EFFECT OF DIETARY SUPPLEMENTATION OF COPPER AND KAPOK MEAL ON FAT CHARACTERISTICS OF PIGS

Masakazu Irie[1]

Livestock Division, Osaka Agricultural Research Center
Habikino-shi, Osaka 583, Japan.

Summary

Fifteen Landrace pigs were used to determine the effects of supplemental copper or kapok meal, or both on the characteristics of the depot fat. The pigs were allocated into five groups of 3 pigs each. The animals were fed diets as follows: (1) control diet 100%; (2) control diet plus 20 mg/kg copper; (3) control diet plus 200 mg/kg copper; (4) control diet plus 3% kapok meal; (5) control diet plus 200 mg/kg copper and 3% kapok meal. In addition, 100 mg/kg iron and 100 mg/kg zinc were supplemented to all the diets. The pigs were slaughtered at the same time after 8 weeks of feeding period at an average weight of 98.6 kg. The supplementation of 20 or 200 mg/kg dietary copper did not affect the fatty acid compositions, the iodine numbers, the melting points or the copper contents of the inner and outer layers of backfat and the perirenal fat from pigs. Supplementation of kapok meal significantly elevated the melting point, the content of C18:0 and the ratio of C18:0/C18:1 of the porcine fats and decreased the content of C16:1. There was no interaction noted between copper and kapok meal on the porcine fat characteristics. These results indicate that the swine diet supplemented up to 200 mg/kg copper with zinc and iron can be used in growing-finishing swine diets without affecting either porcine fat characteristics or hardening effect of kapok meal on porcine fat.

(Key Words: Pigs, Fats, Carcass Fat, Fatty Acids, Kapok Meal, Copper)

Introduction

The supplementation of copper to pig diets is widely practiced since it has been shown to improve the rate of gain and the feed conversion in pigs. Supplemental copper has also been to shown to affect porcine fat characteristics. The depot fat from pig fed copper increase the softness, the iodine number and the proportion of unsaturated fatty acids (Taylor and Thomke, 1964; Moore et al., 1968, 1969; Elliot and Bowland, 1968, 1970; Mayer and Bowland, 1972; Amer and Elliot, 1973a, b; Thompson et al., 1973; Ho and Elliot, 1973, 1974; Ho et al., 1975). Supplementation of copper for pig may be lead to a problem of soft fat. Both zinc and iron have been shown to act as copper antagonists (Underwood, 1977). Very little information is available about the effect of copper with supplements of zinc and iron on the porcine fat characteristics during growing-finishing period.

The kapok meal containing cyclopropenoid fatty acids, which have effect hardening porcine fat, is fed to swine to prevent soft fat in Japan. Supplementation of kapok meal has the effect decreasing the unsaturated fatty acids of porcine fat. Therefore, kapok meal may alter the effect of copper on porcine fat characteristics. But the combined effects of supplementation of both copper and kapok meal on porcine fat are not known.

This study was conducted to determine the effects of supplemental copper with zinc and iron or kapok meal, or both on characteristics of depot fat from growing-finishing pigs.

Materials and Methods

Animals and Diets.

Fifteen Landrace pigs produced by this research center were used in this experiment. Four month-old pigs with starting average weights of 55.7kg were allocated on the basis of weight and sex into five groups of 3 pigs each (1 castrated male and 2 females). The animals were fed diets as follows: (1) control diet (Japanese pig progeny testing ration containing 14.1 mg/kg copper, 254.1 mg/kg iron and 107.5 mg/kg zinc) 100%; (2) control diet

[1] Address reprint requests to Dr. Masakazu Irie, Livestock Division, Osaka Agricultural Research Center, Habikino-shi, Osaka 583, Japan.

Received August 5, 1989
Accepted December 28, 1989

plus 20 mg/kg copper ($CuSO_4 \cdot 5H_2O$); (3) control diet plus 200 mg/kg copper; (4) control diet plus 3% kapok meal; (5) control diet plus 200 mg/kg copper and 3% kapok meal. In addition, 100 mg/kg iron ($FeSO_4 \cdot 7H_2O$) and 100 mg/kg zinc ($ZnSO_4 \cdot 7H_2O$) were supplemented to all the diets. The composition of the control diet is presented in table 1.

TABLE 1. COMPOSITION OF CONTROL DIET

Ingredients	Percent
Corn	22.00
Milo	22.00
Barley	22.00
Wheat bran	12.00
Soybean meal	9.00
Defatted rice bran	4.00
Fish meal	4.00
Alfalfa meal	2.50
Calcium phosphate	.80
Calcium carbonate	.70
Salt	.50
Trace mineral mix[1]	.15
Vitamines A and D	.15
Vitamin B	.10
Methionine	.10

[1]Contains .5%, Cu; 5%, Fe; 2%, Mn; 5%, Zn and .05%, I.

Feed and water were offered ad libitum. The pigs were slaughtered at the same time after 8 weeks of feeding period when the pigs reached at an average weight of 98.6 kg. After the carcasses were allowed to chill for 24 hr., the samples of inner and outer layers of backfat over the 5-8th rib section and perirenal fat were taken from cold carcass and were frozen at −20°C until physical and chemical analysis.

Physical and Chemical Analysis

The lipids from the fat samples and the diet were extrated by the method suggested by Folch et al. (1957). The extracted lipids were methylated by 3% HCl in methanol. The methyl esters were analyzed for individual fatty acids (14:0-18:3) on a Varian gas chromatograph, Series 2100, equipped with a flame ionization detector. A glass column, 1.8 m long and 2 mm in diameter, packed with 20% diethylene glycol succinate polyester on 100-120 mesh Chromosorb WAW was used. The column oven was maintained at 180°C isothermally. The injection port and the detector were operated at temperature of 250°C. The flow rate of the carrier gas, N_2, was 25 ml per minute. The fat samples were determined for melting point, iodine number and refractive index by the same methods shown in previous report (Irie and Nishimura, 1986a). Copper contents in the control diet and fat samples were determined by atomic absorption spectrophotometry with perchloric acid and nitric acid.

Statistical analysis

The data in group 1, 2 and 3 were analyzed for treatment of copper by one way analysis method, and the data in group 1, 3, 4 and 5 analyzed for treatments of copper and kapok meal by two way analysis method. For copper and kapok meal treatments, where applicable, Duncan's(1955) multiple range test was employed to determine significance. The data in group 2 versus group 4 or 5 were subjected to Student's t-test.

Results and Discussion

The data of the characteristics in inner and outer layers of backfat and perirenal fat from pigs fed copper or kapok meal, or both are shown in table 2.

Effect of copper

There were no significant differences among the pigs supplemented copper of two levels and the control pigs for fatty acid compositions, melting points, iodine numbers or refractive indexes in either backfat or perirenal fat. Therefore, the supplementation of 20 or 200 mg/kg dietary copper did not affect any fat characteristics from all depot sites determined. These results did not agree with the findings of Taylor and Thomke (1964), Moore et al. (1968, 1969), Elliot and Bowland (1968, 1970), Mayer and Bowland (1972), Amer and Elliot (1973a, b), Thompson et al. (1973), Ho and Elliot (1973, 1974) and Ho et al. (1975) that supplemental copper altered the fatty acid composition, iodine number or melting point. However, this disagreement probably was due to the presence of supplemental iron and zinc or the short feeding period of supplemental

TABLE 2. EFFECTS OF SINGLE SUPPLEMENTATIONS OR COMBINATIONS OF COPPER AND KAPOK MEAL ON PHYSICAL AND CHEMICAL CHARACTERISTICS OF OUTER AND INNER LAYERS OF BACKFAT AND PERIRENAL FAT FROM PIGS

Diet	1	2	3	4	5
Cu (mg/kg)	0	20	200	0	200
Kapok meal (%)	0	0	0	3	3
Outer layer of backfat					
Fatty acids (%)					
C14:0	1.6 ± .2[1]	1.7 ± .1	1.8 ± .1	1.8 ± .2	1.8 ± .1
C16:0	24.2 ± 1.2	24.3 ± 1.2	24.7 ± 1.4	25.4 ± .2	26.0 ± .4
C16:1	3.1 ± .2[a]	2.9 ± .5[a]	3.0 ± .5[a]	1.8 ± .5[b]	1.4 ± .4[b]
C18:0	11.4 ± 1.0[a]	11.6 ± 1.6[a]	11.4 ± .9[a]	20.8 ± 3.7[b]	23.6 ± 2.5[b]
C18:1	43.3 ± 1.7[a]	42.2 ± 2.8[a]	42.8 ± 2.5[a]	34.0 ± .4[b]	31.4 ± 1.6[b]
C18:2	13.8 ± 1.7	14.2 ± .6	13.4 ± 1.7	13.7 ± 2.4	12.8 ± .9
C18:3	2.8 ± 1.1	3.2 ± .6	3.1 ± .8	2.7 ± .4	3.1 ± 1.4
Total saturated	37.2 ± 2.2[a]	37.5 ± 2.5[a]	37.9 ± .9[a]	48.0 ± 3.4[b]	51.4 ± 2.2[b]
C18:0/C18:1	.2 ± .02[a]	.28 ± .06[a]	.27 ± .01[a]	.62 ± .12[b]	.75 ± .11[b]
Melting point(°C)	29.8 ± 1.1[a]	30.0 ± .4[a]	30.4 ± 1.3[a]	47.4 ± 2.1[b]	48.1 ± .4[b]
Iodine number	66.6 ± 3.1[a]	68.2 ± 1.7[a]	67.3 ± 2.1[a]	59.2 ± .6[b]	57.5 ± 2.6[b]
Refractive index[2]	600 ± 3[a]	602 ± 1[a]	601 ± 3[a]	592 ± 4[b]	591 ± 2[b]
Inner layer of backfat					
Fatty acids (%)					
C14:0	1.7 ± .2	1.5 ± .2	1.4 ± .1	1.8 ± .2	2.1 ± .6
C16:0	25.7 ± .6	26.6 ± 1.8	26.1 ± 1.6	26.7 ± 1.2	29.0 ± 4.2
C16:1	3.0 ± .6[a]	2.4 ± .3[a]	2.3 ± .3[a]	1.5 ± .2[b]	1.3 ± .4[b]
C18:0	12.8 ± 2.0[a]	15.3 ± .9[a]	14.8 ± 1.5[a]	23.6 ± 1.6[b]	25.2 ± 2.5[b]
C18:1	41.4 ± 1.3[a]	40.6 ± 1.2[a]	40.9 ± 2.5[a]	31.1 ± 2.5[b]	29.9 ± 5.0[b]
C18:2	12.1 ± 1.2	10.9 ± 1.8	11.9 ± 1.4	12.9 ± 1.0	10.8 ± .9
C18:3	3.3 ± .9	2.7 ± 1.4	2.5 ± .3	2.5 ± .4	1.7 ± .4
Total saturated	40.1 ± 1.4[a]	43.4 ± 1.9[a]	42.4 ± 2.6[a]	52.0 ± 1.8[b]	45.3 ± 4.7[b]
C18:0/C18:1	.31 ± .06[a]	.38 ± .03[a]	.36 ± .04[a]	.76 ± .09[b]	.86 ± .15[b]
Melting point(°C)	31.2 ± .8[a]	32.8 ± 1.1[a]	31.8 ± .5[a]	47.1 ± 2.2[b]	49.9 ± 1.8[b]
Iodine number	61.8 ± 1.4[a]	60.2 ± 1.3[a]	60.4 ± 2.7[a]	56.3 ± 2.8[b]	52.0 ± 3.5[b]
Refractive index	596 ± 3[a]	594 ± 3[a]	595 ± 3[a]	588 ± 1[b]	584 ± 5[b]
Perirenal fat					
Fatty acids (%)					
C14:0	1.8 ± .1	2.0 ± .1	1.7 ± .3	2.1 ± .5	2.0 ± .2
C16:0	28.5 ± .4	29.2 ± .5	27.9 ± 1.9	29.3 ± 1.5	28.5 ± 3.5
C16:1	2.6 ± .4[a]	2.4 ± .5[a]	2.5 ± .5[a]	1.5 ± .1[b]	1.4 ± .4[b]
C18:0	17.2 ± 1.7[a]	18.1 ± 1.3[a]	17.8 ± 1.8[a]	25.9 ± 3.3[b]	27.6 ± 1.8[b]
C18:1	34.8 ± 2.1[a]	33.8 ± 1.2[a]	35.7 ± 1.6[a]	25.2 ± 1.7[b]	24.6 ± 1.0[b]
C18:2	12.9 ± .8	12.2 ± .5	12.6 ± 1.2	13.5 ± 1.7	13.7 ± 1.5
C18:3	2.3 ± .3	2.6 ± .9	2.0 ± .6	2.8 ± .8	2.4 ± .9
Total saturated	47.5 ± 2.0[a]	49.2 ± 1.6[a]	47.3 ± .3[a]	57.2 ± 1.8[b]	58.1 ± 1.9[b]
C18:0/C18:1	.50 ± .07[a]	.54 ± .06[a]	.50 ± .05[a]	1.03 ± .10[b]	1.12 ± .04[b]
Melting point(°C)	42.1 ± 2.0[a]	43.2 ± 1.4[a]	41.6 ± 1.7[a]	51.6 ± .2[b]	51.5 ± .6[b]
Iodine number	59.6 ± 1.4[a]	57.9 ± 1.0[a]	56.9 ± 2.9[a]	51.2 ± 1.2[b]	49.2 ± 1.5[b]
Refractive index	592 ± 2[a]	590 ± 1[a]	591 ± 0[a]	583 ± 1[b]	581 ± 2[b]

[1] Mean ± standard deviation.

[2] $(N_{40}^{D}-1.4) \times 10{,}000$.

[a,b] Within a main effect, means in the same row with no common superscripts differ significantly ($p < .05$)

copper, or both. DeGoey et al. (1971) reported that the increase in iodine number of the fat from pig fed copper could be prevented by supplemental 100 mg/kg zinc and 100 mg/kg iron. Hamada et al., (1985) reported that fatty acid composition in the backfat from the growing pigs receiving 70 mg/kg zinc and 100 mg/kg iron were not affected by 200 mg/kg supplemental copper during 6 weeks.

Supplemental copper did not accumulate in the adipose tissues. This is in support of the findings of Barber et al. (1957) that very little of the copper accumulate in the fat during long term copper supplementation without supplemental iron and zinc. But, supplemental dietary copper accumulates in several tissues, especially in liver (Lillie et al., 1977; Hedges and Kornegay, 1973; Hamada et al., 1985). But higher than normal levels of dietary iron and zinc were need to prevent not only copper toxicity but also copper accumulation in the liver (Barber et al., 1960; Suttle and Miles, 1966; Hedges and Kornegay, 1973). Adipose tissue in pigs is main site of synthesis of fatty acid, especially during growing-finishing period. Copper enhances the specific activity of stearoyl-CoA desaturase systems in tissue, and that this alters the fatty acid composition of depot fat to more unsaturated forms (Ho and Elliot, 1974).

Though minor fatty acids above C20:4 were not determined because firmness of porcine fat mainly depends on major fatty acids, especially C18:0 and C16:0 (Irie et al., 1985), copper influences the fatty acid metabolism of ω 6 family as C20:4 and ω 9 family as C22:6 (Cunnane, 1982; Cunnane et al., 1985). Cunnane (1982) described that copper is an integral component of the Δ 9 desaturase and that zinc in some way is involved with the Δ 6 desaturase. Cunnane et al. (1985) also reported that copper supplementation increased C16:0 and C18:1 in rat tissue lipid whereas decreased C18:2. In the present study, the result that fatty acid composition of adipose tissue was not affected by supplemental copper is probably due to antagonistic interaction between copper and zinc (Cunnane, 1982).

The use of copper-enriched manure as a fertilizer have a detrimental effect on the soil. Therefore large quantities of copper are not permitted for use in swine diets in many countries. In Japan, the temporary maximum level is 20 mg/kg for finishing swine diet.

Effect of kapok meal

Supplemental kapok meal significantly elevated the melting point, the content of C18:0 and the ratio of C18:0/C18:1 of the porcine fats and decreased the content of C16:1. The supplementation of kapok meal decreased in the content of monounsaturated fatty acids with a concomitant increase in the amount of the corresponding saturated fatty acids in tissue lipids. These results are in agreement with those of our previous reports (Irie and Ohmoto, 1985; Irie and Nishimura, 1985). It is postulated that cyclopropenoid fatty acids affect the desaturase systems in adipose tissue (Pande et al., 1970). The results obtained in this study supported the assumption.

In this experiment, the iodine number and the refractive index of the porcine fat significantly decreased at all sites by supplemental kapok meal. These results differed from previous ones (Irie et al., 1984; Irie and Ohomoto, 1985) which the iodine number and the refractive index of the fat from pigs fed kapok meal were similar to those of the fat from control ones. In previous reports, a high content (7-14%) of soybean oil was added to experimental diets to produce soft fat. Dietary oils interfere with lipogenesis in pigs (Allee et al., 1971a, b; Waterman et al., 1975; Mersmann et al., 1984). Kapok meal appear to affect lipogenesis in pigs but did not interfere with preferential deposition of dietary C18:2 in adipose tissue (Irie and Ohomoto, 1985; Irie, 1988). Therefore, in the previous reports, the diet with high oil plus kapok meal hardly influenced on the iodine number and the refractive index of fat. However, when the diet with high carbohydrate and low fat compositions are used as in the present study, lipogenesis activity in pig was probably high and kapok meal affected the iodine number and the refractive index, perhaps, by inhibiting the desaturase system. Since the ratio C18:0/C18:1 reflecting the desaturase activity differed much between the pigs fed the diets with and without kapok meal.

The diets with kapok meal produced a firmer fat than those without kapok meal. The increase in firmness mainly depends on increase in the contents of C18:0 and C16:0 (Irie et al., 1985).

Interaction

The contents of C14:0, C18:2 and C18:3 were not affected by the dietary treatments. But differences between the measurements with and without kapok meal in C16:1, C18:0, C18:1, total saturated fatty acids, C18:0/C18:1, melting point, iodine number and refractive index were significant. In the present study, no significant interactions were noted between the supplemental copper and supplemental kapok meal on any fat characteristics. Especially, the high ratio of C18:0 to C18:1 in back fat of pigs fed kapok meal was unchanged by supplemental copper.

These results indicate that up to 200 mg/kg copper with supplements of zinc and iron can be used if necessary in growing-finishing swine diets without affecting either porcine fat characteristics or the hardening effect of kapok meal on fat.

Literature Cited

Allee, G.L., D.H. Baker and G.A. Leveille. 1971a. Fat utilization and lipogenesis in the young pig. J. Nutr. 101:1415.

Allee, G.L., E.K. O'Hea, G.A. Leveille and D.H. Baker. 1971b. Influence of dietary protein and fat on lipogenesis and enzymatic activity in pig adipose tissue. J. Nutr. 101:869.

Amer, M.A. and J.I. Elliot. 1973a. Influence of supplemental dietary copper and vitamin E on the oxidative stability of porcine depot fat. J. Anim. Sci. 37:87.

Amer, M.A. and J.L. Elliot. 1973b. Effects of level of copper supplement and removal of supplemental copper from the diet on the physical and chemical characteristics of porcine depot fat. Can. J. Anim. Sci. 53:139.

Barber, R. S., R. Braude, K.G. Mitchell, J.A.F. Rook and J.G. Rowell. 1957. Further studies on antibiotic and copper supplements for fattening pigs. Br. J. Nutr. 11:70.

Barber, R. S., R. Braude and K.G. Mitchell. 1960. Further studies on antibiotic, copper and zinc supplements for growing pigs. Br. J. Nutr. 14:499.

Cunnane, S.C. 1982. Differential regulation of essential fatty acid metabolism to the prostagrandins: possible basis for the interaction of zinc and copper in biological systems. Prog. Lipid Res. 21:73.

Cunnane, S.C., D.F. Horrobin and M.S. Manku. 1985. Contrasting effects of low or high copper intake on rat tissue lipid essential fatty acid composition. Ann. Nutr. Metab. 29:103.

DeGogey, L.W., R.C. Wahlstrom and R.J. Emerick. 1971. Studies of high level copper supplementation to rations for growing swine. J. Anim. Sci. 33:52.

Duncan, D.B. 1955. Multiple range and multiple F-test. Biometrics 11:1.

Elliot, J.I. and J.P. Bowland. 1968. Effects of dietary copper sulfate on the fatty acid composition of porcine depot fats. J. Anim. Sci. 27:956.

Elliot, J.I. and J.P. Bowland. 1970. Effects of dietary copper sulfate and protein on the fatty acid composition of porcine fat. J. Anim. Sci. 30:923.

Folch, J., M. Lees and G.H.S. Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497.

Hamada, T., S. Maeda, K. Hodate, E. Nakayama and M. Jinbu. 1985. Effects of supplemental copper and vitamin E on growth, tissue mineral contents and fatty acid composition of backfat in pigs. Bull. Nat. Inst. Anim. Iad. 43:51. (In Japanese).

Hedges, J.D. and E.T. Kornegay. 1973. Interrelationships of dietary copper and iron as measured by blood parameters, tissue stores and feedlot performance of swine. J. Anim. Sci. 37:1147.

Ho, S.K. and J.I. Elliot. 1973. Supplemental dietary copper from and the desaturation of 1-^{14}C-stearoyl-coenzyme A by porcine hepatic and adipose microsomes. Can. J. Anim. Sci. 53:537.

Ho, S.K. and J.I. Elliot. 1974. Fatty acid composition of depot fat as related to the effect of supplemental dietary copper on the specific activities of fatty acyl desaturase systems. Can. J. Anim. Sci. 54:23.

Ho, S.K., J.I. Elliot and G.M. Jones. 1975. Effects of copper on performance, fatty acid composition of depot fat and fatty acyl desaturase activities in pigs fed a diet with or without supplemental copper. Can. J. Anim. Sci. 55:587.

Irie, M. 1988. Influences of supplementary soybean oil and kapok meal on characteristics of porcine fat. Jpn. J. Swine Sci. 25:125.

Irie, M. and K. Ohmoto. 1985. Hardening effect of kapok meal on fat of pigs fed with diet rich in linoleic acid. Jpn. J. Swine Sci. 22:168.

Irie, M. and K. Nishimura. 1986a. Influence of feeding garbage, slaughter age and depot site on characteristics of porcine fat. Jpn. J. Zootech. Sci. 57:642.

Irie, M. and K. Nishimura. 1986b. Effect of feeding period and dietary levels of kapok meal on porcine fat. Jpn. J. Swine Sci. 23:184.

Irie, M., K. Ohomoto and M. Sakimoto. 1984. Effects of cyclopropenoid fatty acids on soft fat pork. Final reports for research grants for meat and meat products (Ito foundation) 2:182.

Irie, M., K. Ohomoto and K. Nishimura. 1985. Standard measurements for determination of porcine soft fat pork. Final reports for research grants for meat and meat products (Ito foundation) 3:156.

Lillie, R.J., L.T. Frobish, N.C. Steele and G. Graber. 1977. Effect of dietary copper and tylosin and subsequent withdrawal on growth, hematology and tissue residues of growing-finishing pigs. J. Anim. Sci. 45:100.

Mayers, A.W. and J.P. Bowland. 1972. Effects of high levels of dietary copper on endogenous lipid metabolism in the pig. Can. J. Anim. Sci. 52:113.

Mersmann, H.J., W.G. Pond and J.T. Yen. 1984. Use of carbohydrate and fat as energy source by obese and lean swine. J. Anim. Sci. 58:894.

Moore, J.H., W.W. Christie, R. Braude and K.G. Mitchell. 1968. The effect of 250 ppm of copper in the diet of growing pigs in the fatty acid composition of the adipose tissue lipids. Proc. Nutr. Soc. 27:45A.

Moore, J.H., W.W. Christie, R. Braude and K.G. Mitchell. 1969. The effect of dietary copper on the fatty acid composition and physical properties of pig adipose tissues. Br. J. Nutr. 23:281.

Pande, S.V. and J.F. Mead. 1970. Inhibition of the stearyl coenzyme A desaturase system by sterculate. J. Biol. Chem. 245:1856.

Suttle, N.F. and C.F. Mills. 1966. Studies of the toxity of copper to pigs. Effect of protein source and other dietary components on the response to high and moderate intakes of copper. Br. J. Nutr. 20:149.

Taylor, M. and S. Thomke. 1964. Effect of high-level copper on the depot fat of bacon pigs. Nature 201: 1246.

Thompson, E.H., C.E. Allen and R.J. Meade. 1973. Influence of copper on stearic acid desaturation and fatty acid composition in the pig. J. Anim. Sci. 36: 868.

Underwood, E.J. 1977. Trace Minerals in Human and Animal Nutrition (4th Ed.). Academic Press, Inc., New York.

Watermann, R.A., D.R. Romsos, A.C. Tsai, E.R. Miller and G.A. Leveille. 1975. Influence of dietary safflower oil and tallow on growth, plasma lipids and lipogenesis in rats, pigs and chicks. Proc. Soc. Exp. Biol. Med. 150:347.