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Factors Affectıng Abdomınal Fat in Chıckens

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Abstract
In broiler chickens, 15-20% of the total body weight consists of fat. The most variable carcass component in broilers is fat. Abdominal fat accounts for approximately 2-3% of live weight. In broiler chickens, age and gender have a significant effect on fat deposition. there is a correlation between body weight and the level of fat deposition. The differences in abdominal and carcass fat content between genotypes indicate the importance of genetic effects on fat storage. Nutrition factors have a significant impact on the carcass composition of broiler chickens. Generally, high-energy diets provide advantages for live weight gain and feed efficiency, but can lead to excessive fat deposition. Environmental factors such as ambient temperature, housing systems, lighting programs, and physical activities are directly related to the life span and physical activities of poultry and affect fat storage. The caliper tool was first developed to estimate abdominal fat thickness in live broiler chickens, and significant phenotypic correlations were found between with this technique and abdominal fat weight.
Keywords: *Abdomınal Fat in Chıckens*

Abdominal Fat In Chickens

As stated by Scheele et al., (1981); Griffin and Whitehead (1982) and Leenstra (1982), in broiler chickens, 15-20% of the total body weight consists of fat, and a minimum of 9 g/kg of fat is required for vital functions (Yoshida and Morimoto, 1970). 15% of the total fat is found in the blood and other tissues, while the remaining 85% is found in adipose tissue (abdominal fat, subcutaneous fat, intramuscular fat, etc.) (Evans, 1977). The most variable carcass component in broilers is fat (Lohman, 1973). Abdominal fat accounts for approximately 2-3% of live weight and is the most variable compared to other fat depots, according to Leenstra, 1986; Richard, 1975; Becker et al., 1979. Studies have reported that the coefficient of variation for abdominal fat (%25-30) is higher than that for total fat (%15-20) (Leenstra, 1984).
In broiler chickens, age and gender have a significant effect on fat deposition, with older birds and females having more fat than younger birds and males (%10-19 for females, %10-13 for males) (Edwards et al., 1973; Hakansson et al, 1978;) Lecrecq et al. 1980; Un, 1981; Grunder et al, 1987). Additionally, there is a correlation between body weight and the level of fat deposition, with rapid weight gain leading to an increase in fat tissue growth (Fisher, 1984). A 40% difference in abdominal fat level was observed among broiler chickens aged four to eight weeks (Griffiths et al., 1978). Growth in fat deposits occurs through an increase in the number of fat cells (hyperplasia) and an increase in the size of fat cells (hypertrophy). In laying and broiler-type chickens, fat growth is hyperplastic up to 14 weeks of age, and hypertrophic after 14 weeks (Pfaff and Austıc,1976; Marcii and Hansen, 1977; Hood, 1982; Hood, 1984). In broiler chickens, it

has been reported that the increase in abdominal fat begins after four weeks of age and that fat growth is hyperplastic up to six weeks of age and hypertrophic thereafter (Cherry et al., 1984;). The increase in cell size is considered the main factor in determining abdominal fat (Simon and Leclercq, 1973).

Feed Conversion Ratio (FCR) and Abdominal Fat

The feed conversion ratio (FCR) feed conversion ratio (FCR) is the amount of feed consumed per gram of live weight gain. A negative correlation has been reported between FCR and carcass fat Leenstra et al., 1987). On the other hand, Thomas et al. (Thomas et al., 1958; Thomas and Glazener et al. 1958) reported that the group with low FCR had higher abdominal fat compared to the group with high FCR. However, upon further investigation, Whitehead and Griffin (1984) reported that FCR was worse in the fatty (FL) line compared to the lean (LL) line when comparing chickens of the same live weight. Generally, due to the high correlation between low abdominal fat and high FCR, selection based on one of these traits results in improvement in the other as well (Cahaner et al., 1986).
The differences in abdominal and carcass fat content between genotypes indicate the importance of genetic effects on fat storage (Edwards and Denman, 1975). When compared to egg-laying chickens of similar age, broiler chickens have approximately twice as many fat cells, resulting in higher levels of abdominal fat (March and Hansen, 1977, March 1984). Significant differences in abdominal fat accumulation have been observed between fat and lean lines created based on various selection criteria (Whitehead and Griffin (1984).

Nutrition and Abdominal Fat

Nutrition factors have a significant impact on the carcass composition of broiler chickens (Un et al, 1980; McLeod, 1982). Generally, high-energy diets provide advantages for live weight gain and feed efficiency, but can lead to excessive fat deposition. In addition, the impact of energy/protein ratio imbalance on abdominal fat deposition is greater than its effect on carcass fat deposition (Jackson et al., 1982). Therefore, the energy level of feed should be kept at an optimum level to prevent deterioration of carcass quality (Freeman, 1983). Furthermore, the amino acid, fat, salt content (Lipstein, et al., 1975; Have et al., 1981; Marks and Washburn, 1983), and physical form of feed (grinding, pelleting, etc.) have a significant impact on fat storage (Pesti et.al, 1983; Marks and Pesti, 1984).

Although the fat transport system in the plasma of poultry is similar to that of mammals, the fat absorbed from the diet goes directly to the collecting vein without passing through the lymphatic system (Griffin, 1996). The liver is the main site of fat synthesis in poultry. Adipose tissue, where fat is stored, originates from very low-density lipoproteins (VLDL) synthesized in the liver or chylomicrons in the intestines that are rich in triglycerides (Gruffat et al., 1992-) Krogdahl, 1985).

The study by Barlov et al. (Bartov and Bornstein, 1976) reported that the relationship between carcass fat and plasma triglyceride levels was not suitable for predicting fat deposition in 8-week-old broiler chickens based on their experimental results. Similarly, in subsequent years, correlation between total plasma lipid concentration and abdominal fat accumulation could not be determined (Mirosh and Becker, 1983). In contrast, Griffin et al., 1982; Whitehead and Griffin, 1984 reported an important biochemical relationship (0.6-0.7) between body fat deposition and very low-density lipoprotein (VLDL) concentration in plasma in broiler chickens, and that this relationship could be used as a good predictor for determining body fat levels in live broiler chickens. By utilizing this biochemical relationship, selection studies were conducted based on high and low VLDL concentrations, and Lean Line (LL) and Fat Line (FL) lines were developed after 3 generations (Whitehead and Griffin, 1982; Whitehead and Griffin, 1986). Whitehead and Griffin, 1984 reported that plasma VLDL levels were 0.123 in males and 0.136 in females at the beginning of selection, and decreased after 3 generations (0.055 in males and 0.077 in females in the LL line), while they increased gradually in the FL line (0.164 in males and 0.177 in females). Similarly, from the third to the eighth generation, plasma VLDL and abdominal fat levels decreased continuously in LL lines, while they increased continuously in FL lines (Whitehead, 1990). Moreover, looking at the selection results of the seventh generation, it was reported that there was a significant difference between plasma VLDL (0.15 and 0.40) and abdominal fat (14.9 and 36.5 g/kg) levels in LL and FL lines, while the difference in live weights (2.24 and 2.18 kg) was not significant. In the eighth generation, they found a low correlation (0.12 in males and 0.15 in females) between plasma VLDL and abdominal fat levels in LL lines, while they found a high correlation (0.70 in males and 0.43 in females) in FL lines. After the eighth generation, significant differences were found in plasma VLDL concentration and body fat content between LL and FL lines (Griffin et al, 1991). In addition, they found a correlation of 0.88 between VLDL secretion rate and body fat content, and 0.74 between abdominal fat ratio and body fat content. The researchers reported that the source of the difference in fat synthesis between lines was the difference in proportional hepatic fat synthesis and proportional volatile fatty acid synthesis (Griffin et al, 1989). As a result, low proportional fatty acid synthesis and increased volatile fatty acid oxidation increased the utilization of proteins due to the differential effect of the LL line on hepatic amino acid oxidation, which led to an increase in protein utilization (Griffin et al, 1989).

Changes in the normal water and feed ratio can cause changes in abdominal fat levels in poultry (Marks,1994). Marks and Washburn, 1983 reported a decrease in abdominal fat content in broiler chickens with an increase in salt level in the diet, which led to an increase in water consumption. In another study, feeding a high protein diet resulted in an increase in normal water and feed consumption, which led to a decrease in abdominal fat levels (Marks an Pesti, 1984). In summary, studies support the idea that the inverse relationship between fat and water in the carcass, as suggested by Donaldson et al.(1956) and Twining et al. (1978), means that an increase in normal water intake leads to a decrease in abdominal fat. However, despite the use of different methods to show the relationship between water/feed ratio and abdominal fat, the reason for this difference has not yet been genetically determined (Darden and Marks, 1985-) Marks and Baik, 1994).

Based on the information provided by Mallard and Douaire (1988) and Ricard and Rouvier (1969), there is a relationship between abdominal fat and many body measurements in poultry, and they have shown that there is a negative relationship between breast and spine measurements and abdominal fat deposition. However, based on Chung et al. (1983), they have reported that this relationship is below the reliability level required to reduce abdominal fat levels in future generations commercially.

Limited feeding techniques can be used to reduce abdominal fat accumulation in chickens, either by reducing the amount of feed or by reducing the nutrient levels in the diet. In studies conducted, broilers fed with limited feeding showed lower abdominal fat accumulation than those fed ad libitum (Fisher and Wilson, 1974; Mollison et al., 1984; Zhong et al, 1995; Beyni and Habi, 1998). It has been observed that restricting energy intake at the beginning of the growth period leads to a decrease in fat storage (Pfaff and Austic, 1976; March and Hansen, 1977; Kubena et al., 1974). However, in a more recent study, it was reported that while the live weight of the free-fed group was 2.25 kg, the live weight of the group fed with 70% of the free-fed group was 1.67 kg, and the %AY (abdominal fat percentage) levels were 1.49 and 0.83, respectively (Beyni and Habi, 1998). As genetic potential increases, it becomes difficult to prevent fat deposition by using limited feeding techniques (Fontana et al., 1992). Both the difficulty in application and the decrease in live weight limit the economic feasibility of this technique.

Amino acid deficiency

Amino acid deficiency disrupts metabolism, causing changes in feeding patterns and reducing feed intake in proportion to the deficiency (Rogers and Leung, 1973; Boorman, 1979). The main reason for this is the rapid decrease in concentration of the limiting amino acid in the blood as a result of consumption of imbalanced feeds (Harper et al., 1970). On the other hand, it has been shown to affect animal behavior, causing a decrease in appetite and a second side effect of reduced growth and reproduction (87 Boorman, 1979). Picard et al. (1993), in a study to determine the reaction of chickens fed with a diet deficient in EAA (essential amino acids) to feed intake, found that the deficient feed was consumed 26% less in the first 24

hours compared to the standard feed. The same researchers reported that when amino acid-sufficient and deficient feeds were offered to animals on a preferential basis, 65% of the consumed feed consisted of sufficient feed and 35% consisted of deficient feed within 7 hours.
In animals, low protein intake reduces nitrogen metabolism density and decreases the catabolism of amino acids, therefore the effect of amino acid deficiency is more pronounced in low protein diets (Harper et al., 1970). In their study, Pesti et al. (1994) showed that the genetic structure is effective in the relationship between plasma amino acid concentration and carcass composition, and reported that this is due to differences in genetic stocks in feed intake. In parallel, Boa-Amponsem et al. (1991) stated that genetic stocks may show different reactions to amino acid deficiency or imbalance. The differences in protein utilization between LL and FL lines may be due to genetic effects on protein synthesis and breakdown, as well as a result of increased amino acid oxidation in FL lines (Whitehead and Griffin, 1986 .

Environmental Factors and Abdominal Fat

Environmental factors such as ambient temperature, housing systems, lighting programs, and physical activities are directly related to the life span and physical activities of poultry and affect fat storage. Kubena et al. (1972) and Fisher (1984) reported a positive correlation between total body fat and ambient temperature, with a linear increase of 0.19% in total body fat for every degree increase. Broiler chickens raised in cages have less activity and therefore deposit more fat than those raised on the ground (Deaton et al., 1974; Haye and Simons 1978). Lewis et al. (1994) reported that another environmental factor, lighting, did not have a significant effect on abdominal fat deposition, but intermittent lighting resulted in less fat accumulation.
The caliper tool was first developed to estimate abdominal fat thickness in live broiler chickens, and significant phenotypic correlations of 0.76 in males and 0.75 in females were found between the results obtained with this technique and abdominal fat weight (Pym and Thompson, 1980). In parallel, another research group used their own version of the caliper tool and found similar correlations (-0.77) between % abdominal fat and caliper measurements (Schwartzberg et al, 1980). It was suggested that this technique could be used as an indirect selection criterion for abdominal fat estimation in commercial broiler breeding programs and was implemented in breeding programs. However, in the following years, other researchers found variable and lower correlations when estimating abdominal fat using Pym's caliper method (Whitehead and Griffin,1982; Chambers, 1982; Mirosh and Becker, 1983). The reasons for the low and variable results in studies using Pym’s caliper technique, whether identical or modified, have been attributed to genetic variations, physical differences in the caliper tool, variations in the conducted studies, and individual differences among operators in using the tool (Marks, 1988).

Different Techniques and Abdominal Fat

Mallard and Douaire (1988) and Bentsen et al. (1986) used X-ray technology, which is commonly used in various fields of science, to determine different fat deposits in chickens. They reported significant correlations (0.70-0.90) between scanned fat areas. However, the high cost of this method limits its use in the industry. According to Mallard and Douaire (1988) and Robelin (1973) and Russeil (1987), there is a significant negative correlation (-0.7 and -0.86) between water and fat content in the carcass of farm animals. Mallard and Douaire (1988) reported that the method is not yet sufficient for indirect selection studies in their evaluation.

Another method for reducing abdominal fat accumulation is hormone application. Mitchell and Burke (1993) used TRH (thyrotropin-releasing hormone), Burke et al. (1987) used rcGH, and Huybrechts et al. (1992) used IGF-I (human insulin-like growth factor I) hormones on chickens, and they reported a reduction in abdominal fat by an average of 15%. However, the use of this method is not practical or economical.

References

i. BARTOV, I., BORNSTEIN, S., 1976. Effects of degree of fatness in broiler on other carcass characteristics: relationship between fatness and the composition of carcass fat. British Poultry Science, 17, 17.,

ii. BECKER, W,A., SPENCER, J.V., MIROSH, L.W., VERSTRATE, J.A., 1979. Prediction of fat and fet free live weight in broiler chickens using back-scin fat and live weight. Poultry Science 58, 835-842,.

iii. BENYI, K., HABI H., Effects of food restriction during the finishing period on the performance of broiler chickens. British Poultry Science, 39, 423-425, 1998.

iv. BOA-AMPONSEM, K., DUNNINGTON, E.A., SIEGEL, P.B., 1991. Genotype, feeding regimen, and diet interactions in meat chickens, II. Feeding behaviour. Poultry Science, 70, 689-696.

v. BOORMAN, K.N., 1979. Regulation of protein and amino acid intake. In: Food intake Regulation in Poultry (Eds. K. N. Boorman and Freeman) Longman, Edinburgh, p. 87-126.

vi. BURKE, W.H., MOORE, J.A., OGEZ, J.R., BU1LDER, S.E., The properties of recombinant chicken growth hormone and its effects on growth, body composition, feed efficiency and other factors in broiler chickens. Endocrinology 120, 651-658,1987.

vii. CAHANER, A., NITSAN, Z., NIR, I., 1982. Weight and fat content of adipose and nonadipose tissues in broilers selected for or against abdominal adipose tissue. Poultry Science, 65:215,1986.

viii. CHAMBERS, J.R., Prediction of broiler abdominal fatnessby caliper measurements of abdominal vvall thickness. Poultry Science, 61, 1434

ix. CHERRY, JA., SWARTWORTH, W. J. and SIEGEL, P.B., 1984. Adipose cellularity studies in commercial broiler chickens. Poultry Science, 63, 97-108.

x. DARDEN, J.R., MARKS, H.L., 1985. The influence of dietary salt on water consumption and carcass lipids in Japenese quail. Poultry Science, 64, 1269.

xi. DEATON, J.W,, KUBENA, L.F., CIEN, T.C., REECE, F.N., 1974. Factors influencing the quantity of abdominal fat in broilers. 2. Cage versus floor rearing. Poultry Science, 53, 574-576.

xii. DONALDSON, W.E., COMBS, G.F. ROMOSER, G.L., 1956. Studies on energy levels in poultry ratios. I. The effect of calorie-protein ratio of the ration on growth, nutrient utilazation and body composition of chicks. Poultry Science, 35, 1100-1105.

xiii. EDWARDS, Jr., RM, DENMAN, F., 1975. Carcass composition studies. 2. Influences of breed , sex and diet on gross composition of the carcass and fatty acid composition of the adipose tissue. Poultry Science, 54, 1230-1238.

xiv. EDWARDS, Jr,, H.M, DENMAN, F., ABOU-ASHOUR, A., NUGARA, D., 1973. Carcass composition studies. 1. Influences of age, sex and type of dietary fat supplementation on total carcass and fatty acid composition. Poultry Science, 52, 934-948.

xv. EVANS, A. J., 1977. The growth of fat in: Growth and Poultry Meat Production. pp 29-64. Eds. Boorman, K. N. and Wilson, B. L, British Poultry Science Ltd. Edinburgh, Scotland.

xvi. FISHER, C., 1984. Fat deposition in broilers. İn: Fats in animal nutrition. p. 437-470. Proceedings of the 37th Nottingham Easter School. Ed. Wiseman, L, Nottingham, England.

xvii. FISHER, C., WlLSON B.J., 1974. Response to dietary energy concentration by growing chicken Energy Requirements of Poultry (Morris, T.R. and Freeman, B.M., eds). p. 151-184. Edinburgh British Poultry Science.

xviii. FONTONA, E.A, WEAVER, W.D., DENBOW, D.M. 1983. Effects of early feed restriction on growth, feed convarsion and mortality in broiler chickens. Poultry Science, 71, 1296-1305, 1992.

xix. FREEMAN, C.P., Fat supplementation in animal production - monogastric animals. In: Proceedings of the Nutrition Society, 42, 351-359.

xx. GRIFFIN, H.D., ACAMOVIC, A., GUO, K., PEDDIE, J., 1989. Plasma lipoprotein metabolism in lean and fat chickens produced by divergent seleetion for plasma very low density lipoptrotein concentration, J. of Lipid Science. 30, 1234-1250.

xxi. GRIFFIN, H.D., HERM1ER, D., 1988. In: Leclercq, B., Whitehead, CC. (Eds) Leanness in Domestic Birds: Genetic, Metabolic and Hormonal Aspect, London.

xxii. GRIFFIN, H.D., WHITEHEAD, C.C., BROADBENT, L.A., 1982. The relationship between plasma triglyceride concentrations and body fat content in male and female broilers – a basis for selection? British Poultıy Science, 23, 15-23.
xxiii. GRIFFIN, H.D., WINDSOR, D., WHITEHEAD, C.C., 1991. Changes in lipoprotein metabolism and body composition in chicken in response to divergent selection plasma very low density lipoptrotein concentration. British Poultry Science, 32, 195-201.
xxiv. GRIFFITHS, L., LEESON, S,, SUMMERS, J.D., 1978. Studies on abdominal fat with four commercial strains of male broiler chicken. Poultry Science, 57, 1198-1203.
xxv. GRUFFAT, D., DURAND, D., GRAULET, B., BAUCHART, D., 1996. Regulation of VLDL synthesis and secretion in the liver. Reproduction Nutrition Development, 36, 375-389.
xxvi. GRUNDER, A.A., CHAMBERS, J.R, FORTIN, A., 1987. Plasma very low density Lipoproteins, abdominal fat Lipase, and fatness during rearing in two strains of broiler chickens. Poultry Science, 66, 471-479.
xxvii. HAKANSSON, J., ERIKSSON, S., SVENSSON, S.A., 1978. The influence of feed energy level on feed consumptian, growth and development of different organs of Chickens. Report No. 59. Swedish University of Agricultural Science, Department of Animal Husbandry.
xxviii. HARPER, A.E., BENEVENGA, N.J., WOHLHUETER, R.M., 1970. Effects of ingestion of dispropportionate amounts of amino acids. Physlological Reviews, 50, 428-558.
xxix. HAVE, H.G.M., SCHEELE, C.W., A., 1981. Comparison of the effects of different factors on the carcase composition of three broiler strains at two ages. In: Quality of Poultry Meat. pp 386-396. Eds. Mulder, R.W.A. W., Scheele, C.W. and Veerkamp, GR, Beekbergen, The Netherlands.
xxx. HAYE, U., SIMONS, P.C.M, 1978. Twisted legs in broilers. British Poultry Science, 19, 549-557.
xxxi. HOOD, R.L., 1984. Cellular and biochemical aspects of fat deposition in broiler type chicken. World's Poultry Science Journal, 40, 160-169.
xxxii. HOOD, RL., 1982. The cellular basis for growth of the abdominal fat pad in broiler type chickens. Poultry Science, 61, 117-121.
xxxiii. HUYBRECHTS, L.M., DECUYPERE E., BUYSE, J., KUHN, E.R., TIXIER-BOICHARD, M., 1992. Effect of recombinant human insulin-like growth factor-I on weight gain, fat content, and hormonal parameters in broiler chickens. Poultry Science, 71, 181-187.
xxxiv. JACKSON, S., SUMMERS, J.D., LEESON, S., 1982. Effect of dietary protein and energy on broiler carcass composition and efficiency of nutrient utilization. Poultry Science, 61, 2224-2231.
xxxv. KROGDAHL, A., 1985. Digestion and absorption of lipids in poultry. Journal of Nutrition, 115, 675-685.
xxxvi. KUBENA, L.F., CHEN, T.C., DEATON, J.W., REECE, F.N., 1974. Factors influencing the quantity of abdominal fat in broilers. 3. Dietary energy levels. Poultry Science, 53:974-978,
xxxvii. KUBENA, L.F., LOTT, B.D., DEATON, J.W., REECE, F.N., MAY, J.D., 1972. Body composition of chicks as influenced by environmental temperature abd selected dietary factors. Poultry Science, 51, 517-522.
xxxviii. LECLERCQ, B-, BLUM, J.C., BOYER, J.P., 1980. Selecting broiler for low or high abdominal fat: initial observations. Poultry Science, 21, 107-113.
xxxix. LECLERCQ, B., CIIAGNEAU, A.M, COCIIARD, T., KHOURY, J., 1994. Comparative responses of genetically lean and fat chickens to lysine, arginine and non-essential amino acid supply. I. Growth and body composition. British Poultry Science, 35, 687-696.
xl. LEENSTRA, F.R, 1982. Genetic aspects of fat deposition and feed efficiency. 24th British Poultry Breeders Roundtable Conference, Edinburgh, Scotland.
xli. LEENSTRA, F.R., 1986. Effect of age, sex, genotype and environment on fat deposition in broiler chickens. World's Poultry Science Journal, 42, 12-25.
xlii. LEENSTRA, F.R., 1984. Influence of diet and genotype on carcass quality in poultry and their consequences for selection. In: Rccent Advances in Animal Nutrition. pp 3-16. Eds. Haresign, W. and Cole, D. J. A., Buttemorth, London, England.

xliii. LEENSTRA, F.R., VEREIJKEN, P.F.G., PIT, R., 1987. Fat deposition in a broiler sire strain. 1. Phenotypic and genetic variation İn, and correlations between, abdominal fat, body weight and feed.

xliv. LEWIS, P.D., MACLEOD, M.G., PERRY, G.C., 1994. Effects of lighting regimen and grower diet energy concentration on energy expenditure, fat deposition and body weight gain of laying hens. British Poultry Science 35, 407-15.

xlv. LIN, C.Y., FRIARS, G.W., MORAN, E.T., 1980. Genetic and environmental aspects of obesity in broilers. World's Poultry Science Journal, 36, 103-111.

xlvi. LIPSTEIN, B., BORNSTEIN, S., BARTOV, L, 1975. The replacement of some of the soybean meal by the first limiting amino acids in practical broiler diets. 3. Effects of protein concentrations and amino acid supplementalions in broiler finisher diets on fat deposition in the carcass. British Poultry Science 16, 627-635.

xlvii. LOHMAN, T.G., 1973. Biological variation in body composition. Journal of Animal Science, 32, 647-653.

xlviii. M1ROSH, L.W., BECKER, W.A., 1983. Predition of abdominal fit in broiler chickens, Poultry Science, 59,945.

xlix. MALLARD, J., DOUAIRE, M., 1988. Strategies of selection for leanness in meat production, in: Leclercq, B., Whitehead, CC. (Eds) Leanness in Domestic Birds: Genetic, Metabolic and Hormonal Aspect, London.

l. MARCH, B.E., HANSEN, G., 1977. Lipid accumulation and cell multiplication in adipose bodies in White Leghorn and broiler-type chicks. Poultry Science, 56, 886-894.

li. MARCH, B.E., 1984. Plasma triglyceride and glucose clearance in broiler-type and White Leghorn chickens with different degrees of adiposity. Poultry Science, 63,1586-1593.

lii. MARKS, H.L., PESTI, G.M., 1984. The roles of protein level and diet form in water consumption and abdominal fat deposition of broilers. Poultry Science, 63, 1617-1625.

liii. MARKS, H.L., BAIK, D.H., 1994. Selection for eight-week body weight in two randombred chicken populations under altered water to feed ratios. 2. Feed intake, Water intake and abdominal fat levels. Poultry Science, 73, 1489-1498.

liv. MARKS, H.L., PESTI, G.M, 1984. The roles of protein level and diet form in water consumption and abdominal fat deposition of broilers. Poultry Science, 63, 1617-1625.

lv. MARKS, H.L., 1994. Selection for eight-week body weight in two randombred chicken populations under altered vvater to feed ratios. 1. Selection responses. Poultry Science, 73, 1175-1182.

lvi. MARKS, H.L., WASHBURN, K.W., 1983. The relationship of altered water/feed intake ratios on growth and abdominal fat in commercial broilers. Poultry Science, 62, 263-272.

lvii. MARKS, RL., 1988. Genetic manipulation of abdominal fat in broilers .CRC Critical Rev. POULTRY BIOL., 1, 271-284.

lviii. McLEOD, J.A., 1982. Nutritional factors influencing carcass fat in broilers. Zootechnica International, 7, 60-64.

lix. MIROSH, L.W., BECKER,.W.A., 1983. Testing a caliper for measuring thickness of the abdominal region live broiler chickens. Poultry Science, 62, 1.

lx. MIROSH. L.W., BECHER.W.A., SPENCER, J.V., VERSTRATE, J.A., 1980. Predition of abdominal fat in broiler chickens. Poultry Science, 59, 945.

lxi. MITCHEL, R.D., BURKE, W.H, The effect of orally administered thyrotropin-releasing hormone on growth and carcass characteristics of seven-to ten-week-old broilers. Poultry Science, 72, 1952-1960,1993.

lxii. MOLLISON, B., GUENTER, W., BOYCOTT, B.R., 1984. Abdominal fat deposition and sudden death syndrome in broiler: 1 he effect of restricted intake, early life caloric restriction and calorie:protein ratio. Poultry Science, 63, 1190-1200.

lxiii. PESTI, G.M, WHITEING, T.S., JENSEN, L.S., 1983. The effect of crumbling on the relationship between dietary density and chick growth, feed efficiency and abdominal fat pad weights. Poultry Science, 62, 490-494.

lxiv. PESTI, G.M., LECLERCQ B., CHAGNEAU, A.M, COCHARD, T., Comparative responses of genetically lean and fat chickens to lysine, arginine and non-essential amino acid supply. II. Plasma amino acid responses. British Poultry Science, 35, 697-707, 1994.

lxv. PFAFF, F. E., AUSTIC, RE., 1976. Influence of diet on development of the abdominal fat pad in the pullet. Journal of Nutrition, 106, 443-450,

lxvi. PICARD, M.L., UZU, G., DUNNINGTON, E.A., SIEGEL, P.B., 1993. Food intake adjustment of chicks: short term reactions to deficiencies in lysine, methionine and tryptophan. British Poultry Science, 34, 737-746.

lxvii. PYM, R.A.E., THOMPSON, J.M., 1980. A simple caliper technique for estimation of abdominal fat in live broiler. British Poultry Science, 21, 281-286,

lxviii. RICARD, F.H., 1975. Facteurs génétique influenfant la qualité des carcasses du poulet. In: The quality of Poultry meat. pp 4(1)–4(16). Proceedings of the 2nd European Symposium on Poultry Meat Quality. Ed. Erdtsieck, B., Oosterbeek, The Netherlands .

lxix. ROGERS, Q.R., LEUNG, P.M.B., 1973. The influence of amino asids on the neuroregulation offood intake. Federatlon Proceedlngs American Socs., Experimental Biology, 32,1709-1719.

lxx. SCHEELE, C.W, SCHAGEN, P.J.W. VAN., HAVE, H.G.M TEN., 1981. Abdominal and total fat content of three broiler strains at two ages affected by nutritional factors. In: Quality of Poultry Meat. pp 397-407. Eds. Mulder, R. W. A. W., Scheele, C. W. and Veerkamp, C. H., Beekbergen, The Netherlands.

lxxi. SCHWARTZBERG, K, ADAMS, R.L., STADELMAN, W.L., 1980. Correlation of fet thickness probe to actual weight of broiler fat pad. Poultry Science, 59,1659; (Abstr.).

lxxii. SIMON, J., LECLERCQ, B., 1961-1973. Longitudinal study of adiposity in chickens selected for high or low abdominal fat content: further evidence of a glucose-insulin inbalace in the fat line. Journal of Nutrition, 112:

lxxiii. SUMMERS, J.D., LEESON, S., 1985. Poultry nutrition handbook. Uni. of Guelph, Canada,

lxxiv. THOMAS, C.R, BLOW, W.L., COCKERHAM, C.C., GLAZENER, E. W., 1958. The heritability of bodyweight, gain, feed consumption and feed conversion in broilers. Poultry Science, 37, 862-869,

lxxv. THOMAS, C.R, GLAZENER, E.W., BLOW, W.L., 1958. The relationship between feed conversion and ether extract of broilers. Poultry Science, 37, 1177-1179.

lxxvi. TWINING, Jr. P.V., THOMAS, O.P., BOOSARD, E.H., 1978. Effect of diet and type of birds on the carcass composition of broilers at 28, 49 and 59 days of age. Poultry Science, 57, 492-497.

lxxvii. UN, C.Y., 1981. Relationship between increased body weight and fat deposition in broillers. World's Poultry, 37, 106-110.

lxxviii. WHITEHEAD, C.C., 1990. Divergent seleetion of lean and fat lines over eight generations using plasma very low density lipoptrotein concentration as seleetion criterion. British Poultry Science, 31, 293-305,.

lxxix. WHITEHEAD, C.C., GRIFFIN, H.D., 1982. Plasma lipprotein concentration as an indicator of fatness in broilers: Effect of age and diet. British Poultry Science, 23, 299-305.

lxxx. WHITEHEAD, C.C., GRIFFIN, RD., 1984. Development of divergent lines of lean and fat broilers using plasma very low density lipoptrotein concentration as selection criterion: The first three generations. British Poultry Science, 25, 573-582.

lxxxi. WHTEHEAD, C.C., GRIFFIN, H.D., 1986. Development of divergent lines of lean and fat broilers using plasma very low dcnsity lipoprotein concentration as selection criterion; rcsult over the four generation and lack of effect of dietary fat on performance and carcass fat content. British Poultry Science, 27, 317-324.

lxxxii. YOSHIDA, M, MORIMOTO, R., 1970. Interrelationship between dietary protein level and carcass composition of chicks. Agricultural and Biological Chemistry, Vol. 34, No:3, p. 414-422,

lxxxiii. ZHONG, C., NAKAUE, H.S., HU, C.Y., MIROSH I..W., 1995. Effect of full feed and early feed restriction on broiler performance, abdominal fat level, cellularity, and fat metabolism in broiler chickens. Poultry Science, 74, 1636-1643.