THE LIPID CONTENT OF BLOOD, LIVER, AND YOLK SAC OF THE NEWLY HATCHED CHICK AND THE CHANGES THAT OCCUR IN THESE TISSUES DURING THE FIRST MONTH OF LIFE*

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The features that distinguish the lipid metabolism of the bird from that of the mammal were pointed out in recent reports from these laboratories. In the bird, maturity brings with it an increased content of lipids in both blood and liver (1, 2), and these changes were shown to be the result of estrogenic activity (3, 4). In the course of these investigations, birds between the ages of 59 and 299 days were studied. At the present time a survey of the entire life cycle is under investigation. The present report deals with the period between hatching and 36 days of age. It is shown that the bird enters the external world with a lipemia and a fatty liver. The liver of the newly hatched bird contains enormous amounts of cholesterol, the major part of which is in the esterified form.

Although high lipid levels in the tissues of the chick embryo have been recognized for some time, the lipid metabolism of the bird during the period studied here has received very little attention. A few observations dealing with the blood fat (5) and blood cholesterol (6) of 1 and 2 day-old chicks have appeared, but the values reported are not in accord with the findings obtained in the present investigation.

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Lipid Content of Chick Tissues

EXPERIMENTAL.

Chicks were obtained from eggs produced by the single comb white Leghorn flock of the Poultry Division. They were hatched in incubators of the forced draft cabinet type with separate hatching compartments. On the 22nd day after the eggs were placed in the incubators, all healthy chicks were transferred to battery brooders kept at constant temperature, and thereafter the chicks had access to food and water. It has been noted that little or no food is eaten by chicks during the first 24 hours after hatching.

The average weights of the chicks taken for analyses are recorded in Fig. 1. Liver, blood, and yolks were pooled for analyses. No attempt was made to separate the yolk sac from its contents. Lipids were determined on the entire structure.

The data shown below were obtained from three separate experiments. In two of these blood, liver, and yolk sacs were obtained, in the third only blood.

The microoxidative procedures employed for lipid analyses of blood and liver have been recorded elsewhere (1, 2). The yolks were treated like the liver.

 Liver Lipids

The data shown in Fig. 2 represent the mean values obtained from two separate experiments. Total Lipid\(^1\)—In Experiment 1, the liver of the newly hatched bird contained from 13 to 14.7 per cent of total lipid, whereas in Experiment 2 values as high as 23 per cent were found immediately after hatching. This high lipid content did not remain for long, for in Experiment 1 a fall had already occurred by the 4th day and despite irregularities the loss of lipids from the liver became quite definite by the 6th day. Between 5.0 and 5.6 per cent of total lipids was found in the 8 day-old chick, and little change was observed during the remainder of the 16 days of Experiment 1. In Experiment 2, several chicks were also examined on the 22nd and 36th day after hatching. In these pools, values for total lipid between 1.6 and 3.2 per cent of the wet weight of the liver were noted.

\(^1\) Calculated as the sum of total fatty acids and total cholesterol.
Cholesterol—Enormous concentrations of cholesterol are present in the liver of the newly hatched chick. During the first 3 days the chick livers in Experiment 1 contained from 5.9 to 8.5 per cent of total cholesterol. In Experiment 2, the values were even higher; the maximum observed was 9.7 per cent. Cholesterol at this time may account for as much as 48 per cent of the total lipids. From the 3rd day on, the decline in the cholesterol content is rapid. In the 9 day-old chick the total cholesterol content of the liver had fallen to approximately 1 per cent, while values close to 0.5 per cent were found in the 11 day-old chick. The 22 day- and 36 day-old chick livers contained between 0.3 and 0.4 per cent of total cholesterol; these values approximate closely those found in the livers of adult birds.

The major portion of the cholesterol was in the esterified form during the early days after hatching. Values as high as 1.2 per
cent were found for free cholesterol; high values were still present as late as 3 days after hatching in Experiment 1 and as late as 5 days in Experiment 2. On the day of hatching esterified cholesterol was present to the extent of 5.4 to 5.9 per cent in the livers in Experiment 1, whereas in Experiment 2 values of 6.6 to 8.6 were found. In the 7 day-old chick the content of esterified cholesterol in the liver was still above 1 per cent. Values as low

![Graph](http://www.jbc.org/)  

**Fig. 2.** Liver lipids of the chick from the day of hatching (Day H) to 36 days of age. □ total fatty acids, ■ esterified cholesterol, ○ free cholesterol, ▲ phospholipids. The values are expressed as the per cent of the wet weight of tissue. Each point represents the average values obtained from two to five pools, each of which contained from two to four livers, the number used depending upon the weight of tissue obtained. More pools were taken from younger than from older chicks.

as those found in the mature bird do not appear until the chick attains an age of 14 days or more.

***Total Fatty Acids***—The liver of the chick is particularly rich in fatty acids during the first 7 days after hatching. In Experiment 1, the highest value, namely 10.4 per cent, was found in 4 day-old chicks, but in Experiment 2 values of 14.0 and 12.7 per cent were noted during the first 24 hours after hatching. High values may still be present as late as 7 days after hatching, although—to
judge by the average values (Fig. 2)—the liver loses fatty acids rapidly during the first 7 days after hatching. Fatty acids continue to be lost thereafter, but the rate at which this occurs is much slower and more irregular between the ages of 7 and 22 days than between the time of hatching and the age of 7 days.

Shift in Liver Fatty Acids from Cholesterol Esters to Triglycerides during Early Days after Hatching—The fatty acids combined as phospholipid, triglycerides, and cholesterol esters have been calculated for the chick liver and shown in Fig. 3. Phospholipid fatty acids remained essentially constant throughout. Between the 2nd and 7th day after hatching, a rise in the triglyceride fatty acids was found in the liver. This occurs simultaneously with a rapid loss of cholesterol fatty acids. Apparently, during the utilization of cholesterol esters in the liver, the fatty acid portion is converted to triglycerides. It can be observed from Fig. 2 that the various lipid constituents do not fall at the same rate; this shift in fatty acids from cholesterol esters to triglycerides is in keeping with the finding of a more precipitous fall in esterified cholesterol than in total fatty acids.

Phospholipids—This lipid constituent showed no major change
Lipid Content of Chick Tissues throughout the period studied. Thus in Experiment 1 phospholipids were present to the extent of 1.6 to 2.5 per cent in the

**Table I**

**Blood Lipids of Chick**

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* Mainly neutral fat fatty acids (see the legend of Fig. 3).
† Day of hatching.

livers of the newly hatched chicks, whereas in the 16 day-old bird values of 2.2 to 2.4 per cent were found. The 36 day-old bird contained 2.7 to 2.8 per cent phospholipid.
Blood Lipids

The lipid concentration of the blood is particularly high during the first 4 days after hatching (Table I). Values for total lipid well over 1000 mg. per 100 cc. of whole blood were found during this interval. By the time the chicks reached an age of 15 days, the level of the total lipids in the blood fell to 452 mg. On the day the chicks were hatched, values of 284 to 326 mg. were observed for total cholesterol, while in the 8 day-old chick it had dropped to 143 to 154 mg. As much as 50 per cent of the cholesterol was in the esterified form during the early days but the ratio of ester to total cholesterol fell as the chick grew older. Phospholipids were also present in increased amounts during the early days after hatching. Values between 410 and 446 mg. were found on the day of hatching.

Yolk Sac

The yolk sac is a diverticulum of the small intestine and weighs approximately 5 gm. in the newly hatched chick. Yolk material is absorbed directly from the sac into the blood stream. Absorption proceeds rapidly after the bird is hatched, and normally by the 3rd day the weight of the sac is reduced to about 1 gm. The absorption of this structure is practically complete 5 days after the chick has hatched, but small remnants of the sac often persist much longer.

The content of cholesterol, phospholipid, and fatty acids, measured as percentage of the wet weight of this organ, is recorded in Fig. 4. The yolk sac at the time of hatching contained 11 per cent of fatty acids (Fig. 4) or a total of about 0.5 gm. (Figs. 4 and 5). The other lipid constituents were present in much smaller amounts. At the time of hatching, the entire yolk sac contained about 0.07 gm. of phospholipid and about 0.06 gm. of total cholesterol. So rapidly does the absorption of fatty acids proceed that, by the 5th day after the chick has hatched, less than 0.03 gm. of this lipid constituent remains in the entire yolk sac. The loss in fatty acids occurs not only in absolute amounts contained in the entire sac but also in the amount present as percentage of the wet weight of the organ. The loss in cholesterol
FIG. 4. The lipids of the yolk sac from the day of hatching (Day H) to 8 days of age. ■ total fatty acids, ● esterified cholesterol, ○ free cholesterol, ▲ phospholipid. The values are expressed as per cent of the wet weight of the yolk sacs.

FIG. 5. The average weights of the yolk sacs and livers from the day of hatching (Day H) to 8 days of age. ▲ yolk sac, ○ liver.
and phospholipid occurs in a less striking manner. Little or no change was observed in free cholesterol during the first few days after hatching when this lipid constituent was measured as percentage of the wet weight of the yolk sac, but some loss in absolute amount did occur, since this organ was rapidly shrinking in size. Phospholipids decreased in both the total amount present and the amount measured as percentage of the wet weight of the yolk sac. The cholesterol esters of the yolk sac showed decreases in absolute amounts, but when the amounts of this lipid constituent were expressed as percentage of the organ, it was noted that a rise had occurred (Fig. 4). This suggests that the removal of cholesterol esters from the yolk sac is proceeding less rapidly than that of other constituents.

**DISCUSSION**

The chick emerges from the egg with large deposits of lipids in three tissues, liver, yolk sac, and blood. The rapid loss of these lipid stores affords an opportunity for comparing the utilization of the various lipid constituents of these three tissues. Phospholipids, cholesterol, and triglycerides (neutral fat) do not leave the tissues at the same rate. Triglycerides are most rapidly removed from the yolk sac, and this results in a relative—though not absolute—increase in the percentage of ester cholesterol. The liver behaves differently. In this tissue, esterified cholesterol is most rapidly removed. The fatty acids combined with cholesterol are not as rapidly removed but reappear temporarily as triglycerides in the liver. Thus at a time when the chick's liver is being rapidly depleted of its large store of cholesterol, an absolute increase in neutral fat is found in the liver, an observation that suggests that esterification serves merely for storage of cholesterol.

The mechanism by which the fatty liver and lipemia are produced in the newly hatched chick remains to be considered. During its development the chick is nourished by the yolk, which is unusually rich in both fat and cholesterol. A rough parallel may be observed between the time of disappearance of the yolk sac after hatching and the time of disappearance of excessive amounts of fat from both blood and liver (compare Figs. 2 and 5). This suggests that the high content of cholesterol in the yolk
contributes to the fatty liver and lipemia found in the chick. Okey and Yokela (7) reported that rats fed egg yolk or purified cholesterol for as long as 60 days had fatty livers containing as much as 26 per cent fatty acids and 8 per cent cholesterol, over 90 per cent of which was esterified. The striking similarity between this type of fatty liver and that observed in newly hatched chicks lends support to the view that cholesterol is responsible for the fatty liver of the chick. Still another factor may play a part in the production of the high lipid content of the chick tissues. It has been reported by several investigators (8–10) that appreciable quantities of estrogens are present in the yolk. It was previously observed in these laboratories that the injection of estrogens in immature birds results in a lipemia similar to that found normally in laying birds (4); the estrogens present in the egg yolk may thus be responsible for the lipemia of the baby chick. A fatty liver is also observed in the laying bird (2). But, judging from the distribution of the various lipid constituents in the liver, the fatty liver of the baby chick resembles more closely the fatty liver of the cholesterol-fed rat.

SUMMARY

The lipid content of the blood and liver of the chick was investigated during the first 36 days after hatching.

1. The liver of the newly hatched chick contained an average of 7.3 per cent cholesterol (90 per cent of which is esterified) and 9.0 per cent total fatty acids.

2. The blood of the newly hatched chick contained as much as 1000 mg. of total lipid per 100 cc. of whole blood. All lipid constituents, namely cholesterol, total fatty acids, and phospholipids, were present in amounts greater than in the blood of the mature male and mature non-laying female bird.

3. A rapid decline in the lipid content of blood and liver set in on the 3rd day after hatching. The rapid fall in esterified cholesterol in the liver was associated with a temporary rise in triglycerides.

4. When the chicks were hatched, the yolk sacs contained about 12 per cent fatty acids, 1.6 per cent phospholipid, and 1.3 per cent total cholesterol. Their absorption proceeded rapidly and was
nearly complete by the time the chicks were 5 days old. Neutral fat was absorbed more rapidly than the other lipid constituents.

BIBLIOGRAPHY

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