THE EFFECT OF DIETARY FAT ON THE PERFORMANCE, CARCASS QUALITY, FATTY ACID COMPOSITION AND STORAGE STABILITY OF TURKEYS

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ABSTRACT

The effect of the level and source of dietary fat on the performance of growing turkeys and on the finish, meat yield, composition and storage stability of the carcass was studied. Male turkeys were fed, from day-old to 24 weeks of age, diets of equal calorie:protein ratio containing either rapeseed or palm oil at either 2 or 11.4% of the diet, in comparison with a control diet which contained no added fat. Treatments were included in which the dietary fat was changed at 16 weeks from palm to rapeseed oil or vice versa, to permit observation of the effect of a change of the fat source on carcass composition and of the rate of change of carcass fatty acid composition following a change of dietary fat.

Body growth was found to be depressed by 11.4% rapeseed oil but stimulated by 11.4% palm oil. Feed conversion was inversely proportional to the level of added fat.

Increasing the dietary fat level improved carcass fat scores, increased the yield of skin, the fat content of breast and thigh meat and drip losses in cooking, and decreased the yield of breast meat, thigh meat and drumstick and volatile cooking losses. The initial addition of 2% fat to the diet had more effect on the carcass characteristics than a further

increase from 2 to 11.4% fat.

Volatile cooking losses decreased and drip losses increased with increasing carcass skin percentage.

The source of dietary fat influenced the carcass fat score, carcass composition and cooking losses.

Back fat score and back skin fat were more reliable indicators of overall finish as measured by carcass skin percentage than breast fat score and breast skin fat.

The fatty acids of abdominal depot fat and thigh and breast meat were strongly influenced by the level and source of dietary fat. Birds fed no added dietary fat deposited palmitic, palmitoleic, stearic and oleic acids in greater proportions than were provided in the diet. Increasing the level of fat in the diet resulted in the deposition of fat that resembled the dietary fat in composition, the greatest similarity occurring at the higher level of added fat.

Increasing levels of palmitoleic, stearic and oleic acids with age indicated that the rate of fatty acid biosynthesis increased as the birds approached maturity.

Thigh meat contained a higher level of stearic acid than depot fat, and breast meat contained higher levels of

stearic and arachidonic acids and fatty aldehydes than thigh meat. These differences reflected the greater proportions of phospholipids in thigh and breast meat, which were reflected also in decreased sensitivity of the meat lipids to changes in fatty acid composition in response to dietary fat.

The average rate of change of fatty acid levels following a change of dietary fat at 16 weeks was such that half the total change in level took place in 2.4 weeks.

Carcasses of birds fed 11.4% rapeseed oil were subject to rancidity, as measured by TBA value, when stored for eight months at a temperature of $-12^{o}C$, but not when stored at $-22^{o}C$. Carcasses of birds fed 11.4% palm oil were equally stable at both storage temperatures. The instability associated with dietary rapeseed oil was related to higher levels of linoleic and linolenic acids in the tissues as compared with those of birds fed palm oil.

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Gratefully,

R. E. Salmon.

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1. GENERAL INTRODUCTION

Fat is used extensively in the formulation of poultry feeds as an efficient and economical source of dietary energy. Recent advances in the understanding of the importance of nutrient balance have made it possible to obtain excellent performance from diets of high fat content.

Adjustment of nutrient ratios by means of dietary fat, and the incorporation of fat *per se* in the diet, have been shown to influence the amount of carcass fat. The source of fat is capable of profoundly influencing the fatty acid composition of the tissue lipids, but little is known of the interrelationships of the level and source of dietary fat with age, or of the rate of change of tissue fatty acids following a change of dietary fat. Similarly, little consideration has been given to the effect of the properties of different fats on the characteristics of the carcass, although some work has been done on storage stability as related to dietary fat.

The research described herein was planned to advance the state of knowledge of nutrition with regard to the effects of dietary fat on various aspects of the carcass quality and composition of turkeys.

The specific objectives of this study are:

1. To determine the effect of dietary fat on the performance and carcass quality of turkeys.
2. To determine the effect of dietary fat on the fatty acid composition of the carcass fat of turkeys.
3. To determine the rate of change of tissue fatty acids following a change of dietary fat.
4. To determine the effect of carcass fatty acid composition on storage stability of turkey meat.

2. REVIEW OF LITERATURE

2.1 Effect of dietary fat on feed intake, body weight gain and feed conversion

2.1.1 Use of fat in poultry diets

The sixth decade of the twentieth century saw a reversal in the attitude of nutritionists to the use of fat in poultry diets. An early edition of a major reference book contained the following passage: "Fats... are digested only with difficulty, and are absorbed slowly. The difficulties are such that large proportions of fat in the food may retard digestion and upset the normal metabolism of other nutrients. Consequently, large amounts of fat are always to be avoided in animal feeding" (Ewing, 1947). The dramatic development in understanding of the nutritional value of fat which took place in the ensuing years is illustrated by the statement in a recent edition by the same author: "More recently, the use of 30 or even 50 percent fat in experimental chick rations, properly balanced with respect to minerals, vitamins, and particularly amino acids and protein, has resulted in striking increases in feed efficiency, and in rates of growth comparable to those obtained with modern, properly balanced, practical-type rations" (Ewing, 1963).

2.1.2 Fat and performance of growing chickens

Vermeersch and Vanschoubroek (1968) reviewed 60 papers published prior to 1966 in an attempt to establish the quantitative effect of dietary fats on the performance of chicks. As a result of their detailed analysis of the data, the authors concluded that within the range of 2 to 20% of incorporated fat, feed intake decreases linearly as the percentage of fat in the diet increases. The fats studied, which included soybean oil, soybean soapstock, maize oil, lard, grease and tallow, were found to be similar in their effects on feed intake. While the addition of fat to the diet of growing chicks was found to improve the growth rate, the authors were unable to establish a relationship between weight gain and the percentage of dietary fat. Without regard for the level of fat added, it was concluded that soybean oil and maize oil improved weight gains to a greater degree than soybean soapstock and tallow. Feed conversion was shown to be strongly related to the level of fat in the diet, the degree of improvement being greatest in the case of soybean oil and least in the case of tallow.

Vanschoubroek et al. (1971) recently reported a comparison of the effect of lard and soybean oil on the

performance of broiler chicks. Soybean oil, included at 4.5% of the diet, improved feed conversion by 4.5% over lard to 4 weeks and by 3.3% to 8 weeks, in general agreement with the results previously calculated by Vermeersch and Vanschoubroek (1968) using data from the literature.

Herstad (1970), who reported the results of 15 experiments dealing with fat supplements in broiler diets, concluded that soybean oil, grease, rapeseed oil and linseed oil increased the rate of gain of broilers. Hydrogenated marine fat of melting point 33°C gave less weight increase, while more completely hydrogenated marine fat of melting point 43°C, and talloil, a wood pulp byproduct, did not affect the rate of gain. The first 3% of soybean oil or grease increased feed consumption; more than 3% fat in the diet decreased feed consumption, although metabolizable energy consumption increased. Hydrogenated marine fat tended to increase feed consumption because of its poor digestibility.

2.1.3 Fat and performance of growing turkeys

Research with turkeys produced findings similar to those reported for chickens. Biely and March (1954) found that supplementation with tallow increased the level of protein necessary for maximum growth of both chicks and poults.

Yacowitz et al. (1956) found that 3 or 6% added tallow improved the growth rate of male turkeys, but not females from 9 to 16 weeks of age; feed conversion of both sexes was improved. Waibel (1958) reported that supplementation of turkey diets with animal fat resulted in a marked growth response and improvement in feed efficiency, provided the protein level was adequate. Combs et al. (1958) found that 10% added fat improved the growth rate and feed conversion of fryer turkeys as compared to 2% added fat. Blakely et al. (1965) found that 10% of either tallow or rapeseed oil added to finishing diets, from 20 to 24 weeks of age, improved weight gains and feed conversion. Six percent tallow, soybean oil or rapeseed oil, however, did not significantly increase weight gains, but did improve feed conversion. Touchburn and Naber (1966) showed that the substitution of fat calories for carbohydrate calories in diets fed to Large White males improved the growth rate, and permitted a wider calorie protein ratio in the diet without impairment of growth. Fat added to diets of Wrolstad Small Whites did not improve weight gains but did increase feed efficiency. Carson et al. (1969) reported a growth response in only one of two trials in which 4% corn oil was added to the diet of Large White turkeys from 12 to

24 weeks.

2.1.4 Relationship of fat to nutrient density

Pepper et al. (1960) reported that the addition of 2.5 to 5% fat in mash diets increased the average weight of chickens and turkeys, but had no effect in pelleted diets, suggesting that the effect of fat in improving weight gains was through increasing the density of the diet, thereby permitting the bird to consume more nutrients within its physical capacity to consume feed. The work of Dunkelgod and Thayer (1960) emphasized the importance of the nutrient density of the diet in permitting the turkey to consume enough nutrients to achieve its growth potential.

2.1.5 Importance of nutrient balance

The lack of consistency in the findings reported in the literature on the effect of fat on weight gain was soon recognized to be due to restriction of nutrient consumption as a result of reduced feed intake when high fat levels were fed. Not only was protein incriminated (Aitken et al., 1954; Slinger et al., 1955) but other dietary requirements were found to be increased when fat was added to the diet. The folic acid requirement, for example, was shown to be increased in the presence of a high dietary fat level (March and Biely,

1955), as was the requirement for choline (March and Biely, 1956). Davidson (1956) showed that where balance was maintained between protein and total digestible nutrients in the ration, high levels of fat consistently improved feed conversion and growth rate. The current opinion was well expressed by Ewing (1963) in the quotation given above, which emphasizes the importance of the proper balance of all nutrients for the utilisation of high dietary fat levels.

2.1.6 Relative value of different fats

The relatively limited improvement in feed conversion attributed to tallow is associated with the poor utilisation of the saturated fatty acids of tallow. Sunde (1954) found that the saturated fatty acids of hydrogenated fat were largely excreted as free fatty acids. The relative absorbability of tallow in comparison to soybean oil was 77%, and its metabolizable energy value was 79% of that of soybean oil (Vermeersch and Vanschoubroek, 1968). Young (1961) found that 70% of the gross energy of tallow was utilized, compared with 98% of the gross energy of either soybean oil or lard. The metabolizable energy value of tallow was 6.56 kcal/g., and those of soybean oil and lard were 9.26 and 9.20 kcal/g., respectively. Renner and Hill (1960)

and Pepper et al. (1962) found that the utilisation of tallow improved with increasing age of the bird. The difference in utilisation between tallow and lard, which contain similar levels of saturated fatty acids, is attributed to the difference in glyceride structure between the fats (Scott et al., 1969). Palmitic acid in lard is present largely in the 2- position of the triglyceride, in contrast with tallow, in which palmitic and stearic acids are distributed preferentially on the 1- and 3- positions of the triglyceride. Pancreatic lipase specifically hydrolyses the ester bond at the 1- and 3- positions, which converts a high percentage of the saturated fatty acids of tallow to poorly absorbed free fatty acids, while the 2- monoglycerides of palmitic acid from lard are readily absorbed.

The absorption of the saturated fatty acids of tallow may be improved by feeding a mixture of fats (Renner and Hill, 1961; Young, 1961). The presence of oleic acid was shown to improve the absorption of palmitic acid (Young and Garrett, 1963). Lewis and Payne (1966) demonstrated a synergistic improvement in digestibility when a vegetable oil, rich in unsaturated fatty acids, was mixed with a fat containing a higher proportion of saturated fatty acids. Salmon (1970)

found that the low digestibility of tallow was due to poor absorption of the saturated fatty acids. The digestibility of palmitic and stearic acids was greatly improved in mixtures of tallow with rapeseed oil. The relatively high absorbability of tallow reported by Carver et al. (1955) may be accounted for by the synergistic effect of the fats contributed by the basal diet, when combined with the comparatively low level of tallow (3%) that was fed in their experiments.

2.1.7 Nutritional and environmental factors affecting digestibility

Other factors besides glyceride structure and the fatty acid composition of the mixture may influence fatty acid absorption. Young et al, (1963) found that the absorption of lard fatty acids was greater when fed in a diet containing 28 or 30% protein as compared to a 24% protein diet. They found greater absorbability of fatty acids after the diets were fed for 3 weeks as compared to 2 weeks.

The incorporation of lecithin has been shown to improve the digestibility of fats. Auger et al. (1947) reported that the addition of lecithin at 1/6 or 1/5 of the level of dietary fat (15%) improved the digestibility of hydrogenated cotton-seed oil of melting point 63^{o}C from 24 to 44%. The

digestibility of cottonseed oil of melting point 54°C was improved from 60 to 83% and that of melting point 46°C from 84 to 88%. March and Biely (1957), on the other hand, reported that 0.5% lecithin did not improve the utilisation of 12% beef tallow or hydrogenated animal fat. Sibbald et al. (1962), however, found that soybean lecithin appeared to increase the utilisation of the energy of the tallow. Salmon (1969)[1] found that the incorporation of soybean lecithin improved the feed conversion of poults fed diets containing 7% tallow.

Fatty acid absorption was significantly improved by raising chicks in a fumigated laboratory as contrasted to a contaminated laboratory which contained chicks of various ages (Young et al., 1963). A similar effect may have been responsible for the greater growth response to 10% added fat that occurred in chicks housed in new, regularly cleaned batteries, as opposed to old ones which were not cleaned during the experiment (Donaldson, 1962). However, it is not known

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[1] Salmon, R. E., 1969. Unpublished data. Research Station, Research Branch, Canada Department of Agriculture, Swift Current, Saskatchewan. S9H 3X2

if the effect observed by this author was related to fat absorption. Afifi (1959, cited by Young et al., 1963) observed an improvement in growth, feed utilisation and digestibility of fat in 4 week old chicks fed either 25 ppm aureomycin or 40 ppm penicillin. Supplee (1960) observed a 20% growth response when 13% corn oil was added to the diet in the presence of 50 mg. of oleandomycin phosphate per kg., but only a 10% increase in growth in its absence. These reports suggest that the absorption of fat may be influenced by the level of contamination of the environment by micro-organisms or by the balance of the intestinal microflora (Donaldson, 1962). Variation in these factors may account for some of the variation in response to fat as reported in the literature.

2.1.8 Carbohydrate-free diets

The use of fat in the diet has perhaps reached its zenith in carbohydrate-free diets, in which fats provide virtually all the non-protein energy. Rand et al. (1957b) fed levels of corn oil from 0.5 to 31% of the diet, contributing from 1 to 57% of the total metabolizable energy, or up to 97% of the nonprotein calories of the diet. The authors concluded that the chick's tolerance for fat, per se., is unlimited.

Diets containing soybean oil as the only source of nonprotein calories are capable of supporting normal early growth of chickens. Soybean fatty acids, however, depress growth unless glycerol or glucose is supplied in the diet to provide for the conversion of fatty acids to triglycerides (Renner, 1964; Renner and Elcombe, 1964; Brambila and Hill, 1966). Edwards and Hart (1971) found that lard, corn oil or linseed oil were superior to menhaden oil as the sole non-protein energy source. These authors postulated that the polyunsaturated fatty acids in menhaden oil may have created an essential fatty acid deficiency, by inhibiting the conversion of linoleic acid to arachidonic acid as demonstrated in rats by Edwards and Marion (1963).

2.2 Effect of dietary fat on carcass composition

2.2.1 Early studies

The composition of the diet has been shown to influence the fat content of the carcass of chickens. Mitchell *et al.* (1931, cited by Hoffman, 1969) reported that birds on dilute diets are lean and those on concentrated diets are fat. Dilution of the diet with 40% oat hulls reduced the percentage of carcass fat, on a dry basis, from 26.8 to 16.1%.

Maw (1935) reported differences in fat deposition in chicken roasters fed different cereals. Corn fed birds had a greater fat deposition in the flesh and less in the abdomen and skin than birds fed barley, oats or wheat. Taste tests tended to bear out the results of the tissue fat analyses, as corn fed flesh rated best and moist, while wheat fed flesh lacked flavour and was dry. Maw and Maw (1939) again stated that corn-fed broilers contained more fat in the edible portion and less in the skin than birds fed other cereals. Fraps (1943) reported that the substitution of cottonseed oil for part of the corn meal in a standard ration reduced the rate of growth, but produced birds with much higher carcass fat content. Substitution of high-protein ingredients or oat hulls for part of the corn meal reduced the carcass fat content. The author suggested the possibility of producing chickens of desirable fat content by adjusting the ration.

2.2.2 Carcass composition of chickens

Varying the calorie:protein ratio of the diet has repeatedly been shown to influence the tissue fat deposition of chickens. Dansky and Hill (1952) found much more fat in the carcasses of birds fed a high energy diet than in those fed a diet of more moderate energy level.

Donaldson et al. (1955, 1956) showed that as the ratio of energy to protein in the ration was widened, the energy intake and carcass fat deposition increased and the water content of the carcass decreased. Leong et al. (1955), reporting on the effect of calorie:protein ratio on growth performance, stated that visceral depot fat varied from 1.1 to 23 g. per kg. of live weight, depending on the dietary fat level. Rand et al. (1957a) reported that the amount of fat in the carcass was inversely correlated to the protein: energy ratio, but was not affected by the energy or fat level of the diet per se. Spring and Wilkinson (1957) showed that increasing the dietary protein level increased carcass protein and water and decreased the carcass fat of broilers. Increasing dietary energy increased carcass fat but decreased carcass protein and water. Baldini and Rosenberg (1957) reported that increasing the fat content of a broiler diet without increasing the caloric content did not increase the deposition of carcass fat. Miller et al. (1962a) reported that the addition of 17.5% of either corn oil or lard to a basal diet significantly increased the fat content of breast and thigh muscle. Mickelberry et al. (1964) reported a similar increase in the ether extract

content of breast, thigh and skin when 10% cerelose (dextrose) was replaced by 10% of either corn oil, lard or hydrogenated cocoanut oil. In both the latter cases, the increased fat deposition was associated with an increase in dietary calorie:protein ratio as well as increased dietary fat. Summers et al. (1965) investigated the influence of a wide range of dietary protein and energy ratios on the carcass composition of broiler chickens. Carcass protein increased and carcass fat decreased in a linear manner as dietary protein was increased. Conversely, increasing levels of dietary energy resulted in decreased carcass protein and increased carcass fat. Sell and Thompson (1965) found that carcass fat content and efficiency of energy utilisation increased when 5 or 10% animal tallow was added to the ration of growing chicks. Herstad (1970) reported increased fat and decreased water content of broilers fed diets containing 3 to 5% fat supplement. The protein level was held constant in each of his experiments, resulting in a widening of the calorie:protein ratio when fat was added to the diet.

2.2.3 Carcass composition of turkeys

In studies with turkeys, Donaldson et al. (1958) found that, as in chickens, increasing the calorie-protein ratio

of the diet increased carcass fat and decreased carcass protein. In contrast with many reports on chickens, however, increasing the dietary fat level at a constant calorie:protein ratio was even more effective in increasing carcass fat deposition and decreasing the carcass protein and water content. Carlson et al. (1962), studying the effect of dietary energy on three strains of turkeys, found little difference in finish or muscle fat content that was attributable to diet, but fat added to the diet tended to increase cooking losses. Moran et al. (1969) found that the grade of finish of both the breast and back of Large White turkeys improved with increasing dietary caloric density. Finish was assessed visually, and also by measurement of back skin fat content in accordance with a method reported earlier (Moran et al., 1968). Bixler (1969) reported that poults fed low-protein diets that were limiting in lysine gained less rapidly in body weight, increased in carcass fat, and decreased in carcass protein and water content.

Blakely et al. (1965) found that the addition of 10% fat to the finishing diet of heavy type turkeys, from 20 to 24 weeks of age, improved their carcass fat scores. Touchburn and Naber (1966) found that the carcass fat scores of Wrolstad

Small White turkeys at 14.5 weeks of age were improved by increasing the fat content but not by widening the calorie: protein ratio of the diet.

2.2.4 Metabolic efficiency of fat *versus* carbohydrate

Touchburn and Naber (1966) explained the greater metabolic efficiency of fat as opposed to carbohydrate in terms of a saving of energy needed to convert carbohydrate to fat for deposition in the tissues. Forbes and Swift (1944) had shown with rats that the heat increment of diets containing fat was lower than that of diets in which the main nonprotein energy source was carbohydrate. In a further experiment, Forbes *et al.* (1946) fed diets of constant metabolizable energy and energy:nutrient ratios containing 2 to 30% fat. They found that the heat increments of the energy supplements diminished in order of increasing fat content of the diets. Carew and Hill (1958) showed that when fat was substituted isocalorically for cerelose, diets containing 10 to 20% corn oil resulted in greater tissue energy gains by chicks, indicating that corn oil increases the efficiency of energy utilisation. These authors, in a later paper (1964), attributed the increased metabolic efficiency of energy utilisation of fat over carbohydrate by chicks to the lower heat increment associated

with fat. These findings agree with those of Forbes et al. (1946) based on work with rats. Carew et al. (1964) compared the energetic efficiency of a series of fats with that of a low fat diet at equal metabolizable energy intake. They found that with corn oil, beef tallow, soybean oil and lightly hydrogenated olive oil, but not hydrogenated cocoanut oil, more energy was deposited in the carcasses as compared with the low fat diet. Begin (1969), feeding diets in which approximately 65% of the total calories were supplied either by corn oil or carbohydrate, found differences in efficiency of nitrogen and energy utilisation between breeds of chickens. The energetic efficiency of the fat diets, fed on the basis of equalized caloric intake, was numerically superior to that of the carbohydrate diets in the case of each breed, but the differences were not statistically significant.

The Specific Dynamic Action or heat increment associated with energy intake has been described as the energy cost for transforming nutrients which cannot be stored in their original form (Cahn and Houget, 1960, cited by Touchburn and Naber, 1966). The heat increment associated with the ingestion of glucose probably represents the energy of fatty acid synthesis (West et al., 1966). Ingested fatty acids,

by contrast, may be stored without undergoing metabolic change.

2.3 Effect of dietary fat on carcass fatty acid composition

2.3.1 Early studies

It has been known for many years that dietary fats influence the composition of body fats, milk and eggs. Burr and Barnes (1943) reviewed the early literature, dating back to 1869. They concluded that "the pig, rat and chicken are very responsive to dietary fats, their body lipids being profoundly changed by the diet... without apparent effects on their metabolism or well-being. In contrast, the body fat of beef and sheep... remain fairly constant in composition regardless of diet".

Early studies on the fat metabolism of poultry included the work of Cruickshank (1934), who reported that the ingestion of palm oil or mutton fat by hens increased the saturation of body fats, whereas consumption of hempseed oil resulted in a marked increase in unsaturation. Egg fats were found to be modified by ingestion of unsaturated fats, but were little affected by saturated fats. This author used the iodine number to indicate the relative unsaturation of the fats. Hilditch et al. (1934) found little difference in carcass fat between hens fed 7% fish meal which contained

2.5% fish oil, and those fed no fish meal. Separating the fatty acids by fractional distillation, he reported the body fat of the hen to consist of 25 - 30% palmitic acid, 7 - 8% palmitoleic acid, 5 - 7% stearic acid, 35 - 38% oleic acid and 20 - 22% linoleic acid.

An early opinion that highly unsaturated fatty acids were either metabolized or converted to a more saturated form before being stored was challenged by Beadle et al. (1948), who showed that the pig and the rat deposited large amounts of trienoic fatty acids in the depot fat.

The early investigators were hampered by time-consuming analytical techniques of fractional crystallization and distillation which required large samples of fat. Since the development of newer techniques has made possible rapid and precise determinations of fatty acids in much smaller amounts of material, many reports have demonstrated the effect of dietary fat on the tissue lipids of many animal species.

2.3.2 Scope of recent research

A few examples suffice to illustrate the variety of species that have been studied. The dietary origin of the characteristic fatty acids of marine fats has been demonstrated. Kelly et al. (1958) showed that, on a fat-free diet, the

mullet does not synthesize the large amounts of polyunsaturated fatty acids normally found in its body fat. Mullet fed diets containing cottonseed oil or menhaden oil, following a depletion period, deposited fat that was similar to the dietary source. Rabbits fed diets containing 20% of either oleic or linoleic acid for 8 to 12 weeks after weaning deposited approximately 63% of each fatty acid in their respective adipose fats (Borgman, 1964). The increase in deposition of the unsaturated fatty acids was largely at the expense of palmitic and stearic acids. The depot fat of mice exhibited extensive changes in fatty acid composition following the ingestion of graded levels of vegetable oils or fatty acids (Tove and Smith, 1960). Rats fed diets containing 20% rapeseed oil or 20% corn oil deposited tissue fatty acids that were generally similar to the dietary fatty acids, although erucic acid from rapeseed oil was deposited at a lower level than was present in the dietary source (Craig et al., 1963).

Carroll (1965) outlined the scope of recent literature on dietary fat and the fatty acid composition of tissue lipids in a review which cites 254 sources. His report briefly discusses the typical fatty acid composition of the depot fats of various forms of animal life, and indicates the major

distinguishing features of the fatty acids of the phospholipids as compared with triglycerides. Phospholipids generally contain more stearic and arachidonic acid and less oleic acid than triglycerides. A few of the differences in fatty acids between phospholipid classes are indicated. The sources of tissue fatty acids, whether endogenous, arising by biosynthesis from simple precursors or interconversion of existing fatty acids, or exogenous, from dietary fat, are discussed, and the effects of dietary fatty acids on the various lipid classes are considered. The less common classes of fatty acids including the long-chain acids such as erucic, the trans, conjugated, acetylenic, branched-chain and epoxy fatty acids are considered and their implications are discussed.

Further consideration of dietary fats in this discussion will be restricted to recent reports on their effects on the fatty acid composition of the tissue lipids of poultry.

2.3.3 Fatty acids of chickens

Feigenbaum and Fisher (1959) studied the effect of the ingestion of 10% of either cocoanut, cod-liver, cottonseed, olive or safflower oil on the body depot fat and egg fat of mature hens. After five weeks the saturated fatty acids of depot fat were markedly increased by cocoanut oil (from 32 to 65% of the total fatty acids) and moderately decreased (to 24 - 29%) by safflower, cod-liver or olive oil. Oleic acid was decreased by safflower or cocoanut oil, and linoleic acid was strongly influenced by each of the dietary fats. In agreement with the early observation of Cruickshank (1934), egg fat was influenced only by the unsaturated fatty acids. Horlick and O'Neil (1958) reported a six-fold increase in linoleic acid of egg fat (from 5.6 to 30.4%) after feeding 10% sunflower-seed oil to hens for 8 weeks. Hegsted (1960) found that after feeding 10% of either safflower, cocoanut, corn or olive oil or a mixture of oils for 33 weeks, the adipose fatty acids of hens approximated those of the fat ingested. Machlin et al. (1962) studied the effect on tissue and egg fatty acids of feeding 15% of either safflower or hydrogenated cocoanut oil to mature hens for 12 weeks. Using gas liquid chromatographic techniques, they found that hens

fed hydrogenated cocoanut oil laid eggs containing significantly more lauric, myristic, myristoleic, palmitoleic and oleic acids and less linoleic and arachidonic acids than hens fed safflower oil. The tissue fats of hens fed hydrogenated cocoanut oil contained significantly more lauric and myristic acids and less linoleic acid than tissues of hens fed safflower oil. It was concluded that, contrary to the findings of Cruickshank (1934) and Fergenbaum and Fisher (1959), both egg and tissue fats were influenced by saturated as well as unsaturated dietary fats.

Machlin (1961) investigated the synthesis of fatty acids by chicks fed low fat diets, containing less than 0.005% linoleate, to 28 days of age. The average total carcass fatty acids increased from 2.6 g. to 29 g. during the 28 day growth period, through synthesis of saturated and monounsaturated fatty acids. The final levels of carcass fatty acids which were increased by synthesis were approximately 33% palmitic, 20% palmitoleic, 3% stearic and 31% oleic acids. Linoleic and arachidonic acids decreased to less than the initial amounts in the day-old carcass.

Marion and Woodroof (1963a) investigated the fatty acid composition of breast, thigh and skin tissues of broilers

as influenced by different dietary fats. Each tissue responded to 6% of corn oil or beef tallow, or mixtures of 5% of each with 1% menhaden oil, by tending to assume the fatty acid composition of the dietary fat. The fatty acid pattern in each of these tissues differed mainly in the 20-, 22- and 24-carbon acids present. No fatty acids of longer than 20-carbon length were detected in skin tissue, but appreciable quantities of 22- and 24- carbon acids were detected in breast tissue and smaller quantities in thigh tissue. Marion and Edwards (1963) noted that the addition of 5% corn oil to the diet of female chickens increased the level of linoleic acid in the eggs, plasma, heart, liver and depot fat, and decreased the palmitoleic and oleic acid content. Marion (1965) considered the effect of age and dietary fat on the lipids of chicken muscle. Total lipid and phospholipid levels in breast muscle were not influenced by the addition of either 6 or 12% dietary fat, but were significantly lowered by age. Phospholipids were higher in stearic acid and long-chain polyunsaturated fatty acids, whereas neutral lipids contained more oleic and linoleic acids. Each lipid fraction tended to assume the fatty acid pattern of the dietary fat (corn or beef tallow), with neutral lipids affected far more than

phospholipids. Age had little effect on the fatty acid content of neutral lipids, but tended to reduce the level of linoleic acid in phospholipids while increasing the levels of long-chain polyunsaturated fatty acids.

Mickelberry et al. (1966) noted that environmental temperature did not influence the fatty acid composition of chicks, but the addition of fat to the diet decreased the levels of palmitic, palmitoleic and oleic acids, and in the case of corn oil, stearic acid as well.

Chung et al. (1967) investigated the effect on liver lipid fractions of increased lipid synthesis induced by injection of diethylstilbestrol in 10 - week old cockerels. The administration of diethylstilbestrol caused an increase in palmitic, palmitoleic and oleic acids and a decrease in stearic, linoleic and arachidonic acids. The response of cockerels fed hydrogenated cocoanut oil was greater than that of those fed corn oil.

Miller et al. (1967) reported the deposition of poly-unsaturated fatty acids of menhaden oil in broiler muscle lipids. The fatty acids 20:5, 22:6 and 22:5, in that order, were deposited in muscle in proportion to their content in the diet.

Salmon (1969b) reported that the depot fat of chicks fed 10% soybean or 10% rapeseed oil to 6 weeks of age resembled the dietary source in composition. Erucic acid of rapeseed oil was deposited at 50% of the level in the dietary oil, while oleic acid was increased by a corresponding amount. The decrease in level of erucic acid, accompanied by an increase in oleic acid, may be explained by the partial degradation of erucic acid by β-oxidation through eicosenoic to oleic acid, which was demonstrated in the rat by Craig and Beare (1967). Carreau et al. (1968) also showed the conversion of erucic to oleic acid.

Sheppard et al. (1971) compared 16% of either corn, rapeseed or crambe oil with a low-fat control diet, and found only 1.0 and 1.2% erucic acid in the depot fat of the chicks fed rapeseed and crambe oil, respectively, which was approximately 10% of the level of erucic acid found by Salmon (1969b) in the depot fat of chicks. Oleic acid was somewhat increased in the rapeseed and crambe groups. Palmitoleic acid deposition tended to be decreased by the addition of oil to the diet. Sell and Hodgson (1962) fed 4 and 8% levels of rapeseed oil, of 32% erucic acid content, to broiler chicks and observed 4.7 and 6.1% erucic acid in the depot fat of birds fed the

respective levels of rapeseed oil. The reason for the limited deposition of erucic acid found by Sheppard et al. (1971) in comparison with that found by Sell and Hodgson (1962) and Salmon (1969b) is not immediately apparent, but a strain difference may be postulated between the slow-growing White Leghorn cockerels employed by Sheppard et al. (1971) and the fast-growing broiler strain chicks used in the other two studies.

Herstad (1970) reported the strong influence of the dietary fat on the fatty acid composition of the carcass fat. There was an increasing correlation between the composition of the dietary and carcass fat as the dietary fat level increased. A progressive decrease in deposition of palmitoleic acid, from approximately 6% of the carcass fatty acids when the diet contained no added fat to about 1.5% when the diet contained 9% soybean oil, is of interest and will be discussed in a later section.

2.3.4 Fatty acids of turkeys

Reports on the fatty acid composition of turkey lipids are few in number, in comparison with those dealing with chicken lipids.

Nutter et al. (1943) found no difference between chickens and turkeys in the composition of depot fat. Fat from both species contained approximately 32% saturated and 67% unsaturated fatty acids. The unsaturated fraction consisted of about 46% oleic and 22% linoleic acids. No acids more unsaturated than linoleic were found.

Hite et al. (1949) studied the effect of 2% hydrogenated fat and 1% raw linseed oil, along with certain other ingredients, on the fatty acids of fat extracted from the skin, gizzard and liver of turkeys. In comparison with hydrogenated fat, linseed oil caused an increase in the linoleic acid content of skin and gizzard fat, and the appearance of linolenic acid in skin fat but not in the gizzard or liver fat. The effect of the dietary fat sources was reflected in a higher iodine value of the skin fat from birds which had received linseed oil in the diet. The fat extracted from the various tissues differed in that arachidonic acid was concentrated in the liver fat at levels of 6 to 10%, while gizzard fat contained 1 to 2% and skin fat only traces. Liver fat also contained less linoleic and oleic acids and more saturated fatty acids than the skin or gizzard fat.

Klose et al. (1951) reported that 5% cocoanut oil, fed for 8 weeks, increased the saturated fatty acid content of the carcass fat from 32%, produced by feeding a practical ration, to 50%, at the expense of oleic and linoleic acids. Linseed oil, at the same level, reduced the degree of saturation of the carcass fat only slightly, but resulted in the deposition of 20% linolenic acid. The inclusion of 10% fish meal in the diet tended to increase the deposition of arachidonic acid. Klose et al. (1952b) subsequently fed turkeys a simplified, low-fat basal diet, alone or supplemented with 2% of either beef fat, corn oil, linseed oil, sardine oil or soybean oil. The total saturated fatty acids in the depot fat were maintained at a fairly constant level at this low level of supplementation, but linoleic and linolenic acid deposition was correlated with the dietary fatty acid composition.

Miller et al. (1962b) briefly compared the fatty acid content of the skin of chickens and turkeys fed practical-type diets. The skin fat of turkeys contained approximately 60% more linoleic and 50% more linolenic acid than did the skin fat of chickens. No further details of fatty acid composition were given.

Neudoerffer and Lea (1966, 1967) showed that the long-chain polyunsaturated fatty acids of fish oil, up to 22:6, were deposited in the skin fat of turkeys. The lipids of breast and leg muscle were fractionated into five "neutral" and six phospholipid fractions, and the effects of various beef fat and anchovy oil treatments on the fatty acid composition of each component were described in great detail. The effects of beef fat were small and mainly on the neutral lipid fractions. The polyunsaturated fatty acids of fish oil extensively displaced linoleic and oleic acids from all fractions except sphingomyelin. The addition of 2.5% of either dietary fat to the basal diet, which itself contributed 2.3% fat, reduced the deposition of palmitoleic acid in the skin lipids and muscle triglyceride fraction from approximately 11 to 7% of the fatty acids, in spite of an increase in the palmitoleic acid content of the diet when beef fat or anchovy oil was added. A similar decrease in palmitoleic acid was found in most of the neutral lipid and some phospholipid fractions when fat was added to the diet. The 1967 paper contains a wealth of detailed information on the fatty acid composition of the various lipid fractions from turkey muscle.

A later paper by the same authors (1968) reports the effect of dietary fat on the levels of the individual lipid fractions of turkey muscle, and shows that the effect was primarily on the triglyceride fraction.

Osborn et al. (1969) showed that the implantation of estradiol-17-β-monopalmitate altered the fatty acid content of turkey lipids by increasing the deposition of palmitoleic and oleic acids. Stearic and linoleic acids were decreased. Total carcass fat content did not appear to increase as a result of the hormone treatment, as might have been expected if the hormone treatment increased fat synthesis, but the estimates of total fat content, based on specific gravity measurements, are variable and of questionable precision. The data of Moreng et al. (1963) reveal serious discrepancies and inconsistencies in the application of the specific gravity method when compared with laboratory analysis of carcass fat content.

Carlson et al. (1969) showed that 4% corn oil affected the fatty acid composition of abdominal and drip fat of Large Broad White turkeys by reducing palmitic, palmitoleic and oleic acids, and increasing the linoleic acid fraction. Stearic, myristic and linolenic acids remained relatively

constant.

Further evidence of the susceptibility of turkeys to alteration of their carcass fat by manipulation of the dietary fat source was provided by Salmon (1969a). Feeding a series of diets containing 9% of either rapeseed oil, soybean oil, or mixtures of rapeseed oil with either soybean oil or tallow to 6 weeks of age resulted in depot fatty acids almost unaltered in composition from those found in the dietary fats. The only consistent difference between the dietary and depot fats was a decrease in erucic acid in the depot fat by 20% of the dietary level, accompanied by corresponding increases in eicosenoic and oleic acids. The relationship between dietary and depot fatty acids observed in turkeys was considerably greater than had been observed in chickens fed similar dietary oils (Salmon, 1969b).

2.3.5 Comparative observations

It is clear from the reports cited that the fatty acid composition of chicken and turkey lipids is readily altered in response to changes in the composition of the dietary fat. Adjustment of the dietary fat source makes possible the production of poultry meat of specific lipid characteristics which may be considered desirable.

It is difficult to reach any conclusions, on the basis of the data available, as to the relative susceptibility of the lipids of chickens and turkeys to changes of dietary fat source. Considerable differences in the effect of similar dietary fats on carcass fats were seen even between chickens in different experiments (Sell and Hodgson, 1962; Salmon, 1969b; Sheppard et al., 1971). If a tentative observation may be made from the response of chickens and turkeys to diets containing similar oil treatments, fed in the same laboratory, turkeys appeared to be considerably more responsive to the dietary fat source than chickens (Salmon, 1969a,b).

Numerous reports cited have revealed a tendency for the deposition of palmitoleic acid, as well as other fatty acids, to decrease in the presence of added dietary fat. This phenomenon has been observed in chickens (Marion and Edwards, 1963; Mickelberry et al., 1966; Sheppard et al., 1971; Herstad, 1970) and in turkeys (Neudoerffer and Lea, 1967; Carlson et al., 1969). Palmitoleic acid is one of those which Machlin (1961) found to be the predominant biosynthetic fatty acids. Yeh et al. (1970) and Yeh and Leveille (1971) have shown by tracer techniques, using labeled acetate, that dietary fat inhibits hepatic lipogenesis in the chick.

Donaldson (1966) also found that the interconversion of labelled fatty acids was reduced by increasing the dietary fat content.

Chung et al. (1967), on the other hand, noted an increase in palmitic, palmitoleic and oleic acids upon administration of diethylstilbestrol to cockerels, probably indicating an increase in the rate of lipid biosynthesis. Osborn et al. (1969) also showed that hormone administration to turkeys increased the deposition of palmitoleic and oleic acid.

Since palmitoleic acid, alone among the four major biosynthetic fatty acids, is present in most dietary fats in only small amounts, it appears reasonable to hypothesize that the level of palmitoleic acid in the carcass fat may serve as an index of the relative proportion of biosynthetic fatty acids deposited in comparison with those of dietary origin.

2.4 Effect of fatty acid composition on carcass fat characteristics

2.4.1 Physical characteristics

Although the source and level of fat in the diet have been shown to affect both the amount and composition of the carcass fat (Sections 2.2, 2.3), and fats of different fatty acid composition vary widely in chemical and physical properties

(West et al., 1966), little consideration has been given to the effect of the dietary fat on the physical characteristics of the poultry carcass. Unsaturated dietary fats have long been known to cause soft fat in pork, imparting undesirable characteristics to the meat (Burr and Barnes, 1943). Blakely et al. (1965) found no significant difference in carcass fat score between turkeys fed diets containing rapeseed oil, soybean oil or tallow. However, the fats were included only in the finishing period, for 4 weeks prior to slaughter, which may have been too short a period to allow the dietary fats to exert their full influence on the composition of the carcass fat. Further study of the rate of change of tissue fatty acid composition following a change of dietary fat source is desirable.

2.4.2 Storage stability

The effect of fatty acid composition on the storage life of meat is well illustrated by the problem that arises in pork when hogs are fed diets that are high in unsaturated fat content. This subject was reviewed and the influence of fat composition, storage temperature, length of storage and packaging treatment on deterioration of frozen pork was studied by Palmer et al. (1952). The authors concluded, following a

lengthy investigation, that pork containing unsaturated fat as a result of feeding appreciable quantities of soybeans was more susceptible to the development of rancidity than pork from pigs fed a standard ration. Proper packaging and storage at -17.6°C or lower were found to be of paramount importance to maintain the quality of pork with soft fat. The degree of saturation of fat had no significant effect on the keeping quality of pork that was properly packaged and stored at -17.6°C.

The problem of storage life may be more acute with pork than with poultry meat because of the higher fat content of pork (Scott, 1956). However, considerable study has been devoted to factors which, because of the relatively unsaturated nature of poultry fat, might affect the storage of poultry products.

Schreiber et al. (1947) reported that alfalfa or fish oil, if included in the diet of turkeys for 1 or 2 weeks before slaughter, greatly decreased the stability of the carcass fat during storage. Kummerow et al. (1948) found that the addition of alfalfa meal, raw linseed oil or sodium phosphate to the diet resulted in elevated peroxide values of the carcass fat after 18 months of storage. Organoleptic tests also indicated

corresponding differences in the rate of development of undesirable flavours. The authors recommended that materials containing highly unsaturated fatty acids be avoided in turkey diets.

Kummerow et al. (1950) concluded that the development of rancidity of poultry fat depended primarily on the linolenic acid content of the skin tissue. These authors found heavy concentrations of linolenic acid in the skin fat when linseed oil was included in the diet. Klose et al. (1951) found that 5% linseed oil in the diet of turkeys resulted in a pronounced fishy odour and taste, whether or not the diet contained 10% fish meal; 10% fish meal in the diet, without linseed oil, did not cause either condition. The storage stability of frozen carcasses of birds fed 5% cocoanut oil was much greater than that of those fed linseed oil.

Klose et al. (1952a) reported that the storage stability of frozen turkeys carcasses was not improved by incorporating tocopherol or certain other additives in the diet. Mecchi et al. (1956a) found that there was little difference in fatty acid composition between chickens and turkeys fed the same diet, but that chickens deposited much more tocopherol in the carcass fat than turkeys, whether or not the diet was

supplemented with tocopherol. The stability of chicken fat was much superior to that of turkey fat. Mecchi et al. (1956b) confirmed their previous observations of greater deposition of tocopherol and improved fat stability of chickens as compared to turkeys.

Darrow and Essary (1955) reported that chickens fed 5% tallow or 5 or 10% of either soybean or cottonseed oil for 10 weeks deposited different levels of linolenic acid, but that all carcasses were acceptable to a taste panel after 9 months' storage. Marion and Woodroof (1963b) reported that the development of rancidity in thawed chicken carcasses stored for 8 days at 1.7°C was not influenced by the dietary fat treatments, which consisted of either 6% corn oil or beef tallow, or 5% of each with 1% menhaden oil. Subsequently, however, Marion and Woodroof (1966) found that tissues of chicken broilers fed menhaden oil were more rancid after storage for 12 days at 2°C than tissues of birds fed cocoanut oil, beef tallow or safflower oil. Rancidity was measured by the TBA (thiobarbituric acid) test, which determines the content of malonaldehyde, a product of fatty acid oxidation (Tarladgis and Watts, 1960).

Marion et al. (1967) concluded that the rate of oxidation of chicken muscle lipids, as measured by the TBA value, was related to the levels of 18- carbon fatty acids with 2 or more unsaturated bonds in neutral lipids, and 22- carbon acids with 4 or 5 unsaturated bonds in certain phospholipid fractions. Marion (1969) also found that the oxidation rate of chicken lipids was not influenced by sex, but that TBA values indicated an increase in stability with age.

Clegg et al. (1953) found that fat extracted from chicken liver oxidised more rapidly than fat from leg meat, and breast fat oxidised least rapidly. Marion and Forsythe (1964) found that raw, ground red turkey meat oxidised more rapidly than white meat.

Hartung (1965) reported that bag breakage tended to accelerate the development of rancidity in frozen turkey carcasses, and that fat samples from male turkeys were more rancid than those from females. Hartung and Froning (1967) later confirmed that lipids from male turkeys were less stable than those from females, and found that stability increased with age. Osborn et al. (1969) found that the greater susceptibility to oxidation of lipids from male turkeys was associated with a difference in fatty acid composition between the sexes; fat from males contained more

linoleic and less oleic acid than fat from females. The greater stability of older birds was also associated with a reduction in linoleic acid level. Implantation with estradiol-17-monopalmitate retarded oxidation by increasing the levels of less saturated fatty acids, palmitoleic and oleic, mainly at the expense of linoleic acid.

The reports cited tend to suggest that a greater problem exists in the storage of turkeys than is the case with chickens, not primarily as a result of a difference in tissue fatty acid composition between the species, but possibly because of lower tocopherol deposition by turkeys, as reported by Mecchi et al. (1956a). The problem of instability of turkey fat appears to be aggravated by the ready deposition of unsaturated fatty acids, such as linolenic acid, from feed sources.

3. PART 1. THE EFFECT OF THE LEVEL AND SOURCE OF DIETARY FAT ON THE GROWTH RATE, FEED EFFICIENCY, GRADE AND CARCASS COMPOSITION OF TURKEYS

3.1 Introduction

The incorporation of fat from many animal and vegetable sources in balanced diets has been shown to reduce the feed intake and increase the growth rate and efficiency of feed utilisation of chickens and turkeys (Sections 2.1.2, 2.1.3). The inclusion of fat in the diet has been shown to increase the tissue fat content and carcass fat score of turkeys (Section 2.2.3). The nature of the fat in the diet has long been known to influence the composition of the carcass fat of many species (Section 2.3).

Fats from many different sources have been used in studies reported over the years. Since fats vary widely in chemical and physical properties and the carcass fat is related in composition to the dietary fat, it seems logical to expect the composition of the dietary fat to influence the characteristics of the carcass. However, little research has been reported on the effect of the dietary fat source on the physical characteristics of the carcass (Section 2.4.1).

This section describes an investigation of the effect of the level and source of dietary fat on the performance of growing turkeys and on the composition and characteristics of the carcass. A low level of dietary fat, comparable to that found in many commercial diets, was fed, as well as a higher level that contributed a substantial proportion of the dietary energy supply. Palm and rapeseed oils were selected as examples of a highly saturated fat and one very low in saturated fatty acids.

3.2 Experimental procedure

Day-old male poults (Silver Auburn male x Bronze female) were distributed at random into 27 groups and placed in electrically heated battery brooder compartments. At two weeks of age the birds were moved to unheated batteries in a room where the temperature was thermostatically controlled. The turkeys were housed in floor pens in an unheated pole barn from 46 days of age until termination at 24 weeks. Feed and water were available at all times.

Each experimental treatment was applied to three groups of 15 poults each. The treatments included a basal diet, which contained no fat except that present in the feed ingredients, and diets which contained 2 or 11.4% of either

rapeseed or palm oil. The nine treatments included four in which the dietary fat was changed at 16 weeks from rapeseed to palm oil and *vice versa*; the purpose of doing so was to permit observation of the effect of a change in the dietary fat source on carcass composition. A constant ratio of metabolizable energy to each of the other nutrients was maintained by removing an isocaloric amount of cornstarch as the level of oil was increased (Table 3.1). The protein and energy levels of the diets were adjusted at 27 days of age and at four week intervals thereafter.

Ages at times of weighing or sampling will be referred to in terms of weeks in the interests of simplicity and readability; it will be understood that the operation was carried out one day prior to the stated time, for reasons of labour management. Group weights were obtained at two week intervals to six weeks of age, and individual weights at four-week intervals from eight weeks to slaughter at 24 weeks of age. Feed consumption by pens was recorded at each weighing.

The turkeys were slaughtered in a commercial processing plant. Each carcass was graded visually for finish according

Table 3.1 Composition of experimental diets

Ingredient	Prestarters (0-4 weeks)			Basal diets				
	Basal	2% fat	11.4% fat	Starter (4-8 weeks)	Grower (8-12 weeks)	Grower (12-16 weeks)	Developer (16-20 weeks)	Finisher (20-24 weeks)
	kg.	kg.	kg.	kg.	kg.	kg.	kg.	kg.
Corn starch	22.0	18.0	0	22.0	22.0	22.0	22.0	22.0
Oil (variable)	0	2.0	10.0	0	0	0	0	0
Ground wheat	18.5	18.5	18.5	24.5	33.5	42.0	50.0	60.0
Soybean meal (48% protein)	45.0	45.0	45.0	40.0	32.0	25.0	20.0[1]	10.0
Herring fish meal (73% protein)	5.0	5.0	5.0	4.0	3.0	2.0	0	0
Dehydrated alfalfa	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Distillers' dried solubles	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Dicalcium phosphate	2.5	2.5	2.5	2.5	2.0	1.5	1.5	1.5
Calcium carbonate	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5
Vitamin-mineral premix	2.0[2]	2.0[2]	2.0[2]	2.0[2]	2.0[3]	2.0[3]	1.0[4]	1.0[4]
Total	100.0	98.0	88.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis								
Protein %	29.1	29.8	33.1	26.9	23.6	21.0	17.5	14.6
Kcal. M.E. per kg./ percent protein	94	95	95	103	120	137	167	206

[1] 44% protein, 16-24 weeks.

[2] Contributed per kg. of basal diet: vit. A, 12,000 I.U.; vit D_3, 2,500 I.C.U.; vit. E, 20 I.U.; vit. B_{12}, 0.012 mg.; riboflavin, 8 mg.; calcium-d-pantothenate, 12 mg.; niacin 65 mg.; pyridoxine HCl, 3 mg.; choline chloride, 600 mg.; folic acid, 1 mg.; d-biotin, 0.150 mg.; menadione sodium bisulphite, 4 mg.; ethoxyquin, 125 mg.; bacitracin, 20 mg.; oleandomycin 4 mg.; 3-nitro-4-hydroxyphenylarsonic acid, 50 mg.; amprolium, 0.125 mg.; DL-methionine, 2 g.; salt, 2.5 g.; manganese, 60 mg.; zinc, 70 mg.; iodine, 1 mg.; copper, 4 mg.; iron, 40 mg.; furazolidone, 50 mg.

[3] Contributed per kg. of basal diet: vit. A, 8,000 I.U.; vit D_3, 2,000 I.C.U.; vit E, 10 I.U.; vit. B_{12}, 0.01 mg.; riboflavin, 5 mg.; calcium-d-pantothenate, 8 mg.; niacin, 45 mg.; pyridoxine HCl, 2 mg.; choline chloride, 400 mg.; d-biotin, 0.075 mg.; menadione sodium bisulphite, 2 mg.; ethoxyquin, 125 mg.; oleandomycin, 2 mg.; 3-nitro-4-hydroxyphenylarsonic acid, 50 mg.; amprolium, 125 mg.; DL-methionine, 1.5 g.; L-lysine, 2 g.; furazolidone, 125 mg.; minerals as under (1) above.

[4] Contributed per kg. of basal diet: vit. A, 4,000 I.U.; vit. D_3, 1,500 I.C.U.; vit. E, 5 I.U.; vit. B_{12}, 0.008 mg.; riboflavin, 4 mg.; calcium-d-pantothenate, 6 mg.; niacin 20 mg.; pyridoxine HCl, 1 mg.; d-biotin, 0.05 mg.; choline chloride, 200 mg.; menadione sodium bisulphite, 2 mg.; ethoxyquin, 125 mg.; 3-nitro-4-hydroxyphenylarsonic acid, 50 mg.; DL-methionine, 1.5 g.; L-lysine, 1 g.; furazolidone, 125 mg.; minerals as under (1) above.

to government regulations[2] and scored on a five-point scale for breast and back finish. Grading was carried out on the eviscerating line and again after chilling overnight in a mixture of ice and water, by an inspector of the Poultry Division, Production and Marketing Branch, Canada Department of Agriculture.

One frozen, eviscerated carcass selected at random from each pen was retained for meat yield study. A 2.54 x 10.16 cm. sample of breast skin was removed from an area extending longitudinally from the ventral midline, parallel to the caudal edge of the rib cage (Figure 3.1). A 5.08 cm. square sample of back skin was removed from an area extending laterally from the dorsal midline and caudal to the scapula (Figure 3.2). The wings and legs were removed. The right wing was separated into upper wing and flat wing segments, and the upper wing was skinned and boned. The right leg was separated into thigh and drumstick. The drumstick was skinned but not boned (Figures 3.3, 3.4). The balance of the carcass, with the exception of the tail, which was removed separately, was skinned and the breast and back meat

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[2] SOR/59-368, Livestock and Livestock Products Act, Dressed and Eviscerated Poultry Regulations, P.C. 1959-1211. Queen's Printer, Ottawa, Canada.

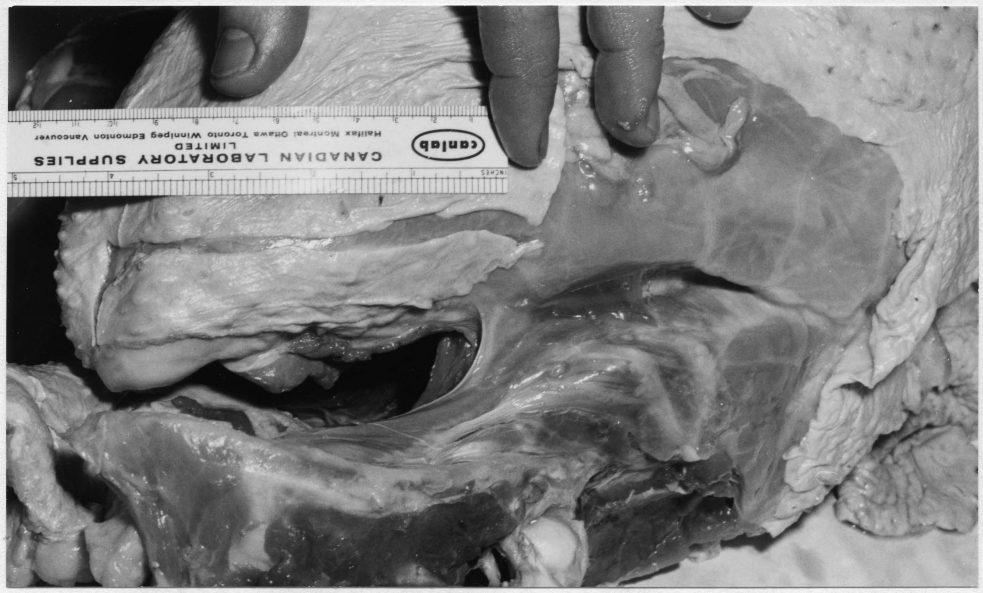

Figure 3.1 Removal of breast skin sample

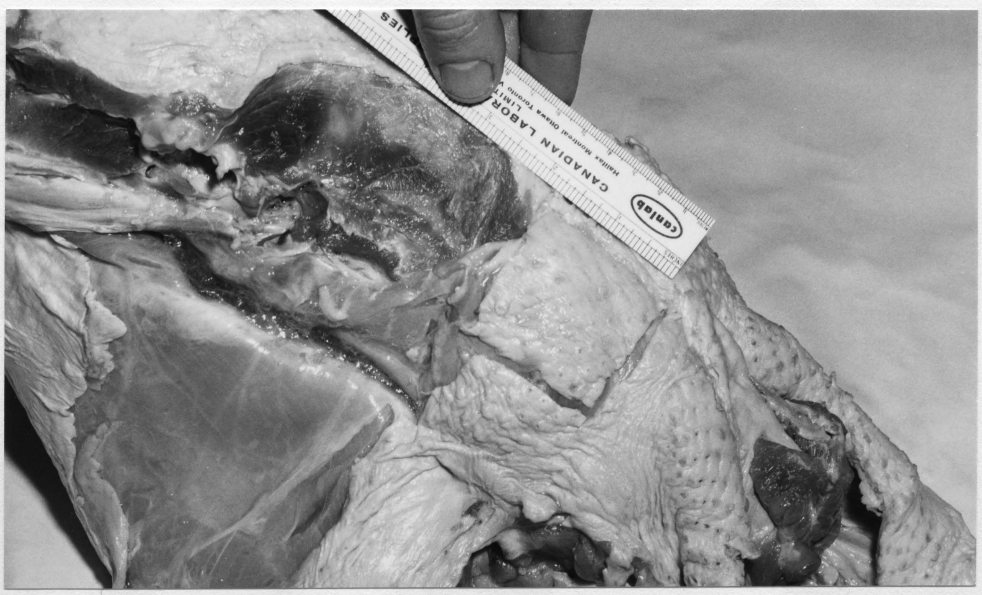

Figure 3.2 Removal of back skin sample

Figure 3.3 Leg and wing, separated into their major components

Figure 3.4 Leg and wing components as dissected for meat yield study

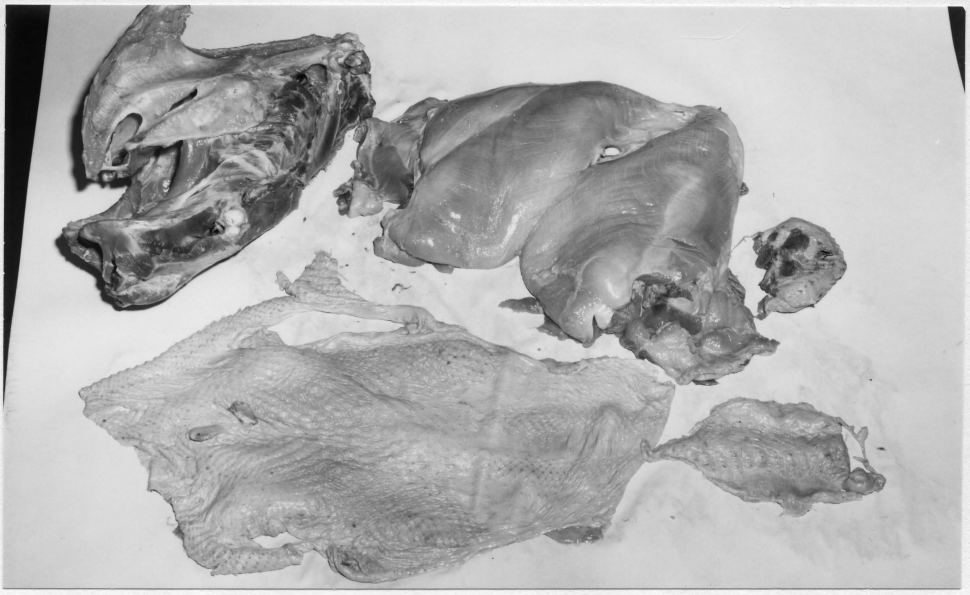

Figure 3.5 Breast and back skin and meat, and waste carcass components

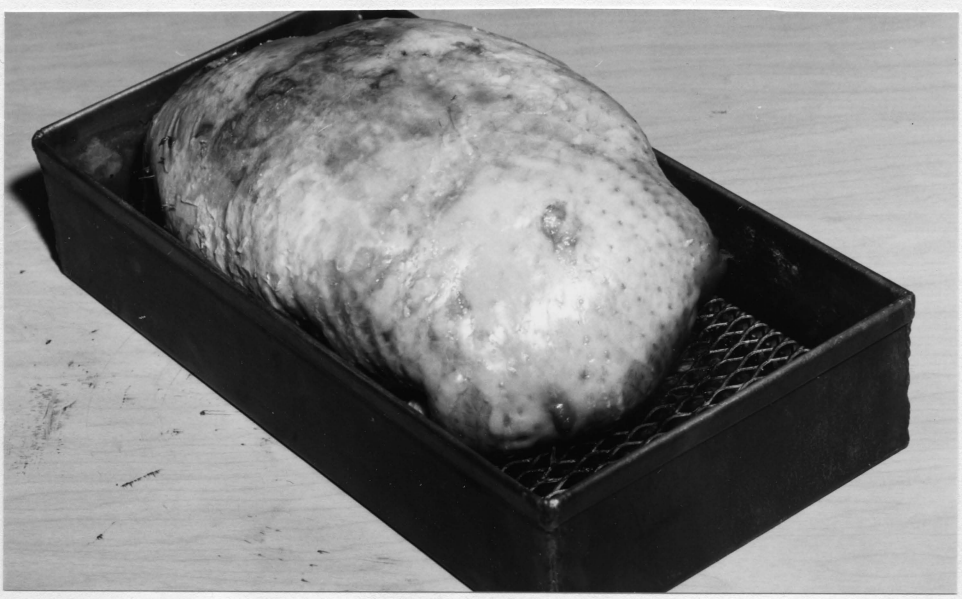

Figure 3.6 Turkey roll in pan, ready to cook

Meat Yield and Cooking Losses

Experiment No. 6804

Wing Band No. 863

Treatment No. 1

	Yield	Skin	Roll	% of Carcass
Carcass wt. (eviscerated)	23 - 1 (10470)			
Wing				
Baby Drumstick:				
skin	44	X2= 88		
meat	173			
bone	83			
Flat Wing	313			
Total Wing	613			
	X2=1226			11.7
Leg				
Thigh:				
skin	42	X2= 84	= 84	
meat	780		X2= 1560	14.9
bone	112			
Drumstick:				
skin	41	X2= 82		
meat and bone	700			
Total Leg	1675			
	X2=3350			32.0
back skin	51	= 51		
breast skin	685	= 685	= 685	
breast meat	3285		= 3285	31.4
breast and back bone	1560			
tail	136			1.29
Skin Samples:				
breast (1" x 4")	4.0	= 4	= 4	
back (2" x 2")	7.9	= 8	= 8	
Total		1002	5626	
% of Carcass		9.58	53.8	

Turkey Roll

1. Roll, pan and rack	7125	
2. Cooled roll, pan and rack	5755	
3. Pan, rack and drips	2312	
4. Pan and rack	1905	
1 -4 roll (initial wt.)	5220	
2 -3 roll (cooked)		
1 -2 volatile loss	1370	26.2 %
3 -4 drip loss	407	7.80%
		34.0 %

Figure 3.7 Form used to record and calculate meat yield

were removed in one piece (Figure 3.5). A "theoretical turkey roll" was calculated to include the meat and skin of the thigh, multiplied by two, and the breast and back meat and skin. An actual turkey roll was made by enclosing the breast and thigh meat in a casing of the skin (Figure 3.6). The rolls were roasted at 163°C to an internal temperature of 88°C and the cooking losses were recorded (Figure 3.7).

Samples of breast and thigh meat were taken from each carcass. The meat samples consisted of cross sections of the thigh and breast meat, taken after removal of the skin and subcutaneous fat depots. No attempt was made to separate intermuscular fat from muscle tissue. The samples were therefore representative of turkey meat as food, rather than isolated muscle tissue.

The dry matter content of the meat and skin samples was determined by freeze-drying to constant weight. Crude protein (N x 6.25) was determined on the freeze-dried meat samples by the Kjeldahl method. The ether extract content of the freeze-dried meat samples was determined by Soxhlet extraction using petroleum ether.[3] The ether extract content

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[3] Skellysolve F., Skelly Oil Company, P.O. Box 435, Kansas City 41, Missouri, U.S.A.

of the skin samples was determined by measuring the weight loss from freeze-dried, individually tagged samples following extraction of the pooled samples for 10 days in boiling petroleum ether. The solvent was changed daily for the first four days and every second day thereafter until only trace amounts of fat were found to be removed.

Body weight gain, feed conversion, carcass grade, composition and meat yield data were subjected to analysis of variance, and treatment effects were compared by analysis of individual degrees of freedom, using standard methods of computation. Where the source of fat added to the diet was changed at 16 weeks of age, the selection of the specific hypotheses to be tested by isolation of individual degrees of freedom was determined by the prior assumptions that growth effects would tend to reflect the influence of the dietary fat during the starting period, but that the final composition of the carcass would be more strongly influenced by the fat consumed during the finishing period. The purpose of this procedure was to satisfy the criterion that the hypothesis of the individual degree of freedom should be formulated without knowledge of the treatment means, to prevent disturbance of the significance level (Li, 1964). The t - test for paired

observations, as described by the same author, was used to compare the means of repeat observations on the same samples, such as the grades of warm versus chilled carcasses or breast versus back fat scores (Li, 1964).

3.3 Results

The level of dietary fat did not influence body weight when the effects of the fat sources were combined (Tables 3.2, 3.3). The source of fat did not influence body weight when added at a level of 2% of the diet. However, rapeseed oil at 11.4% of the diet depressed body weight when compared to 2% fat, whereas 11.4% palm oil increased body weight. A change of dietary fat source from rapeseed to palm oil at 16 weeks did not influence body weight at 24 weeks.

The feed conversion (feed consumption/weight gain) of the birds fed the basal diet was higher than that of those fed diets containing added fat during all periods except 16 to 24 weeks; 11.4% fat gave lower feed conversion than 2% fat during all periods of the experiment. Feed conversion was related linearly to the level of fat incorporated in the diet (Figure 3.8). The sources of added fat had little or no effect on feed conversion at either 2 or 11.4% of the diet. The lower feed conversion of the birds fed 2% rapeseed oil as

Table 3.2 Effect of level and source of dietary fat on body weight and feed conversion

Dietary treatment	Av. weight (kg.)			Feed conversion (feed/gain)			
	8 wks.	16 wks.	24 wks.	0-8 wks.	8-16 wks.	16-24 wks.	0-24 wks.
Fat level							
0	2.45	7.57	12.59	2.09	2.77	4.62	3.38
2%	2.46	7.60	12.71	1.94	2.66	4.63	3.31
11.4%	2.43	7.52	12.58	1.60	2.36	4.16	2.96
Fat source (2%)							
RSO	2.44	7.62	12.72[1]	1.81	2.69	4.70[1]	3.32[1]
PO	2.48	7.58	12.70[2]	2.06	2.63	4.54[2]	3.29[2]
Fat source (11.4%)							
RSO	2.28	7.26	12.20[1]	1.54	2.32	4.18[1]	2.95[1]
PO	2.58	7.78	12.96[2]	1.67	2.41	4.14[2]	2.94[2]

[1] Includes those changed from RSO to PO at 16 weeks

[2] Includes those changed from PO to RSO at 16 weeks

Table 3.3 Analysis of variance, effect of level and source of dietary fat on average weight and feed conversion of turkeys

Source of variation	Degrees of Freedom	Mean square x 10,000						
		Average weight			Feed conversion (f./g.)			
		8 wks.	16 wks.	24 wks.	0-8 wks.	8-16 wks.	16-24 wks.	0-24 wks.
Fat level								
0 vs. others	1	1	1	71	2,766**	1,757**	1,385	1,689**
2% vs. 11.4%	1	51	459	1,067	6,633**	5,281**	12,558**	7,993**
Fat source (2% level)								
RSO vs. PO[1]	1	37	65	3[1]	1,800*	96	816[1]	37[1]
RSO vs. RSO-PO[2]	1			66			17	38
PO vs. PO-RSO[2]	1			66			182	96
Fat source (11.4% level)								
RSO vs. PO[1]	1	2,581**	7,956**	17,633**[1]	481	208	56[1]	2[1]
RSO vs. RSO-PO[2]	1			20			1,837	353
PO vs. PO-RSO[2]				504			1,908	661*
Error	22[3] or 18[4]	36[3]	516[3]	2,088[4]	231[3]	192[3]	1,147[4]	119[4]

[1] RSO to 16 or 24 weeks vs. PO to 16 or 24 weeks. See footnotes, Table 3.2
[2] Dietary fat changed at 16 weeks
[3] To 16 weeks
[4] 16 to 24 weeks

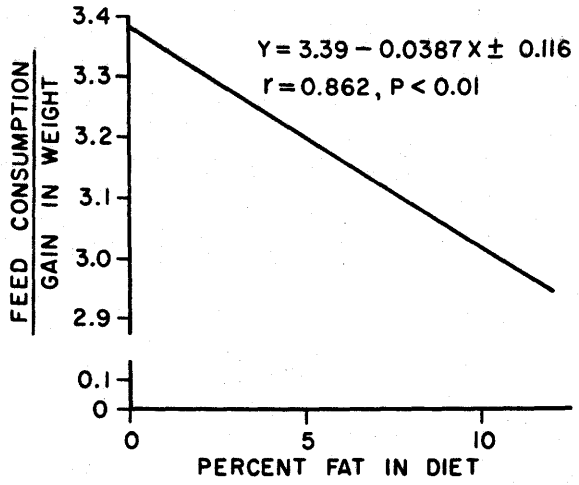

Figure 3.8 Regression of feed conversion on dietary fat level

compared to 2% palm oil during the first eight weeks was not maintained during the later periods of the experiment. Following a change of dietary fat source at the 11.4% level from rapeseed to palm oil, an increase in feed conversion from 4.01 to 4.36 occurred, and a decrease of equal magnitude, from 4.32 to 3.97, occurred following a change from 11.4% palm to rapeseed oil. These effects were not significant during the 16 to 20 week period, but the overall feed conversion (0 to 24 weeks) of the birds whose dietary fat was changed from 11.4% palm to rapeseed oil was significantly lower than the overall feed conversion of those fed 11.4% palm oil for the entire period.

Neither the levels nor sources of dietary fat influenced the percentage of Grade A carcasses significantly when graded warm (Tables 3.4, 3.5). After chilling, 2 or 11.4% dietary fat resulted in a higher percentage of Grade A carcasses than the basal diet; the fat source did not influence the grades of the chilled carcasses. The difference in the overall mean grade of the warm carcasses in comparison to the chilled carcasses (89.0% versus 96.1% Grade A) was not statistically significant.

The chilled carcass fat scores revealed a significant

Table 3.4 Effect of level and source of dietary fat on carcass fat grade, fat score, weight of skin samples and ether extract in skin samples

	Carcass fat grade (% Grade A)		Fat score[1] (chilled)		Skin samples			
					Weight (g.)		Ether extract (% of wet weight)	
	Warm	Chilled	Breast	Back	Breast	Back	Breast	Back
Fat level								
0	75.6	86.0	3.43	2.60	3.73	6.73	12.4	32.4
2%	91.1	98.5	3.98	3.42	4.36	8.33	26.4	49.2
11.4%	90.2	97.5	3.87	3.72	5.86	9.93	28.6	55.3
Fat source (2% level)								
RSO[2]	85.5	100.0	3.76	3.25	4.20	8.27	28.1	49.0
PO[3]	96.7	95.1	4.18	3.58	4.52	8.38	24.7	49.3
Fat source (11.4% level)								
RSO[2]	82.7	100.0	3.66	3.51	5.48	9.97	28.9	56.5
PO[3]	97.7	95.8	4.07	3.92	6.26	9.88	28.3	54.2
Overall mean	89.0	96.1	3.87	3.46	4.96	8.86	25.8	50.1
± standard error	±3.8	±1.8	±0.05	±0.09	±0.16	±0.34	±1.6	±1.4

[1] Carcasses scored for finish from 1 to 5.

[2] Includes those changed from PO to RSO at 16 weeks.

[3] Includes those changed from RSO to PO at 16 weeks.

Table 3.5 Analysis of variance, effect of level and source of dietary fat on carcass fat grade, fat score and weight and ether extract content of skin samples

Source of variation	Degrees of Freedom	Mean square x 100[1]							
		Carcass fat grade		Fat score (chilled)		Skin samples			
						Weight		Ether extract	
		Warm	Chilled	Breast	Back	Breast	Back	Breast	Back
Fat level									
0 vs. others	1	59,600	55,424*[2]	63**[3]	249**	510*	1,525*	60,468**	105,161*
2% vs. 11.4%	1	5,000	67	7	54	1,380**	1,536*	3,037	22,448
Fat source (2% level)									
RSO vs. PO[4]	1	37,400	7,008	52*	33	30	4	3,468	16
RSO vs. PO-RSO[5]	1	12,200	0	33*	28	1	770	1,667	2,773
PO vs. RSO-PO[5]	1	6,670	14,002	2	2	28	0	67	662
Fat source (11.4% level)									
RSO vs. PO[4]	1	67,500	5,208	48*	48	184	2	96	1,541
RSO vs. PO-RSO[5]	1	24,070	0	17	8	4	24	11,793	434
PO vs. RSO-PO[5]	1	3,270	10,417	1	28	3	88	14,800	20
Error	18	38,600	8,453	7	20	69	309	6,998	5,398
t[6]	26	1.80		4.86**		13.92**		18.73**	

[1] Rounded to nearest whole number.
[2] Significant (P<0.05).
[3] Significant (P<0.01).
[4] RSO (0-24 or 16-24 weeks) vs. PO (0-24 or 16-24 weeks).
[5] Dietary fat changed at 16 weeks.
[6] Comparison of means of paired observations.

improvement in finish of both the breasts and backs of the birds fed diets containing added fat when compared with those fed the basal diet; there was no difference in fat score between the carcasses of birds fed 2 and 11.4% dietary fat. Diets containing palm oil at both 2 and 11.4% resulted in higher scores for breast fat than diets containing rapeseed oil; the differences in back fat score were not significant. The breast fat score (4.00) of the birds fed 2% rapeseed oil for the duration of the experiment was significantly higher than the score (3.53) of those whose dietary fat was changed from palm to rapeseed oil at 16 weeks; however, as no such relationship occurred in the other treatments in which the fat source was changed at 16 weeks, this difference probably represents experimental error. The mean breast fat score (3.87) was significantly higher than the mean back fat score (3.46).

The standard breast and back skin samples were significantly heavier when the diet contained added fat in comparison to the basal diet; 11.4% dietary fat in comparision to 2% dietary fat increased the weights of both breast and back skin samples. The fat source did not affect the skin sample weight.

The fat (ether extract) content of both the breast and

back skin samples was increased by the incorporation of fat in the diet but an increase in dietary fat level from 2 to 11.4% did not increase the skin fat content significantly.

The incorporation of fat in the diet increased the carcass skin yield (Tables 3.6, 3.7); 11.4% fat did not increase the total skin yield significantly in comparison to 2% fat, in contrast with its effect on the weight of skin samples from selected areas.

The carcass skin yield was correlated with the carcass fat scores and with the weight and ether extract content of the skin samples (Figure 3.9). The characteristics associated with the back were more highly correlated with percent skin than those associated with the breast, and the skin sample ether extract was more highly correlated with percent skin than either the fat score or skin sample weight.

The dietary fat level influenced the yield of several carcass components. The percentage of drumstick and of thigh meat and breast meat was lower when the diet contained added fat in comparison to the basal diet; 11.4% dietary fat reduced the percentage of breast meat as compared to 2% dietary fat. The yield of edible tissue in the form of a turkey roll was not affected by the dietary fat level; the increase in weight of

Table 3.6 Effect of level and source of dietary fat on yield[1] of eviscerated carcass components and cooking losses from turkey rolls

Dietary treatment	Total skin %	Upper wing %	Flat wing %	Thigh %	Drum-stick %	Thigh meat %	Breast meat %	Turkey roll (theo-retical) %	Cooking losses		
									Volatile %	Drip %	Total %
Fat level											
0	8.0	6.0	6.0	18.4	14.3	15.5	31.0	52.5	30.2	4.6	34.8
2%	11.4	5.6	5.8	17.7	13.5	14.4	29.3	52.5	28.1	6.2	34.2
11.4%	11.9	5.8	5.9	17.8	13.3	14.3	28.1	51.6	27.9	6.3	34.4
Fat source (2% level)											
RSO[2]	10.9	5.7	5.9	17.6	13.4	14.3	29.2	51.8	28.3	6.9	35.0
PO[3]	11.8	5.4	5.6	17.7	13.6	14.5	29.3	53.3	27.9	5.5	33.4
Fat source (11.4% level)											
RSO[2]	11.3	5.8	6.1	17.7	13.4	14.1	27.9	50.7	28.2	6.6	34.8
PO[3]	12.4	5.7	5.6	17.9	13.3	14.4	28.3	52.5	27.5	6.1	33.9
Overall mean ± standard error	11.2 ±0.3	5.7 ±0.1	5.8 ±0.1	17.8 ±0.1	13.5 ±0.1	14.5 ±0.1	28.9 ±0.1	52.1 ±0.2	28.2 ±0.4	6.1 ±0.3	34.3 ±0.2

[1] Expressed as percent of eviscerated carcass without neck and giblets.
[2] Includes those changed from PO to RSO at 16 weeks.
[3] Includes those changed from RSO to PO at 16 weeks.

Table 3.7 Analysis of variance, effect of level and source of dietary fat on yield of eviscerated carcass components and cooking losses from turkey rolls

Source of variation	Degrees of freedom	Mean square x 1,000[1]										
		Total skin	Upper wing	Flat wing	Thigh	Drum-stick	Thigh meat	Breast meat	Turkey roll	Cooking losses		
										Volatile	Drip	Total
Fat level												
0 vs. others	1	34,800**	345	134	1,291	2,343**	3,656**	13,850**	521	8,852	7,628	882
2% vs. 11.4%	1	1,653	250	113	150	94	120	8,520**	5,042	260	59	202
Fat source (2% level)												
RSO vs. PO[4]	1	2,613	203	200	21	101	120	30	6,453	521	5,880	7,363**
RSO vs. PO-RSO[5]	1	1,213	10	3	482	1,707	327	1,927	3,682	960	1,591	602
PO vs. RSO-PO[5]	1	15	432	25	240	482	240	427	42	1,602	34	1,215
Fat source (11.4% level)												
RSO vs. PO[4]	1	3,521	17	682**	163	13	301	441	10,453*	1,763	706	2,613
RSO vs. PO-RSO[5]	1	337	19	86	667	1,500	427	3,227	107	5,607	273	3,682
PO vs. RSO-PO[5]	1	2,282	286	1,058**	7	540	482	42	5,227	807	4,284	135
Error	18	2,770	254	65	299	248	343	948	1,545	4,522	2,492	1,254

[1] Rounded to nearest whole number
[2] Significant ($P < 0.01$)
[3] Significant ($P < 0.05$)
[4] RSO (0-24 or 16-24 weeks) vs. PO (0-24 or 16-24 weeks)
[5] Dietary fat changed at 16 weeks

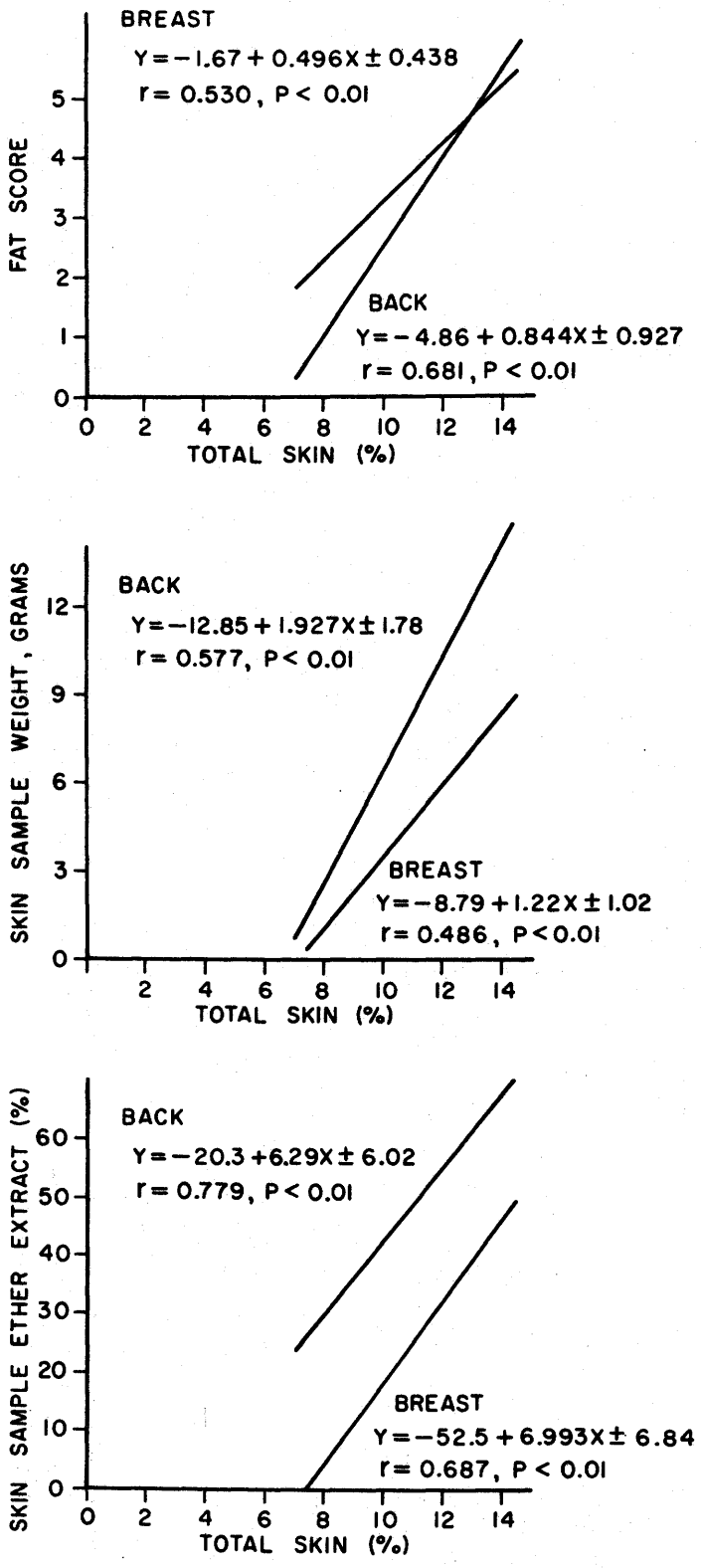

Figure 3.9 Regression of carcass fat score and skin sample characteristics on percent carcass skin

skin tended to compensate for the decrease in meat yield with increasing dietary fat level.

The source of fat in the diet may have influenced the yield of carcass components. Differences in the yield of skin, thigh meat and breast meat associated with a high level of palm as compared to rapeseed oil, although not significant in themselves, resulted in a significant cumulative increase in the yield of turkey roll.

The degree of variability encountered among the cooking loss measurements was such that the treatment effects, with one exception, were not statistically significant. However, both volatile and drip loss were significantly correlated with percent skin (Figure 3.10). Volatile losses were reduced and drip losses increased as percent skin increased; the volatile and drip losses were highly correlated ($r = -0.796$).

Rapeseed oil was associated with an increase in total cooking losses over palm oil when fed at 2% of the diet; the difference between fat sources was not significant when the fats were included at 11.4% of the diet.

The composition of both breast and thigh meat was influenced by the dietary fat level (Tables 3.8, 3.9). The fat (ether extract) content of the meat was increased by the

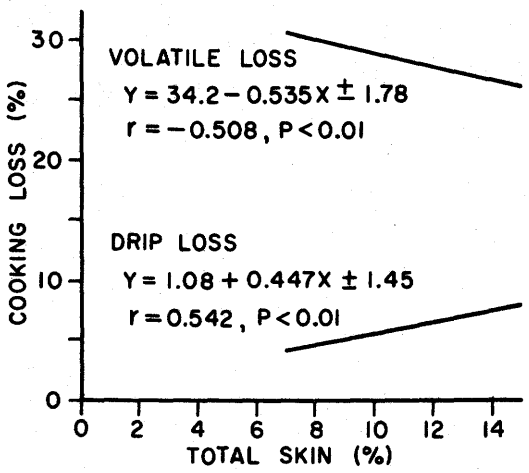

Figure 3.10 Regression of volatile and drip cooking losses on percent carcass skin

Table 3.8 Effect of level and source of dietary fat on composition of turkey breast and thigh meat

Dietary treatment	Breast Meat			Thigh Meat		
	Ether extract[1]	Crude protein[1] (Nx6.25)	Moisture %	Ether extract[1]	Crude protein[1] (Nx6.25)	Moisture %
Fat level						
0	1.7	94.0	74.3	6.2	85.9	76.6
2%	3.8	93.1	73.5	11.2	81.5	75.0
11.4%	4.6	91.5	73.4	12.6	79.6	75.0
Fat source (2% level)						
RSO[2]	4.1	93.0	72.9	11.8	81.2	74.4
PO[3]	3.3	93.2	74.2	10.7	81.9	75.5
Fat source (11.4% level)						
RSO[2]	5.1	90.6	73.5	13.9	78.8	74.8
PO[3]	4.1	92.4	73.4	11.2	80.4	75.2
Overall mean ± standard error	3.9 ±0.2	92.5 ±0.2	73.5 ±0.2	11.2 ±0.4	81.1 ±0.4	75.1 ±0.1

[1] Percent of dry weight

[2] Includes fat changed from PO to RSO at 16 weeks

[3] Includes fat changed from RSO to PO at 16 weeks

Table 3.9 Analysis of variance, effect of level and source of dietary fat, on composition of turkey breast and thigh meat

Source of variation	Degrees of freedom	Mean square x 1000					
		Breast meat			Thigh meat		
		Ether extract	Crude protein	Moisture	Ether extract	Crude protein	Moisture
Fat level							
0 vs. others	1	16,547**[1]	7,565	1,967	875**	75,620**	7,594**
2% vs. 11.4%	1	3,794*[2]	14,553*	12	100	22,450*	4
Fat source (2% level)							
RSO vs. PO[3]	1	1,495	157	4,445*	43	1,400	3,410
RSO vs. PO-RSO[4]	1	941	6,000	2,040	10	427	330
PO vs. RSO-PO[4]	1	1,034	2,640	225	16	4,335	240
Fat source (11.4% level)							
RSO vs. PO[3]	1	3,111	9,363	13	211*	7,520	521
RSO vs. PO-RSO[4]	1	443	7	375	147	2,280	375
PO vs. RSO-PO[4]	1	2,095	2,670	2	28	2,410	240
Error	17[5]	792	2,730	586			
	18[6]				34	4,193	423

1 Significant (P<0.01)
2 Significant (P<0.05)
3 RSO (0-24 or 16-24 weeks) vs. PO (0-24 or 16-24 weeks)
4 Dietary fat changed at 16 weeks
5 Breast meat only
6 Thigh meat only

incorporation of fat in the diet; the addition of 2% fat to the diet resulted in a greater increase in the fat content of both breast and thigh meat than an increase from 2 to 11.4% dietary fat. The increase in fat content of the meat was at the expense of protein and, to a lesser extent, moisture.

3.4 Discussion

The growth depressing effect of a high level of dietary rapeseed oil in this experiment was similar to that previously reported (Joshi and Sell, 1964; Salmon, 1969a). The harmful effects of dietary rapeseed oil have been shown to be due to its erucic acid content (Abdellatif and Vles, 1970) although some studies have shown the growth-depressing effect of rapeseed oil to be overcome by increasing the saturated fatty acid content of the diet (Beare et al., 1963; Salmon, 1969a). The increased growth rate observed when a high level of palm oil was fed was similar to that reported by many workers for a variety of fats.

The absence of a significant difference in final weight between birds fed either fat for the entire 24-week period as compared with those fed a different fat from 16 to 24 weeks indicates the validity of the prior assumption that the effects of fat on growth rate would reflect the influence of the dietary fat during the starting period rather than that fed from

16 to 24 weeks.

The linear relationship of feed conversion to the level of dietary fat indicates that the addition of a low level of fat to the diet did not improve feed conversion more than expected on the basis of the energy contributed by the fat. Such an "extra-caloric" improvement in the utilisation of diets containing certain fats has been reported (Vermeersch and Vanschoubroek, 1968). However, the addition of 2% fat to the diet resulted in a greater increase in carcass fat score, skin weight and fat content, and in the fat content of thigh and breast meat samples, than did a further increase to 11.4% dietary fat. The birds appeared to deposit fat in the tissues more readily when a low level of fat was added to the diet than when the sole source of preformed fat was that naturally present in the feed ingredients. The incorporation of 11.4% fat in the diet resulted in little increase in carcass fat deposition beyond that found when the diet contained 2% added fat.

The carcass fat scores provided a more sensitive indication of differences in degree of finish associated with the dietary treatments than did the percentage of Grade A carcasses. However, since the two measurements of carcass finish were derived

from the same series of observations, it seems likely that treatments which yielded a significant improvement in carcass score in comparison to the basal treatment in this experiment would result in an improvement in the percentage of Grade A carcasses if the numbers of birds were comparable to those involved in a commercial turkey producing operation.

The higher correlation with total carcass skin yield of fat score and skin sample characteristics associated with the back in contrast to the breast indicates that the back skin characteristics gave a more reliable assessment of overall finish than those associated with the breast skin. This observation differs from that of Moran et al. (1969), who obtained a higher correlation of back skin fat to breast finish than to back finish. The correlation coefficient of back fat to back score obtained in this experiment ($r = 0.763$) was similar to that reported by the above authors, but the correlation coefficient of back fat to breast score ($r = 0.425$) was considerably lower in this experiment.

The relationships between the cooking losses and the percentage of skin and between volatile and drip cooking losses, suggest that an increase in skin thickness and fat content may be associated with decreased moisture loss during cooking.

Further study, including sensory testing, will be necessary to clarify the effect of skin thickness and the fat content of skin and meat on the moisture content and flavour of cooked turkey.

On the basis of the results of this study, it appears desirable to include a minimum of 2% fat in practical turkey diets to ensure satisfactory fat deposition and carcass grades. The addition of higher levels of fat may be justified by other economic considerations, including the relative cost of fat in comparison with other energy sources, and the value of an increase in rate of gain which may permit earlier marketing at the final weight desired. The reduction in meat yield observed in this experiment, if confirmed in further studies, may be an undesirable effect of the addition of fat to the diet.

The higher breast fat scores and increased yield of turkey roll of birds fed palm in comparison to rapeseed oil indicate that the source of fat influenced the composition of the carcass. The use of a saturated fat in the diet rather than one high in unsaturated fatty acids is likely to improve carcass grades, resulting in greater returns to the producer; however, current medical opinion tends to favour unsaturated

fats as more desirable in human nutrition.

3.5 Summary

Diets of equal calorie:protein ratio containing 0, 2 and 11.4% palm oil or rapeseed oil were fed to male turkeys from day-old to 24 weeks of age. Body growth was depressed by 11.4% rapeseed oil but stimulated by 11.4% palm oil. Feed conversion was inversely proportional to the level of added fat.

Increasing the dietary fat level improved carcass fat scores, increased the yield of skin, the fat content of breast and thigh meat and drip losses in cooking, and decreased the yield of breast meat, thigh meat and drumstick and volatile cooking losses. The initial addition of 2% fat to the diet had more effect on the carcass characteristics than a further increase from 2 to 11.4% fat.

Volatile cooking losses decreased and drip losses increased with increasing carcass skin percentage.

The source of dietary fat influenced the carcass fat score, carcass composition and cooking losses.

Back fat score and back skin fat were more reliable indicators of overall finish as measured by carcass skin percentage than breast score and breast skin fat.

4. PART 2. THE EFFECT OF THE LEVEL AND SOURCE AND OF A CHANGE IN SOURCE OF DIETARY FAT ON THE FATTY ACID COMPOSITION OF THE DEPOT FAT AND THE THIGH AND BREAST MEAT OF TURKEYS AS RELATED TO AGE

4.1 Introduction

The effect of dietary fat on the composition of tissue lipids has been demonstrated by many authors (Section 2.3). The level and source of fat in the diet of growing turkeys were found to influence the characteristics of the carcass (Section 3). Turkeys fed diets containing added fat deposited more fat in skin and muscle tissues than those whose diet included only the fat contributed by the basal diet. The incorporation of palm oil in the diet increased carcass fat scores and influenced carcass composition and cooking losses when compared with similar levels of rapeseed oil. Further study has been conducted to relate the effects observed to the composition of the carcass fat. This section reports the effect of the levels and sources of dietary fat previously described on the fatty acid composition of the abdominal depot fat and thigh and breast meat of turkeys as related to age. The rate of change of tissue fatty acids following a change in the dietary fat source is also reported.

4.2 Experimental procedure

Depot fat and meat samples were obtained from male turkeys whose management and diets have already been described (Section 3.2). The experimental treatments consisted of diets which contained no added fat, 2 or 11.4% of either rapeseed of palm oil, or in which the fat source was changed at 16 weeks from rapeseed to palm oil or vice versa. The fatty acid composition and ether extract content of the experimental diets was determined (Table 4.1).

One bird was selected at random from each of three pens receiving each dietary treatment for slaughter at two weeks, at four weeks and at four-week intervals to 24 weeks of age. A sample of abdominal depot fat was taken from each bird, and thigh and breast meat samples were taken from those slaughtered at 8, 16, 20, and 24 weeks of age as described in Section 3.2.

The meat samples were freeze-dried to constant weight. Fatty acids were determined on the lipids of the individual depot fat or meat samples by gas liquid chromatography. The lipids were extracted and saponified and methyl esters prepared according to the procedures of Craig and Beare (1968).

Table 4.1 Fatty acids and ether extract content of experimental diets[1]

Fatty Acid	Dietary fat treatment				
	No Added Fat	Rapeseed oil		Palm oil	
		2%	11.4%	2%	11.4%
		%			
12:0[2]	0.3	0.2	0.0	0.3	0.1
14:0	0.8	0.4	0.1	1.1	1.0
16:0	16.7	8.7	5.1	31.6	38.6
16:1	1.2	0.5	0.2	0.5	0.4
18:0	2.8	2.0	1.6	4.0	4.8
18:1	16.3	23.6	28.5	28.8	36.7
18:2	50.3	32.3	22.6	28.3	17.0
18:3	6.6	8.1	8.6	3.0	1.2
20:1	2.3	7.7	10.6	1.0	0.1
22:1[3]	2.7	16.3	22.6	1.5	0.1
Ether extract (%)	1.5	3.7	13.3	3.8	13.9

[1] Average of 6 diets, changed at 4-week intervals, within each fat treatment.

[2] Carbon chain length: number of double bonds. Fatty acid content expressed as percent of total fatty acid methyl esters.

[3] Peak includes undifferentiated fatty acids from herring fish meal included in diets to 12 weeks.

A stainless steel chromatograph column, 2.8 mm. inside diameter x 1.93 m. long, packed with 1:6 butanediol succinate on Chromosorb W, was used in an F & M model 402 gas chromatograph with a flame ionization detector; the column temperature was 205°C and helium flow 60 ml. per minute. The fatty acid peaks were identified by comparison with a standard of known composition,[4] and the area under each chromatograph peak was determined by triangulation. The peak areas were assumed to be proportional to the percentage by weight of the methyl esters; this procedure is commonly followed, and was found to be valid by Neudoerffer and Lea (1966).

Tentative identification of chromatograph peaks corresponding to palmitaldehyde (16:A) and stearaldehyde (18:A) from plasmalogens (Farguhar, 1962) was made by comparing their retention times with those of known standards[5] subjected to the same methylation procedure.

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[4] Obtained from Dr. B. M. Craig, Prairie Regional Laboratory, National Research Council of Canada, Saskatoon, Saskatchewan.

[5] Palmitaldehyde sodium bisulphite and stearic aldehyde sodium bisulphite, K & K Laboratories, Inc., 121 Express Street, Plainview, New York, U.S.A.

Further confirmation was obtained by saponification of the fatty acid methyl esters obtained from a breast meat sample, followed by recovery and chromatography of the resistant dimethyl acetals, as described by O'Brien, Fillerup and Mead (1964), and Neudoerffer and Lea (1967). No attempt was made to identify or measure fatty acids of longer rentention time than erucic acid (22:1), although long chain polyunsaturated fatty acids from fish oil in the diet were shown by Neudoerffer and Lea (1967) to be deposited in turkey muscle lipids. Furthermore, a fatty acid of similar retention time to erucic acid, which was contributed in small quantities by fish meal in the diet during the first 12 weeks of the experiment, was not separately identified and is reported as erucic acid. The fatty acid in question may be eicosapentaenoic (20:5), which Neudoerffer and Lea (1966) reported to be similar in retention time to erucic acid.

The precision of the fatty acid determinations was evaluated by taking six samples of abdominal depot fat from one 24-week old turkey, and including one with each day's series of samples on six successive days, without the knowledge of the technician. With the exception of palmitic acid (16:0), the standard deviation of each fatty acid from the mean was less than 1% of the total fatty acids (Table 4.2). As

the variation in fatty acid levels between replicate samples from a single bird was small in comparison with the variation observed between samples from different birds, it was concluded that the precision of a single determination on each sample would be sufficient to reveal differences due to the experimental treatments.

Table 4.2 Precision of fatty acid determinations on six abdominal fat samples from bird #764

Fatty acid	Mean ± standard deviation
	%
14:0	0.9 ± 0.2
16:0	23.3 ± 1.5
16:1	5.6 ± 0.9
18:0	8.3 ± 0.8
18:1	33.8 ± 0.6
18:2	16.8 ± 0.3
18:3	1.9 ± 0.2
20:1	4.6 ± 0.4
22:1	4.6 ± 0.5

The significance of the effects of the treatments on fatty acid composition was evaluated by analysis of variance.[6] The effects of fat levels and sources were compared by analysis of individual degrees of freedom, and the means for the effects of age were compared by Duncan's New Multiple Range Test (Li, 1964). Exponential curves were derived to express the changes in fatty acid levels which followed a change in the dietary fat source.[7]

4.3 Results

The fatty acid composition of abdominal depot fat and the lipid of thigh and breast meat was influenced by the level and source of dietary fat and by age (Tables 4.3, 4.4, 4.5). Increasing the level of dietary fat resulted in decreasing proportions of saturated fatty acids and palmitoleic acid (16:1) in all three tissues studied, while oleic (18:1), linolenic (18:3), eicosenoic (20:1) and erucic acids were

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[6] Gates, C. E. 1969. General Linear HYPothesis (GLHYP), unpublished computer programme. University of Minnesota, Minneapolis, Minnesota, U.S.A.

[7] Kozub, G. E. and W. K. Chelak, 1969. Exponential curve. Computer programme LRS50, Research Branch, Canada Department of Agriculture, Lethbridge, Alberta, Canada.

Table 4.3 Effect of dietary fat and age on fatty acid composition of abdominal depot fat

Source of variation	Fatty acid								
	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:1	22:1
					%				
Fat level									
0	1.4**[1]	28.0**	6.7**	9.9**	28.5**	21.2**	1.9**	1.6**	0.2**
2%	1.2e[2]	25.0e	4.1e	8.7e	30.3e	19.2	2.2d	4.5d	4.4d
11.4%	0.7d	16.2d	1.4d	3.9d	38.2d	18.7	3.4e	7.7e	9.5e
Fat source									
RSO	0.7d	13.0d	2.0d	5.1d	30.0d	19.7e	4.4e	11.0e	13.7e
PO	1.3e	28.4e	3.5e	7.4e	38.7e	18.0e	1.2d	1.1d	0.0d
Age (weeks)									
2	1.2b	22.4	3.5d	6.2d	34.5d	22.0g	2.7	4.2d	2.8d
4	1.2b	22.7	3.4d	7.5fg	28.8a	21.6fg	2.7	5.8f	6.0f
8	1.3b	23.9	4.8de	6.3de	32.4bcd	18.3de	2.3	4.7de	5.4ef
12	1.1b	22.7	3.3d	7.7g	30.9ab	20.6fg	2.5	5.5f	5.6ef
16	1.1b	23.8	3.4d	8.7g	31.0abc	19.9ef	2.4	4.5de	4.8def
20	1.1b	23.1	4.2d	8.6g	33.7cd	17.9d	2.7	3.9d	4.5def
24	0.9a	23.2	5.9e	7.4ef	35.0d	17.4d	2.4	3.8d	3.8de
Overall mean ± standard error	1.1 ±0.03	23.1 ±0.23	4.1 ±0.14	7.5 ±0.12	32.3 ±0.26	19.7 ±0.18	2.5 ±0.07	4.6 ±0.11	4.7 ±0.20

[1] Indicates that the comparison "level 0 vs. others" is significant. * indicates $P < 0.05$, ** indicates $P < 0.01$

[2] Treatment means within sources of variation, followed by different letters are significantly different. Letters a, b, c indicate significance at $P < 0.05$. Letters d, e, f, g indicate significance at $P < 0.01$

Table 4.4 Effect of dietary fat and age on fatty acid composition of thigh meat lipids

Source of variation	Fatty acid											
	14:0	16:A[1]	16:0	16:1	18:A[2]	18:0	18:1	18:2	18:3	20:1	20:4	22:1
Fat level												
0	1.1**[3]	1.6**	26.1**	6.3**	0.3	13.1**	23.7**	22.0**	1.2**	0.5**	2.8**	0.5**
2	1.0e[4]	1.8e	24.5e	4.5e	0.2b	10.9e	27.1d	20.6	2.0d	2.7d	2.2d	2.3d
11.4%	0.7d	1.1d	18.2d	1.9d	0.1a	8.0d	34.6e	19.9	2.8e	5.4e	1.7e	5.4c
Fat source												
RSO	0.6d	1.0d	16.0d	2.7a	0.1	8.9d	29.0d	21.1e	3.8e	7.4e	1.7d	7.4e
PO	1.0e	1.8e	26.8e	3.6b	0.2	10.1e	32.6e	19.4d	0.9d	0.7d	2.2e	0.3d
Age (weeks)												
8	0.9	1.3d	22.4	4.9b	0.2	8.9d	29.7e	21.3	2.1	3.3e	1.7d	3.6f
16	1.0	2.3e	22.4	3.3a	0.3	12.5e	26.5d	20.4	1.9	3.3e	2.6e	3.0ef
20	0.9	1.6e	22.3	4.2ab	0.1	11.7e	28.3de	21.6	1.9	2.6d	2.2de	2.6de
24	0.8	1.5e	24.6	4.6b	0.2	9.8d	29.4e	20.1	2.0	2.2d	2.5e	1.9d
Overall mean ± standard error	0.9 ±0.03	1.7 ±0.07	22.9 ±0.34	4.3 ±0.20	0.2 ±0.03	10.7 ±0.16	28.5 ±0.20	20.9 ±0.20	2.0 ±0.07	2.9 ±0.08	2.2 ±0.07	2.8 ±0.11

[1] Palmitaldehyde

[2] Stearaldehyde

[3] Indicates that the comparison "level 0 vs. others" is significant. * indicates $P < 0.05$, ** indicates $P < 0.01$

[4] Treatment means within sources of variation, followed by different letters are significantly different. Letters a, b, c indicate significance at $P < 0.05$. Letters d, e, f, g indicate significance at $P < 0.01$

Table 4.5 Effect of dietary fat and age on fatty acid composition of breast meat lipids

Source of variation	Fatty acid											
	14:0	16:A[1]	16:0	16:1	18:A[2]	18:0	18:1	18:2	18:3	20:1	20:4	22:1
Fat level												
0	0.8	4.8**[3]	25.5**	3.9**	0.7**	14.5**	19.6**	23.5**	0.8**	0.2**	4.3**	0.6**
2%	0.8e[4]	3.6e	25.6e	3.1e	0.5	13.0e	22.6d	22.0e	1.5d	1.7d	3.4	1.7d
11.4%	0.6d	2.6d	19.8d	1.5d	0.4	10.4d	30.4e	20.5d	2.3e	4.3e	3.2	3.8e
Fat source												
RSO	0.6d	2.6d	18.0d	2.2	0.3d	11.5	25.8	22.3e	2.9e	5.4e	3.0	4.8e
PO	0.8e	3.7e	27.3e	2.4	0.5e	11.8	27.1	20.1d	0.8d	0.6d	3.5	0.6d
Age (weeks)												
8	0.5a	4.4e	21.6d	2.7	0.3d	13.1e	22.5d	24.0e	1.2a	2.3	4.3b	2.8e
16	0.8b	4.7e	23.5e	2.3	0.9e	14.7f	22.1d	22.1de	1.3ab	1.6	4.1b	1.5d
20	0.9b	3.2d	24.8e	3.1	0.4d	12.3e	24.7de	21.3d	1.7bc	2.3	3.0a	2.1de
24	0.8b	2.7d	24.7e	3.2	0.5d	10.4d	27.5e	20.6d	1.8c	2.2	3.1a	1.7d
Overall mean ± standard error	0.7 ±0.04	3.8 ±0.13	23.7 ±0.30	2.8 ±0.13	0.5 ±0.04	12.6 ±0.21	24.2 ±0.41	22.0 ±0.26	1.5 ±0.08	2.1 ±0.13	3.6 ±0.16	2.0 ±0.12

[1] Palmitaldehyde

[2] Stearaldehyde

[3] Indicates that the comparison "level 0 vs. others" is significant. * indicates $P < 0.05$, ** indicates $P < 0.01$

Treatment means within sources of variation, followed by different letters are significantly different. Letters a, b, c indicate significance at $P < 0.05$. Letters d, e, f, g indicate significance at $P < 0.01$

deposited in increasing proportions. In addition, palmitaldehyde, stearaldehyde and arachidonic acid (20:4), which were found in thigh and breast meat but not in depot fat, decreased in proportion as the dietary fat level was increased. Linoleic acid (18:2) remained approximately constant or decreased slightly with increasing dietary fat level. It is clear, however, from the effects of the dietary fat source and the significant interactions of level with source, that the effect of dietary fat depended not only on the level but also on the fatty acid composition of the specific dietary fat source. The significant interactions of the treatment effects on the depot fatty acids are depicted graphically; the complete analysis of variance for the fatty acids of each tissue is included in the appendix.

The above noted decrease in saturated fatty acid levels as the dietary fat level increased was associated primarily with the lower levels of those fatty acids provided by the diets containing rapeseed oil (Figure 4.1). With either source of dietary fat, the saturated fatty acid levels in the abdominal depot fat approached the dietary levels when the diet contained 11.4% added fat. An exception was palmitic acid in the case of the diet containing 11.4% palm oil; the

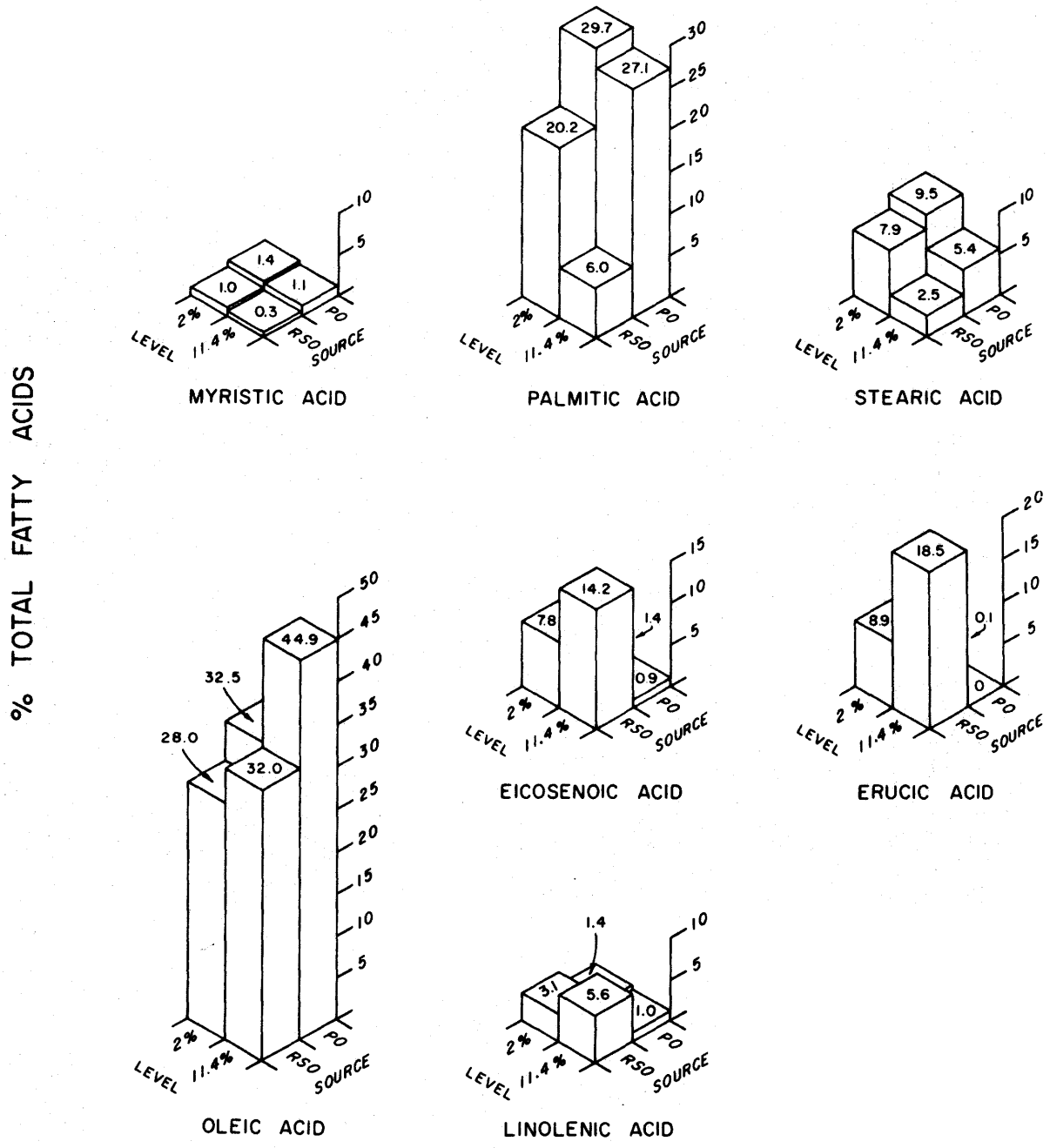

Figure 4.1 Interaction of dietary fat level with source on abdominal depot fatty acids

level in the depot fat was only 27.1%, while the dietary fat contained 38.6% palmitic acid. At the 2% level of dietary fat, the composition of the depot fat was intermediate between that of the fat source and the fat that was deposited when the diet contained no added fat. The levels of unsaturated fatty acids in the depot fat were similarly related to the differences in composition between the fat sources.

The interaction effects involving linolenic, eicosenoic and erucic acids are of greater interest than the main effects, since most of the linolenic and essentially all the eicosenoic and erucic acid were supplied by rapeseed oil. The level of linolenic acid in the depot fat approached, but did not equal, the level supplied in the diet by either fat source. The level of erucic acid in the depot fat was approximately four percent below the level provided in the diet by 11.4% rapeseed oil, while eicosenoic acid exceeded the dietary level by the same margin. Oleic acid was deposited at levels higher by four to eight percent than those supplied by diets containing rapeseed or palm oil at either level. However, when the diet contained no added fat, the depot fatty acids contained 12% more oleic acid than the dietary fatty acids.

Higher levels of the fatty aldehydes, palmitaldehyde and

stearaldehyde, were associated with palm oil than with rapeseed oil as the fat source.

Age exerted relatively little influence on the deposition of the saturated fatty acids. The significant differences due to age which did occur were small and not consistent in the different tissues. The interaction of level with age on stearic, oleic and linoleic acids indicated greater variability in deposition of these fatty acids at the lower levels of added fat (Figure 4.2). Stearic acid was deposited in increasing amounts from 16 to 24 weeks of age when the diet contained 11.4% added fat; this increase appeared to be associated with rapeseed rather than palm oil in the diet (Figure 4.3).

The deposition of the unsaturated fatty acids was more strongly influenced by age. Palmitoleic acid increased in the depot fat at 24 weeks of age. Oleic acid decreased from two to four weeks of age in the depot fat, and increased at 20 and 24 weeks in all tissues studied, the increase occurring at the lower levels of dietary fat. High levels of oleic acid in both depot fat and thigh meat at eight weeks, when the diet contained no added fat, seem inconsistent with the rest of the data and probably represent sampling error. Linoleic

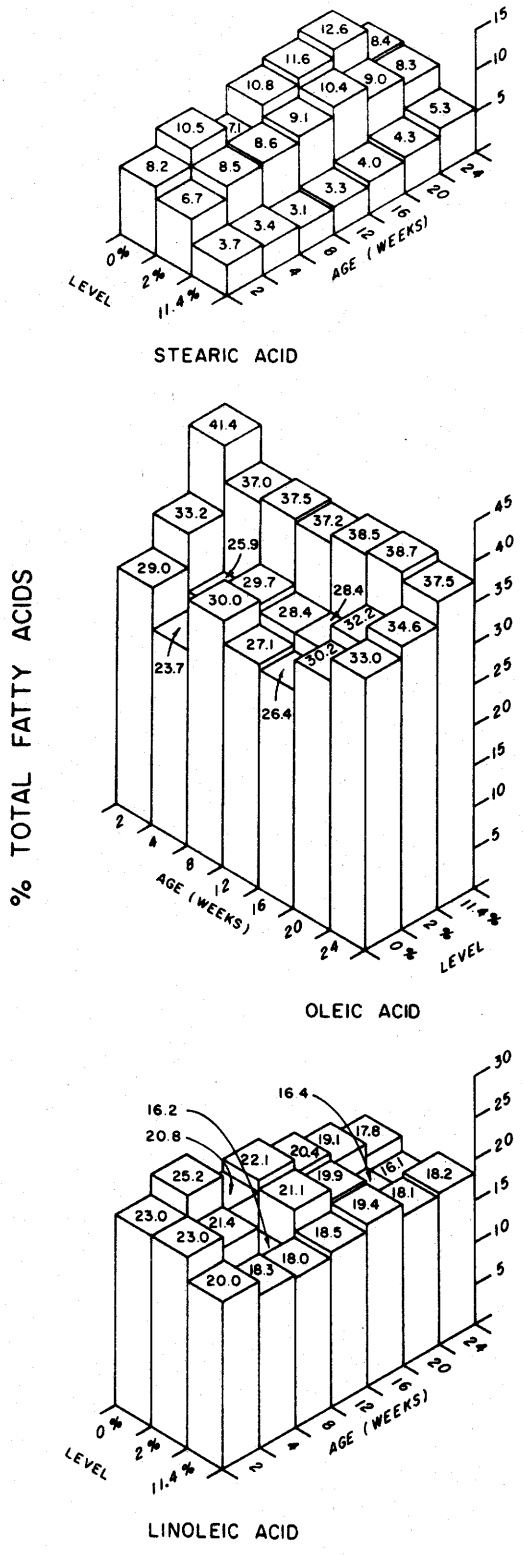

Figure 4.2 Interaction of dietary fat level with age on abdominal depot fatty acids

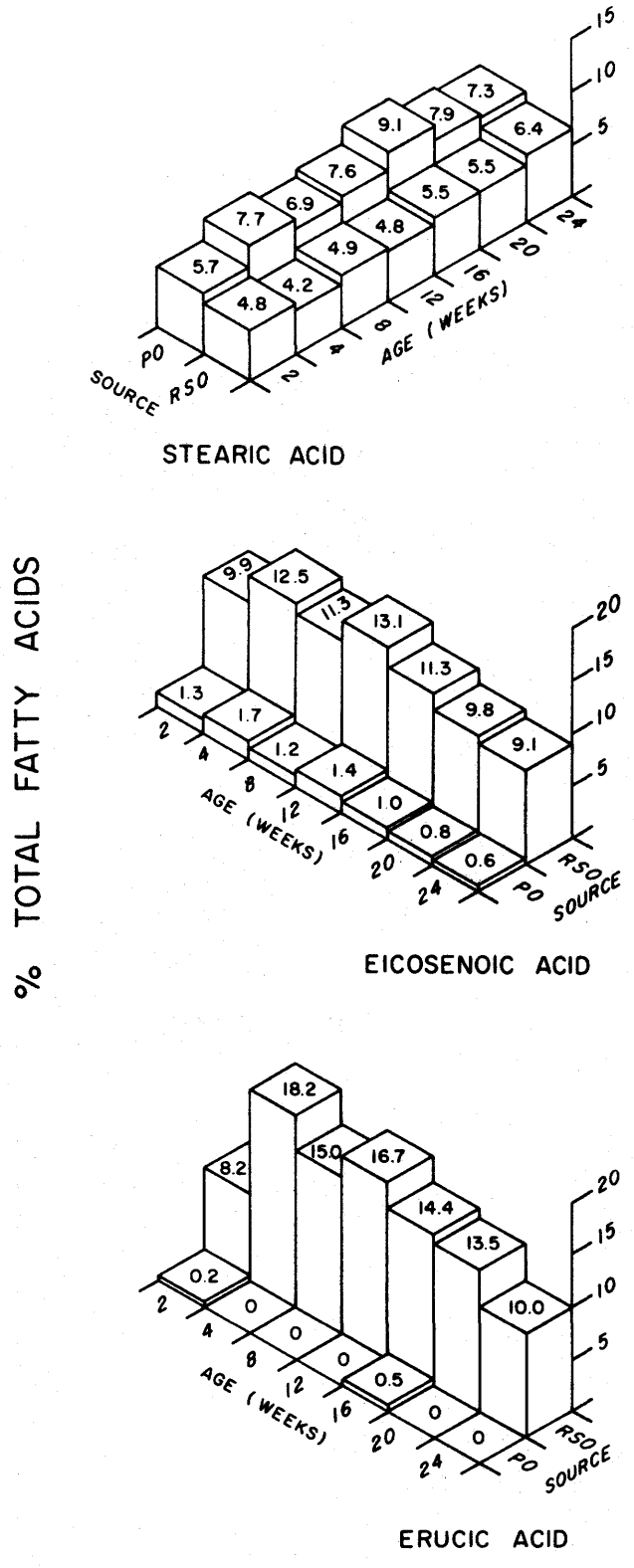

Figure 4.3 Interaction of dietary fat source with age on abdominal depot fatty acids

acid decreased with age at the lower dietary fat levels. Linolenic acid was relatively unaffected by age, but appeared to increase in breast meat. Eicosenoic and erucic acids increased in level to four weeks, remained relatively constant to 12 weeks, and subsequently decreased from 16 to 24 weeks of age; the changes in these fatty acids are clearly evident in the interaction of source with age.

No consistent changes occurred in fatty aldehyde or arachidonic acid levels with respect to age.

The effects of changes in the level and source of dietary fat on the fatty acids of thigh and breast meat were qualitatively similar, but of lesser magnitude in comparison with the effects on the depot fatty acids. Furthermore, the effects on the fatty acids of breast meat were less extensive than those on thigh meat fatty acids. The tissue lipids studied were similar in their overall mean levels of palmitic acid, but thigh meat fatty acids contained proportionally more stearic acid than depot fat, and breast meat fatty acids in turn more than those of thigh meat. The unsaturated fatty acids tended to be present at lower levels in thigh and breast meat fatty acids, and to be lower in breast than in thigh meat fatty acids. Exceptions were linoleic acid, which was

similar in level in all tissues tested, and arachidonic acid, which was higher in breast than in thigh meat fatty acids.

Following a change of dietary fat from rapeseed to palm oil, or vice versa, the tissue fatty acids tended to assume the characteristic composition of the new fat source. Exponential curves of the form $Y = A + B\ (\rho^X)$ were derived to describe the increase or decrease in fatty acid levels. From each equation "H" was calculated, an estimate of the time in weeks taken for each fatty acid to increase or decrease by half of its ultimate change in level. Several fatty acids which did not yield significant regressions, but whose levels nevertheless changed significantly, are also plotted.

A change of dietary fat from rapeseed to palm oil at the 11.4% level led to increases in palmitic, stearic and oleic acids from initial levels of 5.5, 2.0, and 31.4%, respectively, at 16 weeks, to levels asymptotically approaching 30.2, 6.4, and 40.5% of the depot fatty acids (Figure 4.4). Linolenic, eicosenoic and erucic acids simultaneously decreased from 6.4, 14.0, and 19.5%, respectively, to approach levels of 0.8, 1.6, and 2.0%. The inverse change of fat source resulted in decreases in palmitic and oleic acids from 25.4 and 45.6% respectively, to approach levels of 8.7 and 34.3%. Stearic

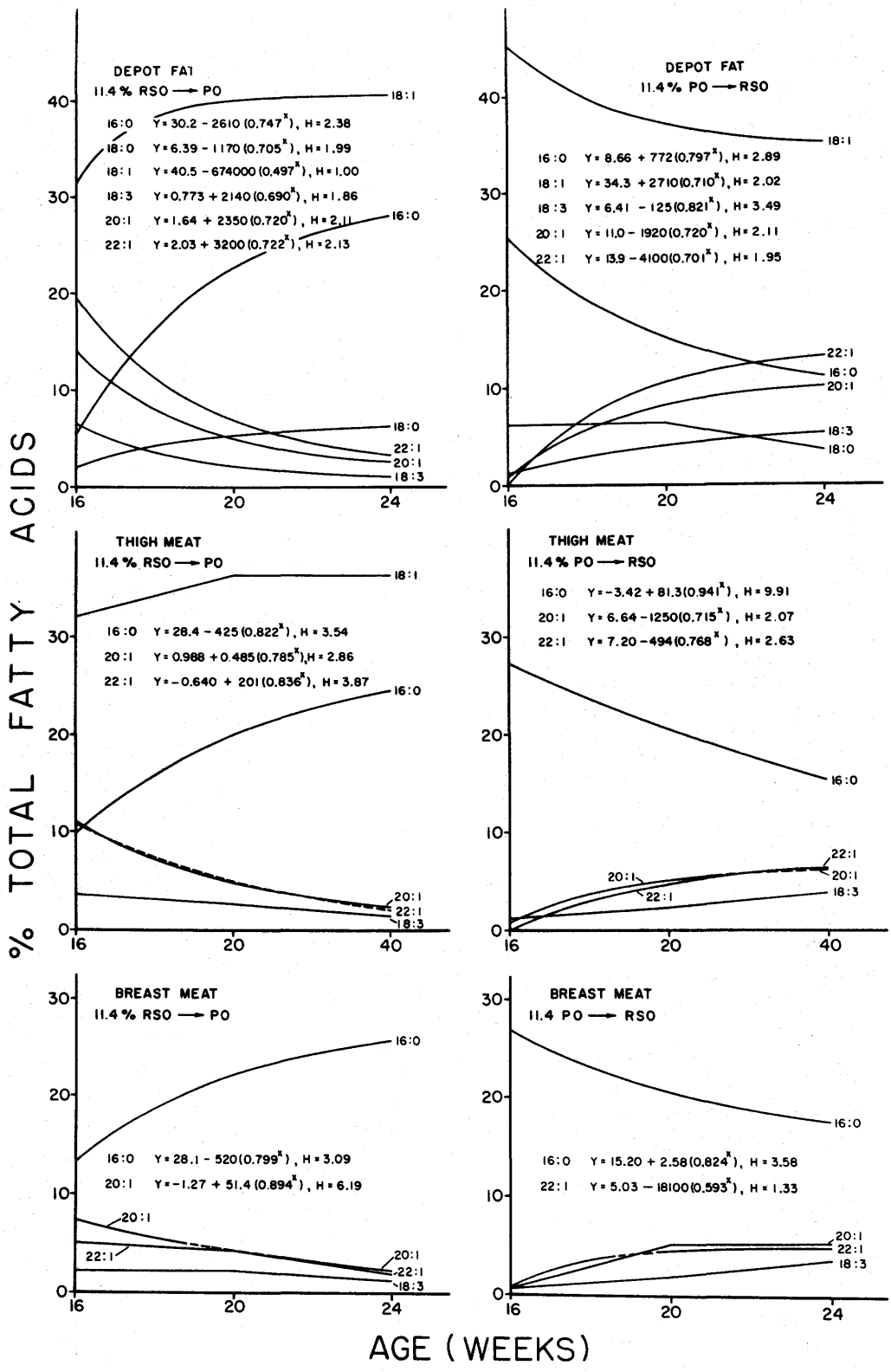

Figure 4.4 Effect of a change of fat source on tissue fatty acid composition, 11.4% dietary fat. Regressions were significant ($P<0.01$). Fatty acids represented by straight lines changed significantly in level ($P<0.05$) but did not yield significant exponential curves

acid decreased significantly, but not exponentially, from 6.2 to 3.6% by 24 weeks. Linolenic, eicosenoic and erucic acids increased simultaneously from 1.1, 0.9 and 0.0% to approach 5.4, 10.1 and 13.1% of the fatty acids, respectively. The final levels approached by eicosenoic and erucic acids, in the latter case, were lower by 3.9 and 6.4% than the corresponding depot levels at 16 weeks of birds fed 11.4% rapeseed oil. This difference corresponds with the decreases in those fatty acids that were observed earlier to be associated with age. It therefore appears that following a change of dietary fat these fatty acids, as well as the others mentioned, approached the approximate levels in the depot fat that were associated with consumption of the new dietary fat for the entire period of time.

In breast and thigh meat, similarly, a change of fat source at the 11.4% level gave rise to changes in fatty acids that corresponded with those in the depot fat. Because of the lesser magnitude of the effect of the fat source on fatty acid levels in meat lipids as compared with depot fat, stearic acid was not found to change significantly when the fat source was changed, and oleic acid changed significantly in only one of four cases.

At the 2% dietary fat level, fewer fatty acids were found to change significantly or to yield a significant exponential curve when the fat source was changed (Figure 4.5). In thigh meat, no significant changes were detected when rapeseed oil was substituted for palm oil. In breast meat, only erucic acid yielded a significant change in level following either change of fat source. Difficulty in detecting significant changes in fatty acid levels at the lower dietary fat level may be accounted for by the reduced magnitude of the changes expected in comparison with experimental error. However, the changes which did occur were in the same direction as those found at the 11.4% dietary fat level.

The value of H varied considerably among fatty acids, probably because of the infrequency of sampling relative to the observed rate of change of fatty acid levels. More frequent sampling than at 4-week intervals would have improved the precision of the curves and H values obtained, and would probably have permitted the derivation of exponential curves and H values for several of those fatty acids which did not yield a significant regression. Examination of the graphs of these fatty acids indicates that in many cases their change in level was essentially complete by 20 weeks. The values of H

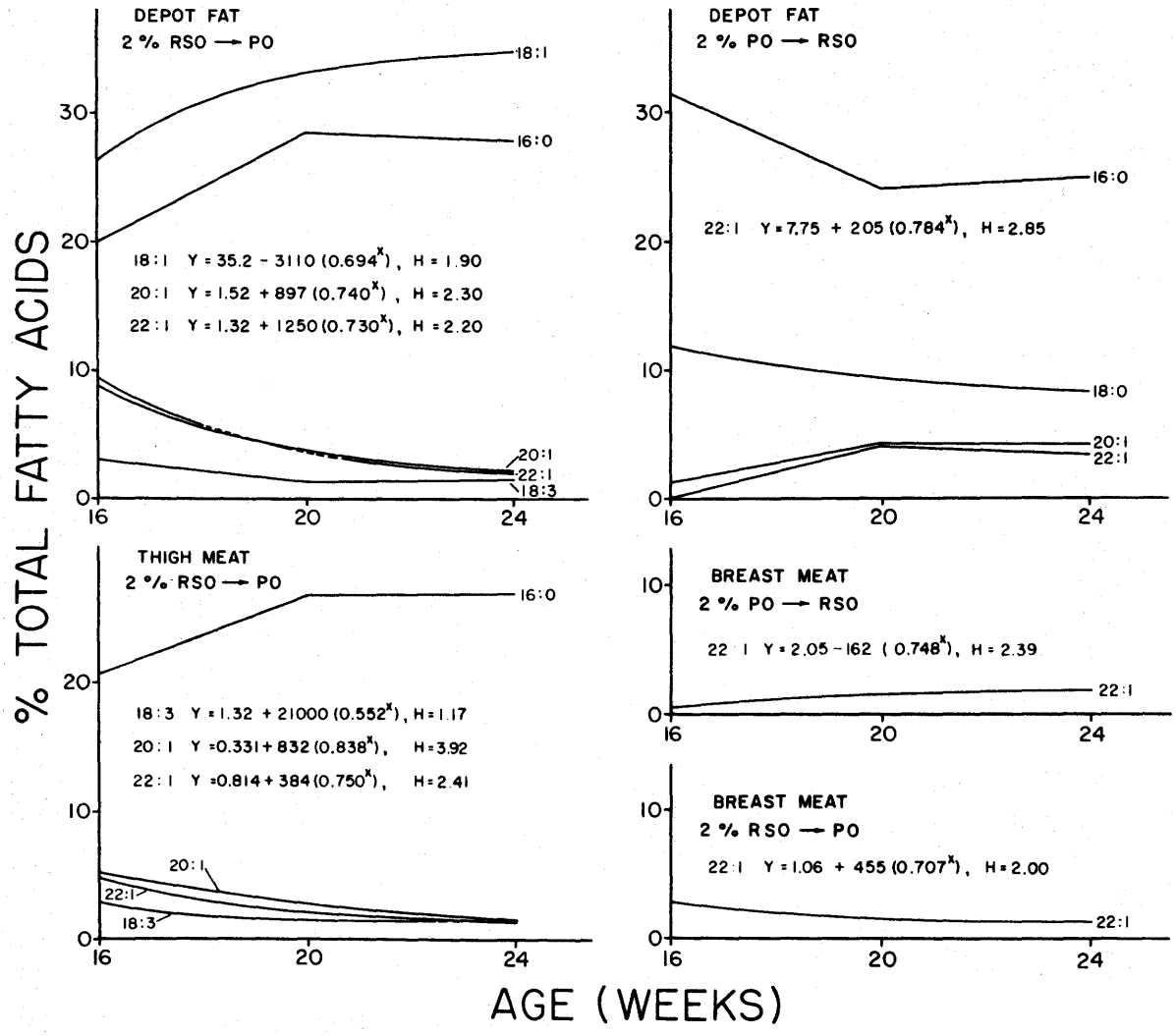

Figure 4.5 Effect of a change of fat source on tissue fatty acid composition, 2% dietary fat. Regressions were significant ($P<0.01$). Fatty acids represented by straight lines changed significantly in level ($P<0.05$) but did not yield significant exponential curves

of these fatty acids would have been low, reflecting their apparently rapid rate of change in response to dietary fat. Two extremely high values of H were inconsistent with the other calculated values, probably also due to sampling error and infrequency. If the latter extreme values are deleted as unreliable, the overall mean value of H of 2.4 weeks, although subject to the above mentioned deficiencies, nevertheless provides an estimate of the average rate of change of tissue fatty acid levels of turkeys following a change of dietary fat at 16 weeks of age.

4.4 Discussion

The fatty acids incorporated in a given lipid are determined, in part, by the mixture of fatty acids in the tissue at the time of incorporation, which may be of dietary or biosynthetic origin. Biosynthetic fatty acids may be expected to contribute substantially to the carcass fat when the dietary fat level is low. Palmitic, palmitoleic, stearic and oleic acids are among the major fatty acids which arise from nonfat precursors (Section 2.3). In this experiment, turkeys were found to deposit substantially greater proportions of those fatty acids than were provided in the basal diet, which contained no added fat and had an average ether extract content of 1.5%.

Increasing the proportion of dietary fatty acids consumed, by increasing the level of fat in the diet, resulted in the deposition of fat which resembled the dietary fat in composition. The similarity in fatty acid composition was considerably greater when the diet contained 11.4% added fat than when it contained only 2% added fat. A similar relationship between the level of dietary fat and its influence on the fatty acids deposited in the carcass has been shown in rats fed 2 or 20% corn oil (Beare and Kates, 1964). However, Marion (1965) found little difference in fatty acid profile between fat levels when chicks were fed 6 or 12% corn oil or beef tallow. The increased deposition of dietary fatty acids when the dietary fat level is raised is due not only to the dilution of the biosynthetic fatty acids as a result of an increase in the proportion of dietary fatty acids present, but also to a depression of hepatic fatty acid synthesis (Yeh et al., 1970).

The higher levels of fatty aldehydes, particularly palmitaldehyde, that were found when the diet contained palm oil in contrast to rapeseed oil, suggest that the rate of production of these compounds depends on the level of their probable precursors, palmitic and stearic acids, that are available in the tissues. Neudoerffer and Lea (1967) found

no difference in fatty aldehyde levels due to diet in phosphatidylcholine, which contained 4 to 5% palmitaldehyde and 0.8 to 2% stearaldehyde, or in phosphatidylethanolamine, which contained 12 to 14% palmitaldehyde and 6 to 7% stearaldehyde. However, they also found much less effect of dietary palmitic acid on the triglyceride fraction than was observed at the much higher upper level of added fat employed in this experiment. It remains possible that sufficiently high levels of dietary fat may impose greater variation in fatty acid composition within the phospholipid fractions than has generally been reported.

The effect of age in increasing the proportions of the biosynthetic fatty acids, palmitoleic and oleic, as well as stearic acid in the case of rapeseed oil diets, indicates an increasing rate of lipogenesis as turkeys approach maturity. The increasing deposition of oleic acid, although most pronounced at low dietary fat levels, may be due in part to an increase in the rate of β-oxidative degradation of erucic through eicosenoic to oleic acid (Craig and Beare, 1967). However, the decreasing proportions of eicosenoic and erucic acids associated with age could in turn be a result of dilution due to the increasing rate of fatty acid biosynthesis.

The higher levels of stearic and arachidonic acids in thigh and breast meat in contrast to depot fat are related to the phospholipid content of the muscle tissues. The phospholipids of chicken thigh and breast meat contained higher levels of these fatty acids than neutral fat, and breast muscle contained proportionally more phospholipid in comparison to neutral lipid than thigh muscle (Marion, 1965). The phospholipids of turkey muscle contained concentrations of stearic acid as high as 30 to 44% of the fatty acids of phosphatidylinositol and 32 to 34% of phosphatidylserine fatty acids, and arachidonic acid constituted over 20% of the fatty acids of phosphatidylinositol (Neudoerffer and Lea, 1967).

The value of H of 2.4 weeks, which estimates the rate of change of tissue fatty acid levels following a change of dietary fat at 16 weeks of age, indicates that in four weeks, the average fatty acid will have attained approximately 70% of its final change in level, and in eight weeks, approximately 90%. It should be emphasized that the value of H in growing animals represents not a simple exchange of fatty acids, but the resultant effect of fatty acid exchange and the increasing total lipid content of the carcass.

4.5 Summary

The fatty acids of abdominal depot fat and thigh and breast meat of turkeys fed 0.2 and 11.4% palm or rapeseed oil from day-old to 24 weeks of age were strongly influenced by the level and source of dietary fat. Birds fed no added dietary fat deposited palmitic, palmitoleic, stearic and oleic acids in greater proportions than were provided in the diet. Increasing the level of fat in the diet resulted in the deposition of fat that resembled the dietary fat in composition, the greatest similarity occurring at the higher level of added fat.

Increasing levels of palmitoleic, stearic and oleic acids with age indicated an increasing rate of fatty acid biosynthesis as the birds approached maturity.

Thigh meat contained a higher level of stearic acid than depot fat, and breast meat contained higher levels of stearic and arachidonic acid and fatty aldehydes than thigh meat. These differences reflected the greater proportions of phospholipids in thigh and breast meat, which were reflected also in decreased sensitivity of the meat lipids to changes in fatty acid composition in response to dietary fat.

The average rate of change of fatty acid levels following a change of dietary fat at 16 weeks was such that half the total change in level took place in 2.4 weeks.

5. PART 3. THE EFFECT OF CARCASS FATTY ACID COMPOSITION ON STORAGE STABILITY OF TURKEY MEAT

5.1 Introduction

The storage stability of turkey meat has been shown to be affected by dietary factors which influence the fatty acid composition of the tissue lipids (Section 2.4.2). Sources of linolenic acid, in particular, have been incriminated as causing instability of tissue lipids. Storage temperature was found to be important in preventing the deterioration of pork which had unsaturated carcass fat, but has not been reported as a factor in the storage of turkey meat.

The availability of carcasses of turkeys fed diets containing fats of contrasting characteristics presented an opportunity to carry out a preliminary study of the effect of dietary fat and storage temperature on the storage stability of turkey meat.

5.2 Experimental procedure

Eight frozen carcasses of turkeys fed diets containing 11.4% of either rapeseed or palm oil, as previously described (Section 3.2), were randomly distributed between storage treatments at either $-12^{o}C$ or $-22^{o}C$. After eight months,

the carcasses were thawed at room temperature and samples of abdominal depot fat, thigh and breast meat removed. TBA values were determined on each sample, in duplicate, by the procedure of Tarladgis et al. (1960), except that a malonaldehyde standard was not available and could not be assayed. The TBA values reported are therefore relative optical density readings as obtained on a Coleman Junior Spectrophotometer, and bear no relationship to the "TBA number" of Tarladgis et al. (1960), which is defined in terms of mg. of malonaldehyde per kg. of sample.

The fatty acid composition of samples of abdominal depot fat and the lipids of thigh and breast meat of birds fed the same dietary oil treatments was determined as described in Section 4.2.

5.3 Results

The TBA values indicated an increase in rancidity of the carcass fat of turkeys fed rapeseed oil when stored at a temperature of $-12^{o}C$, but not when stored at $-22^{o}C$. (Table 5.1). Storage temperature did not affect the stability of the carcass fat of birds fed palm oil. Analysis of variance indicated that the interaction of fat source with storage temperature was significant ($P<0.05$) in the case of depot fat

Table 5.1 Effect of dietary fat and storage temperature on TBA value[1] of turkey tissues

Dietary fat treatment	Storage temperature					
	- 22°C			- 12°C		
	Depot fat	Thigh meat	Breast meat	Depot fat	Thigh meat	Breast meat
Rapeseed oil	40	38	21	190	93	36
Palm oil	33	26	30	41	38	29

[1]Optical density reading x 100

Table 5.2 Analysis of variance, effect of dietary fat and storage temperature on TBA value of turkey tissues

Source of variation	Degrees of freedom	Mean square		
		Depot fat	Thigh meat	Breast meat
Fat source	1	494*[1]	91	1
Temperature	1	499*	88	7
Fat x temp.	1	401*	36	10
Experimental error[2]	12	75	36	55
Analytical error[3]	16	12	1	31

[1]Significant ($P<0.05$)

[2]Replicates within treatments

[3]Duplicate assays

samples (Table 5.2). A sizeable numerical increase in TBA value of the thigh meat of rapeseed oil carcasses at the higher storage temperature was not statistically significant ($P<0.05$). The stability of breast meat was not affected by the storage treatment.

The tissues of turkeys fed rapeseed oil contained from five to six percent linolenic acid, compared with less than one percent in the tissues of birds fed palm oil (Table 5.3). Birds fed rapeseed oil also contained approximately four percent more linoleic acid in their tissues than birds fed palm oil, giving a total of approximately nine percent more fatty acids with two or more double bonds in the tissues of birds fed rapeseed oil.

5.4 Discussion

The effect of storage temperature on the development of rancidity in the tissues of turkeys fed rapeseed oil is in agreement with the findings of Palmer et al. (1952) that pork with unsaturated carcass fat deteriorated in storage at temperatures above -17.6°C. The greater rancidity of depot fat than thigh muscle, and apparently greater rancidity of thigh than breast muscle, may be related to the fat content of the respective tissues. The ether extract content of thigh

Table 5.3 Fatty acid composition of depot fat, thigh and breast meat of turkeys fed 11.4% rapeseed or palm oil

Dietary fat treatment	Fatty acid									
	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:1	20:4	22:1
	% of fatty acid methyl esters									
Depot fat										
Rapeseed oil	0.3	7.8	1.6	3.2	34.4	21.5	6.0	11.2	--	13.7
Palm oil	1.0	28.2	1.6	6.5	44.5	17.0	0.6	0.3	--	0.1
Thigh meat										
Rapeseed oil	0.8	9.5	1.4	6.4	33.0	22.2	5.6	9.1	1.8	9.1
Palm oil	1.6	27.3	2.4	9.0	36.8	18.8	0.7	0.2	2.0	0.0
Breast meat										
Rapeseed oil	1.2	9.3	1.2	7.9	32.2	22.8	5.1	8.9	2.3	7.8
Palm oil	2.2	27.8	1.2	9.3	36.0	17.7	0.7	0.4	2.7	0.0

meat, on a dry weight basis, was approximately 12.6%, while that of breast meat was 4.6% (Table 3.8, page 68). Marion and Forsythe (1964) reported that red turkey meat oxidised more rapidly than white meat. Rancidity of turkey lipids has previously been associated with the level of polyunsaturated fatty acids, especially linolenic acid, in the tissues (Section 2.4.2).

5.5 Summary

Carcasses of turkeys fed 11.4% rapeseed oil were subject to rancidity when stored for eight months at a temperature of -12°C, but not when stored at a temperature of -22°C. Carcasses of birds fed 11.4% palm oil were equally stable at both storage temperatures. The instability associated with dietary rapeseed oil was associated with higher levels of linoleic and linolenic acids in the tissues as compared with birds fed palm oil.

6. GENERAL DISCUSSION

The research which forms the subject of this dissertation has considered many implications of the use of dietary fat in the production of market turkeys. The level of dietary fat, and the incorporation in the diet of fats differing widely in fatty acid composition, have been evaluated in terms of growth performance, efficiency, carcass grade, quality and fatty acid composition. The effect of dietary fat on the maintenance of the quality of the final product, turkey meat, has been discussed.

The incorporation of fat in the diet was shown in Section 3 to improve carcass fat scores and to increase the percentage and fat content of the carcass skin and the fat content of thigh and breast meat. This observation was in agreement with a number of previous reports on turkeys (Section 2.2.3), but differed from several in which dietary fat *per se* was not found to influence the carcass composition of chickens (Section 2.2.2). A species difference in the relative efficiency of utilisation of carbohydrate and fat energy is conceivable. The possibility may receive some support from the observation that the fatty acid composition of turkey lipids appears to be more readily influenced than

that of chickens by the composition of the dietary fat, which suggests that growing turkeys may be limited in their capacity to convert excess energy in the form of carbohydrate into fat. However, no conclusion is possible at present on this highly speculative possibility.

The fatty acid data reported in Section 4 tend to support the observation that the fat source affected carcass fat scores and cooking losses. The breast and back fat scores of the birds fed diets containing palm oil were consistently, though not always significantly, higher than the corresponding scores of birds fed rapeseed oil. The more highly saturated fat derived from diets containing palm oil may have been harder and more opaque in appearance than fat derived from rapeseed oil, which was much higher in unsaturated fatty acids, thereby giving rise to a difference in visual grades for carcass fat. The higher cooking losses from carcasses of birds fed rapeseed oil may also be associated with lower melting characteristics of the less saturated skin fat of these birds.

The data presented in Section 4 demonstrate the ease with which the carcass fat of turkeys may be modified by dietary means. The conclusion in Section 3 that the carcass fat at 24 weeks of birds whose dietary fat was changed at 16

weeks was similar to that of birds fed the new fat for the entire period was substantiated by the observation that by the time of slaughter the carcass fatty acid levels were 90% converted to the levels that were characteristic of the new dietary fat. The production of turkeys with unsaturated carcass fat may be favoured as more desirable for human nutrition than the production of birds with highly saturated carcass fat. However, because of the influence of carcass fatty acid composition on carcass grades, changes in the grading system may be needed to protect the producer from financial losses resulting from differences in carcass characteristics arising from the production of carcasses with unsaturated fat.

Finally, the importance of proper storage conditions for the maintenance of the quality of turkey meat was emphasized by the findings reported in Section 5. The production of turkeys with unsaturated carcass fat will require increased emphasis on proper handling and storage. The maintenance of satisfactory storage conditions may acquire new significance as the marketing of cut-up turkey by retail outlets increasingly exposes the product to less than ideal conditions of inadequate refrigeration and fluctuating temperatures on the

meat counter.

Nutrition research that is limited to the evaluation of the effects of various factors on growth performance is no longer sufficient to meet the needs of the food production industry. Research should investigate the broad implications of production factors on the quality of the product and the needs of the consumer. The study described herein represents an attempt to achieve these desirable objectives.

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TABLE 8.1 Analysis of variance, effect of dietary fat and age on abdominal depot fatty acids

Source of variation	Degrees of freedom	Fatty acid								
		14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:1	22:1
		Mean square								
Fat level										
0 vs. others	1	4.106**	991.1**	251.0**	204.6**	449.7**	80.2**	18.13**	347.2**	772.4**
2% vs. 11.4%	1	4.649**	1417.9**	148.5**	460.1**	1363.2**	7.8	21.93**	176.1**	460.7**
Fat source	1	7.506**	4746.2**	47.3**	106.3**	1550.0**	60.2**	203.84**	1977.7**	3801.5**
Age	6	0.176*	4.4	12.4**	12.6**	65.4**	43.7**	0.31	7.6**	16.7**
Level x source	1	1.153**	679.8**	1.0	8.6**	362.6**	13.8	43.23**	232.5**	468.8**
Level x age	12	0.067	5.5	3.6	5.7**	14.6*	11.6**	0.92	1.3	5.8
Source x age	6	0.057	9.3	1.7	3.4*	5.7	2.7	0.52	4.3**	36.0**
Level x source x age	6	0.032	6.4	0.9	4.3*	0.9	2.9	0.61	0.9	3.2
Error	67	0.071	5.8	2.0	1.4	7.2	3.5	0.54	1.2	4.2

* Significant ($P < 0.05$)

** Significant ($P < 0.01$)