REVIEW

FAT DEPOSITION IN THE BROILER CHICKEN: A REVIEW*

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The phenomenon of fat deposition in broiler chickens is reviewed. The increase in growth rate through genetic selection in broiler chickens has been associated with increased fat deposition. Abdominal and subcutaneous fat are regarded as the main sources of waste in the slaughterhouse. On the other hand, a minimum quantity of intramuscular fat is necessary for an optimal sensory quality because of its positive influence on succulence and tenderness, flavor. In order to elucidate factors affecting the phenomenon and ways to decrease it a great deal of time and expense has gone into research. Results indicate that genotype, sex, age and nutrition of the broiler chicken are some of the main factors affecting fat deposition. Selection can reduce excessive fat deposition in the long term strategy and for reduced body fat deposition, either using abdominal fat content or plasma very-low-density-lipoprotein has been shown to be useful in reducing fat deposition. Also, selection for improved feed conversion ratio also can be used. Reports showed that feed restriction could be a way for reducing body fat, nevertheless, reports are contradicted. Ambient temperature is one of the most remarkable factors among the environmental parameters on fat deposition in broiler chicken. The factor having greatest effect on fat deposition in broiler chicken is the ratio of dietary protein to energy. The use of these concepts to address problem associated with early life fast growth rate require more studies of the nutrition of broiler chicken during the rearing period as well as more studies of the effect of selection against fatness on live performance broiler chicken.

chicken; body fat; selection; feed restriction

INTRODUCTION

Nowadays, excessive fat is one of the main problems faced by the poultry industry, since it not only reduces carcass yield and feed efficiency, but also causes rejection of the meat by the consumers (Lippens, 2003; Jennen, 2004). Nonetheless fat and fatty acids, whether in adipose tissue or muscle, contribute importantly to various aspects of meat quality and are essential to the nutritional value of meat (Wood, 2008). Furthermore, the lipids of fatty tissue are important in the development of flavor in meat (Lawrence, Fowler, 2002). Lipids influence flavor through their effect on flavor perception (mouthfeel, taste and aroma), flavor stability, flavor generation (Stephens, 2001). High concentrations of linoleic acid in the lipid of fatty tissue can have a marked effect on flavor (Lawrence, Fowler, 2002). Chickens have much higher contents of the major polyunsaturated fatty acid (PUFA) linoleic acid (18:2n – 6) in adipose tissues than pig, cattle and sheep. In chicken and pig, the amount of α-linolenic acid (18:3n – 3) is higher than sheep and cattle (Bouderoua, Selselet-Attou, 2003; Crespo, Esteve-Garcia, 2002; Wood, 2008). Live performance of broiler chickens has been improved tremendously since the early 1950s mainly due to selection for rapid early growth, improvements of nutrition, rearing environment so that it takes only 33 days to reach finishing body weight of about 2 kg (Goliomytis et al., 2003; Jang et al., 2009; Benyi et al., 2009). Therefore, these modern broiler chicken strains are characterized by very high growth rate and low feed conversion ratio. Unfortunately, this increase in growth rate is associated with high body fat deposition, high mortality and high incidence of metabolic diseases and skeletal disorders. These negative aspects are of major concern for the farmer and processor, because they can bring about important economic losses (Leenstra, 1986; Pym, 1987; Griffin, 1996; Zubair, Leeson, 1996b; Buys et al., 1998; Buyse, 1999; Havenstein et al., 2003; Nikolova et al., 2007). Moreover, in recent years, consumer preference for leaner meat has increased due to the corollary between human consumption of certain fats and cardiovascular diseases (Leeson, Summers, 1980; Pym, 1987; Cable, Waldroup, 1990). Similarly, in recent years, the proportion of broiler chickens used for partitioning and further processing has become more and more important

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also in this context, fat deposition, especially abdominal fat, subcutaneous fat, has become a very important factor as it contributes to higher wastes and costs. So these factors have stimulated interest in reducing body fat deposition. On the other hand, a minimum quantity of carcass fat is necessary for an optimal sensory quality because of its positive influence on succulence and taste (Chizzolini et al., 1999; Lippens, 2003; Zerhdaran et al., 2004; Zerhdaran, 2005).

The purpose of this review is to describe different techniques which have been shown to reduce fat deposition in broiler chicken and discusses the associated effects upon other parameters and the relative value of the techniques in reducing fat deposition in broiler chicken. Prior to such discussion it would seem appropriate to give a brief summary of general aspects of fat metabolism and fat deposition in broiler chicken.

The origin of fats in broiler chicken body is by means of exogenous (from the diet) or endogenous (synthesized in the liver) or from skeleton (Griffin, 1996; Haro, 2005). In contrast with mammals, where dietary fat is almost exclusively transported from intestine as chylomicrons via lymphatic system, in chicken, absorbed fat is packed into portomicrons and non-esterified fatty acids which pass directly into the hepatic portal blood supply, whereas fat synthesized in the liver is transported to other tissues in the form of triglyceride-rich very low density lipoprotein (Griffin, 1996; Denbow, 2000). Storage fat is localized as: abdominal fat (including fat surrounding gizzard, proventriculus, bursa of fabricius, cloaca, and adjacent muscles), sartorial fat (subcuticular fat in cranial thigh region), fat located in the neck (subcuticular fat in ventro-caudal neck region) and mesenteric fat (fat adhered to mesentery, along the intestine from the pylorus to the colon). Abdominal fat is 20% of total body fat, subcutaneous fat 18%, skeleton fat 15%, liver and feather 2.5%. The reminder of carcass (muscles, intestine, kidneys, lungs, connective tissue…) contains 40% of total body fat (Cahaner et al., 1986; Butterwith, 1989; Crespo, Esteve-Garcia, 2002; Haro, 2005).The chief part of body fat in broiler chicken is deposited in shape of abdominal fat. The abdominal fat tissue constitutes approximately 2–3% of the broiler chicken live weight (Leenstra, 1986). Fat in meat can be present as intermuscular fat, intramuscular fat and subcutaneous fat (Kerry et al., 2005). Subcutaneous fat represents approximately range from 11 to 15% of the carcass weight of chickens (Heydarpour et al., 2007).

Current broiler chicken strains contain about 13–14.5% fat of their body weight (Latshaw, Bishop, 2001; Havenstein et al., 2003; Haro, 2005). This percentage varies depending on several factors affecting fat deposition in broiler chickens including genetic, nutrition, sex, and age of the broiler chicken.

Skřivan and Tůmová (1990) studied the effect of genotype during prolonged feeding on the proportion of breast and thigh muscles in male hybrid chickens (Hybro and Ross 208) and found that the accumulation of fat in hybrid combination Hybro was higher in comparison with Ross 208 chickens. Farran et al. (2000) found that absolute abdominal fat weight of Hybro G males was significantly lower than those of Arbor Acres males. They also reported that the Ross males had significantly lower percentage of abdominal fat and percentage of crude fat than the Arbor Acres males. Ristić (2005) stated that the amount of abdominal fat in broiler chickens of Cobb 500 genotype was significantly smaller for 0.4% compared to Ross genotype. Nikolova et al. (2007) showed that chickens of Hubbard line had significantly greater share of abdominal fat than Cobb 500 line chicken. Kokoszyński and Bernacki (2008) indicated that Hubbard evolution chickens had the lowest contents of skin with subcutaneous fat and abdominal fat in comparison with Ross 308 and JV chickens.

The increase of growth rate through genetic selection in broiler chickens has been associated with increased fat deposition. Moreover, difference in fat deposition between breeds and strains, within breeds indicate the importance of genetics factors in fat deposition. Initially, selection was for greater growth rate and meat yield, but as excessive carcass fat became a problem, the selection changed in feed conversion ratio (FCR). Selection for increased body weight gain tends to cause an increase in carcass fat, whereas selection for decreased FCR tends to reduce fat and increase the carcass water content (Pym, Solvyns, 1979; Chambers et al., 1983; Soller, Eitan, 1984). Nowadays, it is possible to select lines for high or low fat deposition, based on abdominal fat content or on the plasmatic concentration of very low density lipoproteins (Haro, 2005). Cahaner et al. (1986) used a selection based on measured criteria of siblings for abdominal fat, where individuals were slaughtered for assessment of degree of abdominal fat and siblings of those with either high and low fat kept as parents for the high-or-low fat lines. Abdominal skinfold thickness was related to abdominal fat (Pym, Thompson, 1980; Mirosh, Becker, 1984). Latshaw and Bishop (2001) found that correlation of abdominal skinfold thickness and abdominal fat was similar to the result from Mirosh and Becker (1984). Pourreza (1997) estimated body fat by plasma triglycerides and carcass dry matter. He found that correlation of plasma triglycerides and body fat was in agreement with the results from Griffin et al. (1982). Zerhdaran et al. (2004) showed that carcass traits could be improved by selection for increased breast muscle and reduced abdominal fat without decreased intramuscular fat. They estimated the heritability for abdominal fat percentage, 0.71, skin percentage, 0.24 as a measure of subcutaneous fat, and intramuscular fat percentage 0.08. There were a high genetic correlation between abdominal fat weight and skin weight (0.54), whereas the genetic correlation between abdominal fat weight and intramuscular fat percentage was almost zero (0.02). These estimations were in agreement with values reported by Griffin (1996), Le Bihan-Duval et al. (1998, 1999, 2001), Rance et al. (2002) and ranged from 0.45 to 0.85 and it seems that fatness is quite highly heritable in broiler chicken. In each instance, genetic selection in broiler chicken has provided carcasses containing about 10% fat and if carcasses leaner than this will be needed, we need research to identify mechanisms underlying genetic variation in fatness in broiler chickens (Griffin, 1996).

Both, sex and age have a great influence on fat deposition. Females are able to deposit more body fat than males (Leenstra, 1986; Le Bihan-Duval et al., 1998; Sanz et al, 1999; Haro, 2005; Novele et al., 2008). Corzo et al. (2005) and Nikolova et al. (2007) found that female broiler chicken had more amount of abdominal fat, weight and share than in male boiler chicken. Probably these differences were a result of different metabolism, greater competition between males, different capacities for fat accumulation, different nutritional needs and greater impact of hormones in females. Tor et al. (2002) showed that castrated male chickens had more abdominal, intermuscular and subcutaneous fat than the cocks. Excess fat deposition can be prevented to some extent by slaughtering females at earlier ages and therefore lower body weights than males (Leenstra, 1986).

Age of broiler chickens has a distinct effect on fat deposition; older broiler chickens have a higher fat content than the younger ones (Leenstra, 1986; Brake et al., 1993; Haro, 2005; Zerhdaran, 2005). Zerhdaran et al. (2005) found that the broiler chicken abdominal fat percentages were 2.95%, 3.26%, 4.11% at 48, 63, 70 days of age, respectively. Fat depots grow by an increase in the number of fat cells and/or by an increase of the size of the fat cells. In fat deposition, three successive phases are observed in chicken: dominant hyperplasia until 4 or 5 weeks of age, hyperplasia and hypertrophy until 6 or 7 weeks of age, and predominant hypertrophy beyond 7 weeks of age (Leenstra, 1986; Mourot, Hermier, 2001; Jennen, 2004). As a result, increase in the duration of the rearing period will produce broiler chickens with high fat deposition.

It has been long recognized that nutrition has a significant effect on fat deposition. Fat deposition happens when there is a positive energy balance and when the nutrients in the feeds are not balanced. In particular, the energy to protein ratio of the feed and the type and amount of dietary fat are the most important factors affecting body fat deposition (Leenstra, 1986; Pym, 1987; Haro, 2005). Both energy and protein are essential for growth, and when the energy: protein ratio is increased, there is an excess of energy needed for growth due to the relative low protein content, and hence this energy is stored in the form of fat (Leeson, Summers, 1997, 2000). On the other hand, a reduction of this ratio can lead to a loss of body fat due to the lower energy intake and to the energy expenditure to metabolize and excrete the excess protein. Unfortunately, simple changes such as these are not economical, since the required degree of leanness in the carcass often only results from uneconomically high level of protein (Leeson, Summers, 2000). Malheiros et al. (2003) showed that broiler chicken fed with low protein diet had higher fat deposition compared to low lipid or carbohydrate diet. Irrespective of whether protein or energy changes, the result is the same.

In general, body fat deposition may be considered as a result of the balance among dietary absorbed fat, endogenous fat synthesis (lipogenesis) and fat catabolism via β-oxidation (lipolysis). Thus, if the amount of absorbed fat is the same, lower body fat deposition may be attributed to increased fat catabolism or diminished endogenous fatty acid synthesis or to both processes (Sanz et al., 2000a, b). Many reports showed that broiler chickens fed diets containing polyunsaturated fatty acids, rather than saturated or monounsaturated fatty acids, show lower fat deposition (Sanz et al. 1999, 2000a, b; Crespo, Esteve-Garcia, 2001; Wongsuthavas et al., 2007a; Ferrini et al., 2008). Diets with high polyunsaturated fatty acid increase content of polyunsaturated fatty acid in breast muscles and abdominal fat in broiler chicken (Skřivan et al., 2000; Waldroup, Waldroup, 2005). This lowering effect of polyunsaturated fatty acids could be due to lipid synthesis inhibition (Sanz et al., 2000b; Wongsuthavas et al., 2007b) and an increasing of fatty acid oxidation (Sanz et al., 2000b; Crespo, Esteve-Garcia, 2002; Newman et al., 2002) and heat expenditure (Ferrini et al., 2008; Wongsuthavas et al., 2007a).

As already noted, early fast growth rate in broiler chickens is accompanied by increased body fat deposition. This situation most commonly occurs with broiler chickens that consume feed *ad libitum*. Feed restriction programs are strategies that can be used to alter feeding management in order to decrease some extent feed intake and therefore modify to the growth rate, alleviating the occurrence of metabolic disorders, improving feed efficiency and decreasing the breeding cost (Urdaneta-Rincon, 2000; Tůmová et al., 2002; Lippens, 2003; Brunoa et al., 2007). Earlier research indicated that a mild quantitative feed restriction during early life is able to reduce growth rate and fat deposition. The first results with abdominal fat reduction by early feed restriction were published by Plavnik and Hurwitz (1985). Some other authors reviewed similar results (Plavnik, Yahav, 1998; Picard et al., 1999; Oyedeji, Atteh, 2005). However, there were studies which did not confirm these results (Zubair, Leeson, 1996b; Urdaneta-Rincon, Leeson, 2002; Lippens et al., 2002a; Saleh et al., 2004, 2005; Teimouri et al., 2005; Zhan et al., 2007; Benyi et al., 2008, 2009). Contradictory finding could have been caused by different age of chickens in feed restriction, intensity of feed restriction, gender and strain of chicken. Nutritional studies have indicated that age at which the different processes involved in adiposity (hyperplasia and hypertrophy) can be altered by level of feeding, especially at early age. Feed restriction treatments are, therefore, mostly imposed during the second week of age in broiler chickens, as an attempt to alter hyperplastic growth of adipocytes which, at this age, accounts for most of the growth of the adipose tissue. It is hypothesized that this will suppress or delay adipocyte proliferation, and this is expected to be accompanied by lower fat deposition in broiler chickens in the end of rearing period (Zubair, Leeson, 1996b). Furthermore, either hypotrophy or hypoplasia adipocytes were the main cause of lower fat deposition in feed-restricted broiler chickens but hypotrophy adipocytes is more important than hypoplasia adipocytes (Meluzzi et al., 1998). Significant reduction in abdominal fat content has been noted by some authors. For instance, diet dilution significantly reduced abdominal fat in broiler chicken (Leeson et al., 1992; Picard et al., 1999; Hassanabadi, Nassiri-Moghaddam, 2006). Also, quantitative feed restriction had a meaningful reduction in abdominal fat in broiler chicken (Jones, Farrel, 1992; Leeson et al., 1992; Benyi, Habi, 1998; Plavnik, Yahav, 1998; Khadem et al., 2006). In addition, Plavnik and Hurwitz (1991) found that quantitative feed restriction on maintenance requirement significantly reduced abdominal fat in broiler chicken. Likewise, lighting programs were able to reduce significantly abdominal fat (Oyedeji, Atteh, 2005; Rahimi et al., 2005). However, others showed that feed restriction had no significant effect on fat deposition in broiler chicken. For example, skip-a-day feed restriction had not any meaningful reduction in abdominal fat content in broiler chicken (Ballay et al., 1992; Dozier et al., 2002, 2003; Khajali et al., 2007; Lien et al., 2008; Benyi et al., 2009). Likewise, abdominal fat deposition was not significantly affected by the implementation of quantitative feed restriction (Acar et al., 1995; Deaton, 1995; Zubair, Leeson, 1996a; Lippens et al., 2000, 2002b; Camacho et al., 2004; Demir et al., 2004; Özkan et al., 2006; Novele et al., 2008). Similarly, quantitative feed restriction on maintenance energy requirement had no significant effect on abdominal fat in broiler chicken (Lee, Leeson, 2001; Saleh et al., 2004, 2005). Also, diet dilution had not a meaningful effect on fat deposition (Zubair, Leeson, 1994; Yussefi-Kelaricolaii et al., 2001; Teimouri et al., 2005; Hassanabadi, 2008). Furthermore, Lippens et al. (2002a) pointed out that qualitative feed restriction such as a low energy diet or NaCl-deficient diet had no significant effect on abdominal fat, although decreased abdominal fat in broiler chicken. Similarly, Onbaşilar et al. (2009) reported that a feed restriction for 4 h per day from 7 to 21 day reduced abdominal fat but not significantly. The fact that there was no significant reduction in abdominal fat deposition suggests that even feed- restricted broiler chickens are still overeating and that the level of feed intake may control *de novo* lipogenesis (Urdenta-Rincon, Leeson, 2002). On the contrary, Zhan et al. (2007) reported that a feed restriction for 4h per day from 1 to 21 day of age significantly increased abdominal fat yield in Acorned female broiler chicken. Also, Summers et al. (1990) and Urdenta-Rincon, Leeson (2002) reported that quantitative feed restriction increased abdominal fat in broiler chicken. As mentioned, results obtained with feed restriction programs intended to diminish the carcass fat content in broiler chicken have been contradicted. This contradiction may be caused by different strategies of feed restriction are applied, severity and duration of under-nutrition, condition of realimentation, age of imposition, strain of broiler chicken and sex, all factors which may affect the broiler chicken's response. A better knowledge and understanding of which age of initiation, a strain of broiler chicken, a method of feed restriction, severity, and duration of under-nutrition could reduce the body fat content while maintaining meat yield is of economic interest.

Environmental factors can also affect on fat deposition. These factors are ambient temperature, housing systems and lighting regimes. The effect of rearing temperature is small in comparison with the influence of nutritional or genetic factors have on fat deposition. However, the effect of temperature on fat deposition plays an important role in broiler chickens (Leenstra, 1986; Jennen, 2004). For example, Lu et al. (2007) showed that Arbor Acres broiler chickens exposed to heat stress had slightly decreased abdominal fat deposition and significantly decreased subcutaneous fat as well as intermuscular fat deposition compared to control group. On the other hand, Ain Baziz et al. (1996) and Geraert et al. (1996) observed enhanced fat deposition under chronic heat exposure conditions. The differences reported above could be related to the age of the bird, the model of heat stress (constant or cyclic), the method used to measure the fat index (abdominal fat was generally used as the single fatness index), and chicken breed.

CONCLUSION

High body fat deposition in broiler chickens represents economical loss to the producers. Moreover, in recent years, consumer's preference for leaner meat has increased. Therefore, a great deal of time and expense has gone into research in an endeavour to reduce fat deposition in broiler chicken. Selection of live broiler chicken for reduced body fat deposition, either using abdominal skinfold thickness or plasma very-low-density-lipoprotein, has been shown to be useful in reducing fat deposition. Selection can reduce excessive fat deposition in the long term strategy. Selection for improved feed conversion ratio also can be used. The most effective methods of reducing fat deposition are dietary protein to energy ratio and feed restriction. An increase of the dietary protein to energy ratio can lead to a reduction of body fat deposition. Unfortunately, changes in this ratio are not economical during the chick-rearing stage because of increase of diet cost or the adverse effect on live performance of broiler chicken. Feed restriction in broiler chicken also has been substantiated to reduce fat deposition however reports regarding it are contradicted. Ambient temperature is considered one of the most impact factors among the environmental factors on fat deposition in broiler chicken. More research is also needed on the effect of selection against high fat deposition on live performance broiler chicken. Moreover, a great deal of time and expense is needed on research in an endevour to increase intramuscular fat contents of broiler chicken carcass.

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Ukládání tuku u brojlerových kuřat: přehled literatury.

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Přehled literatury se zabývá ukládáním tuku u brojlerových kuřat. V důsledku selekce brojlerových kuřat na intenzitu růstu dochází ke zvýšenému ukládání tuku. Na porážkách drůbeže jsou abdominální a podkožní tuk považovány za odpad. Naproti tomu je potřebné minimální množství intramuskulárního tuku pro optimální senzorické vlastnosti, protože příznivě ovlivňuje jemnost a chuť masa. Je velmi důležité znát faktory ovlivňující ukládání tuku a způsoby, jak toto ukládání snížit. Je zřejmé, že hlavními faktory ovlivňujícími ukládání tuku jsou genotyp, pohlaví, věk a výživa. Selekcí je možné snížit ukládání tuku v dlouhodobém výhledu a významnými selekčními kritérii jsou abdominální tuk a lipoproteiny o velmi nízké hustotě. K tomuto účelu může být použita i selekce na nízkou spotřebu krmiva. Také restrikce krmiva může být metodou pro snížení ukládání tuku, ale v literatuře se často setkáváme s protikladnými výsledky. Významným faktorem vnějšího prostředí, který ovlivňuje ukládání tuku, je teplota prostředí. Jedním z nejúčinnějších způsobů snížení ukládání tuku je dodržování vhodného poměru dusíkatých látek a energie v krmných směsích. V této souvislosti je důležité studovat růst na začátku výkrmu a jeho vztah k potřebě živin. Stejně důležitá je i selekce na nižší obsah tuku a její vztah k užitkovosti kuřat.

kuře; abdominální tuk; selekce; restrikce

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