal adipose tissues in chickens

Fat sources	Abdominal fat (% BW)	Whiteness of fat tissues	Fatty acid composition(%)						
			14:0	16:0	16:1	18:0	18:1	18:2	18:3
YG	4.09[a]	68.9	0.6	25.2	7.6	6.4	44.6	14.5	1.1
BT	3.85[ab]	69.5	1.0	26.5	7.8	7.7	45.5	10.8	0.8
L	3.93[ab]	69.1	0.8	26.9	7.7	7.7	45.1	12.2	0.8
PF	3.69[b]	68.4	0.6	24.8	8.3	6.3	44.0	15.1	1.0

Means with different superscripts in columns are significantly different($P<0.05$).

sources. Beef tallow(BT), lard(L) or poultry fat(PF) was supplemented at 4% in the diets in place of yellow grease(YG) in the control group.

Body weight and feed conversion ratio was not influenced by differences in the fat sources. Abdominal fat content, color of fat tissues as expressed by whiteness and fatty acids composition are shown in Table 4. Abdominal fat content was not changed by feeding BT or Y, while it was decreased by feeding PF. Whiteness of the fat tissues tended to increase in chickens fed BT or L as compared to YG and PF.

It is, therefore, shown that PF is beneficial for reducing abdominal fat content and increasing linoleic acid content of edible meats. On the other hand, feeding BT and L produced chicken meat with high melting point and increased whiteness. As yellowish fat color of chicken meats has sometime been disliked by consumers, feeding BT or L may be useful mean to meet consumers demand.

9. Manipulation of n-6/n-3 fatty acids ratio of chicken meats

Unsaturated fatty acids play physiological and nutritional roles as essential fatty acods in animals. Consumption at least 30 g of fish per day lowered mortality from coronary heart diseases than those who did not consume fish (Kromhout et al., 1985). N-3 series poly unsaturated fatty acids(PUFA) such as alpha-linolenic acid(C18:3), eikosapentaenoic acid(EPA, C20:5) and docosahexaenoic fatty acid(DHA, C20:6) has been reported to prevent the occurrence of coronary heart diseases and cerebral thrombosis. PUFA also functions as precursors of prostaglandines which has numerous physiological function. Thus proper consumption of n-3 PUFA and appropriate ratio of n-6/n-3 are recommended to the public(Hargis and Van Elswyk, 1993).

In the following experiment with broiler chickens, manipulation of n-6/n-3 fatty acid

Table 5. Effects of fish oil and coconut oil feeding on weight, fatty acids composition of abdominal adipose tissue in chickens

Fat sources	Abdominal fat(% BW)	Fatty acid composition(%)				
		18:2	18:3	20:4	20:5	22:6
YG	4.08[a]	12.6	0.70	0.21	0.11	0.15
FO	3.53[b]	11.5	0.59	0.31	1.18	1.30
FO+C	3.69[b]	11.2	0.55	0.27	0.83	1.30

Means with different superscripts in columns are significantly different($P<0.05$).

ratio of fat tissues was examined by feeding fish oil(Matsushita et al., 1998). Chickens were fed ad libitum on the experimental diets which were different in fat sources. Fish oil(FO) or fish oil+coconut oil(FO+C) were supplemented at 3.4% in the diets in place of yellow grease(YG) in the control group.

Abdominal fat content and fatty acids composition of fats in edible meat are shown in Table 5. Abdominal fat content was significantly reduced by feeding FO or FO+C as compared to feeding YG. Feeding FO increased EPA content in the fat tissues by 10 times and DHA content by 8.6 times, respectively.

The decrease of abdominal fat content by feeding fish oil may be due to the high unsaturated fatty acids content since unsaturated fatty acids are potent inhibitors of fatty acid synthesis in chicken liver(Akiba et al., 1995). Feeding fish oil at 3.4% in diet or fish oil supplemented with coconut oil resulted in much increase in n-3 series PUFA content, being in accordance with findings by Hulan et al.(1989). These broiler meats supplemented with EPA and DHA could be provided as a potent food which nourish people who are short in consumption of n-3 PUFA.

Coconut oil is rich in medium-chain fatty acids which are easily absorbed even when bile acid secretion is in a short supply(Akiba et al., 1993). Akiba et al.(1992) reported that feeding medium-chain fatty acids-rich oil in place of yellow grease reduced abdominal fat deposition in broilers. In the present experiment, feeding fish oil with coconut oil resulted in a slight decrease in EPA and DHA contents as compared with feeding fish oil only. As one third of the fish oil was replaced with coconut oil, our data suggest that supplementation of coconut oil has no significant effect on absorption of PUFA and transport of PUFA into tissues of chickens.

The present paper reviewed several nutritional means to control the quality of chicken meats in a background that consumer demands tended to diverse in recent years. It is anticipated to establish the broiler production system aiming at high quality to meet consumer demands in combination with high production efficiency.

적 요

근년에 와서 소비자들의 육질에 대한 요구는 다양하게 나타나고 있다. 본 논문에서는 육계의 육질개선에서 가장 주안점이 되고 있는 계육내의 지방함량을 줄이는 방안에 관해서 언급하고자 한다.

계육 중의 지방함량을 줄이는 방안중의 하나가 medium-chain triglycerides(MCT)를 육계에게 급여시키는 방법인데 연구 보고에 따르면 MCT를 육계에게 급여시키면 계육 중의 지방함량이 감소하였다.

기별 사양방법 또한 육질의 개선 방안으로 중요하다. 육계에 대한 기별 사양은 4~6주령에서 육계가 섭

취하는 사료 중의 단백질 수준을 일부 변경시켜 주므로서 복부 지방의 축적이 감소되고 가슴살과 허벅지살 중의 지방함량도 감소된다.

사료 중에 배합되는 황색 지방물질(yellow grease) 대신에 소기름이나 돼지기름을 사료에 섞어주면 계육 중의 지방세포는 흰색을 띄게 된다. 또 astaxanthin이 함유된 phaffia 효모를 육계사료에 혼합시켜서 섭취시키면 육계의 가슴살고기와 허벅지살고기의 색깔이 더 진한 붉은 색을 띄게 되는데 이러한 사양방법 역시 소비자들의 기호성을 증진시키는데 크게 도움이 되는 방안이다. 어유를 육계에게 급여시키면 복부지방 축적은 감소되는 반면 지방세포내의 EPA와 DHA함량은 증가된다. 이상의 일련의 연구결과들은 모두 육질을 개선시킬 수 있는 방안들이며 이러한 방안들은 소비자들의 요구를 충족시키는데 기여할 수 있다

(Key words: 브로일러, 육질, 지방축적, 영양조절)

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