The distribution of fatty acids in the triglycerides of the Artiodactyla (even-toed animals)

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SUMMARY The distribution of fatty acids in the triglycerides of a number of Artiodactyla (animals with an even number of toes) has been determined. In confirmation of earlier reports, palmitic acid was found predominantly in the 2-position of the triglycerides of the domestic pig. The same pattern was found to exist in the European and American wild boar and also in two species of peccary. In the other members of this group of animals, the palmitic acid was either approximately randomly distributed among all three positions or the 1- and 3-positions contained more of this acid than did the 2-position. In all species, only small amounts of stearic acid were esterified at the 2-position. Myristic acid, although present in only small amounts, tended to concentrate in the 2-position. No apparent pattern of distribution of the unsaturated acids was noted. The relationship of the distribution of palmitic acid to the origin of the various families of animals is discussed.

The Artiodactyla, although commonly referred to as cloven-hooved animals, are, more properly, animals with an even number of toes. Among the animals in this order is the domestic pig. Several years ago it was reported (1–3) that the palmitic acid in the triglyceride of pigs was found almost exclusively in the 2-position. In the few other species that have been studied, the distribution of saturated acids differed sharply from that in the pig (3–5). However, in many of these studies the saturated fatty acids were reported as a class, no differentiation of the individual acids being made. To determine whether the domestic pig is indeed unique in the manner in which it deposits palmitic acid, we have determined the fatty acid distribution in the triglycerides of a number of species of the artiodactyla.

EXPERIMENTAL METHODS

Fats from the following animals were used in this study. The numbers correspond to those given in Table 1.

Domestic pig, *Sus scrofa*. *1.* From local slaughter house. *2.* From a domestic pig raised on a diet containing 25% of safflower seed oil.

Wild boar, *Sus scrofa*. *3.* From Switzerland. *4.* From New Hampshire.

Peccary. *5. Peccari angulatus bangsi* from Panama. *6. Peccari tajacu* from Texas.

Hippopotamus. *7. Hippopotamus amphibius* from Kenya.

Camel. *8. Camelus* from New York Zoo.

White-tailed deer. *9. Odocoileus virginianus* from Michigan.

Sheep. *10. Ovis musimou* from local slaughter house.

Beef. *11. Bos taurus* from local slaughter house.

Samples of both subcutaneous and peritoneal fat were obtained from the Panamanian peccary. The fatty acid composition and distribution were essentially the same in both samples. These results are in agreement with those in an earlier report (5) that the anatomical location from which adipose tissue is taken does not influence the distribution of fatty acids on the triglyceride molecule.

Adipose tissue obtained from the animals listed above was extracted with ethyl ether. Triglycerides were isolated from this extract by silica gel chromatography (6). The distribution of fatty acids in the triglyceride molecule was determined by the selective hydrolysis of the ester linkages at the primary positions with pancreatic lipase (7). Fatty acid compositions of the resulting monoglyceride and the original triglyceride were determined on the methyl esters by gas–liquid chromatography under the following conditions: liquid phase, 12% (w/w) of ethylene glycol adipate polyester on 60–80 mesh, acid-washed and neutralized Chromosorb W; column length, 200 cm; temperature 200°; He flow rate, 50 ml/min, standard temperature and pressure; sample size, 0.5–5 µl; detector, thermal conductivity. Quantitative results with National Heart Institute fatty acid ester standards

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showed that values from 1 to 5% have a maximum relative error of 10%; those above 5%, a maximum relative error of 5%. The over-all relative error of the analytical values is about 7%. Since we are concerned with the distribution pattern of the major fatty acids, any fatty acid that constituted less than 1% of the total is not reported. The sum of these unreported acids varied among the species, but in no instance constituted more than 3% of the total.

RESULTS

The fatty acid distribution in the triglycerides of these various fats is shown in Table 1. For each fat, the first line gives the composition of the whole triglyceride, the second line gives the composition of the fatty acids in the 2-position of the triglyceride, and the third line (Proportion) reports the percentage of each fatty acid that is in the 2-position. If a fatty acid is randomly distributed among all three positions in the triglyceride molecule, the proportion value will be 33%. The occasional proportion value that is in excess of 100% is attributable to the large relative error where a fatty acid is present in very small amounts.

Lard (sample 1) clearly shows a high concentration of palmitic acid in the 2-position. The feeding of a large amount of safflower seed oil to a pig (sample 2) resulted in an increase in the linoleic acid content of the lard and a decrease in the level of the other acids. In spite of the decrease in the content of palmitic acid, this acid was still esterified predominantly in the 2-position.

Domestic pigs probably originated from the selective breeding of the wild boar. The distribution of palmitic acid in the wild boar, both European (sample 3) and American (sample 4), show that this specific positioning of the palmitic acid in the domestic pig is not the result of selective breeding.

The peccary, although similar in appearance to the pig, is usually assigned to a separate family. It is likely that the pig and peccary arose from a common suoid stock which differentiated into the two families during the late oligocene period. This common origin is supported by the preponderance of the palmitic acid that is esterified with the 2-position in the triglyceride of the peccary (samples 5 and 6).

Of the still existing species, the hippopotamus is probably the one most nearly related to the pig and the peccary. The hippopotamus is believed to have differentiated much earlier in time, probably near the end of the eocene period. In this species the suoid pattern of palmitic acid distribution does not occur.

The remaining species in Table 1 are of other families of the artiodactyla. In none of these is there the specific distribution of palmitic acid that is seen in the pig and the peccary.

Besides palmitic acid, only stearic and myristic acids show patterns of distribution. In all species of the present study, stearic acid is esterified predominantly at the 1- and 3-positions of the triglyceride. Although palmitic acid also tends to concentrate in the 1- and 3-positions, except in the pig and peccary, this effect is not as marked as for stearic acid. Thus the statement that saturated fatty acids are esterified predominantly with the 1- and 3-positions of nonsuoid animal triglycerides applies more clearly to stearic than to palmitic acid. Certainly myristic

TABLE 1 Fatty Acid Composition of Whole Triglycerides and of Fatty Acids at the 2-Position; and Proportion of Each Fatty Acid that is at the 2-Position

	14:0	16:0	18:0	16:1	18:1	18:2	18:3
				mmole %			
1. Domestic pig							
Triglyceride	1	28	15	3	42	9	2
2-Position	5	72	4	4	12	3	0
Proportion*	167	86	9	44	10	11	0
2. Domestic pig, "unsaturated"							
Triglyceride	1	13	8	1	20	54	3
2-Position	2	36	3	2	12	42	2
Proportion*	67	92	12	67	20	26	22
3. Wild boar, Switzerland							
Triglyceride	1	28	15	1	45	10	0
2-Position	3	74	4	2	12	4	0
Proportion	100	88	9	67	9	13	—
4. Wild boar, U.S.A.							
Triglyceride	1	25	14	3	43	13	1
2-Position	3	61	4	5	20	7	0
Proportion	100	81	10	56	16	18	0
5. Peccary, Panama							
Triglyceride	1	23	12	3	51	8	2
2-Position	5	58	4	6	20	6	1
Proportion	167	84	11	67	13	25	17
6. Peccary, U.S.A.							
Triglyceride	2	22	16	6	42	7	3
2-Position	4	61	6	9	17	3	1
Proportion	67	92	12	50	14	14	11
7. Hippopotamus							
Triglyceride	4	27	21	5	38	3	2
2-Position	3	15	6	6	63	2	4
Proportion	25	19	10	40	55	22	67
8. Camel							
Triglyceride	5	31	31	4	28	1	Tr.
2-Position	3	9	7	4	70	4	2
Proportion	20	10	8	33	83	133	—
9. White-tailed deer							
Triglyceride	3	24	31	3	36	2	1
2-Position	4	27	23	2	40	3	1
Proportion	44	38	25	22	37	50	33
10. Sheep							
Triglyceride	5	27	27	3	35	2	1
2-Position	6	14	9	5	58	6	2
Proportion	40	17	11	55	55	100	67
11. Beef							
Triglyceride	4	30	25	5	36	1	0
2-Position	8	14	8	6	61	3	0
Proportion	67	16	11	40	56	100	—

* Percentage of fatty acid type esterified with the 2-position, i.e., $\frac{\text{mole \% 14:0 in 2-position}}{3 \times \text{mole \% 14:0 in triglyceride}}$ = percentage 14:0 in triglyceride that is located in 2-position.

acid does not follow such a pattern, for it is found mainly in the 2-position.

Except in the pig and the peccary, there is a tendency for the unsaturated acids to be concentrated in the 2-position of the triglycerides. However, this specificity does not approach that seen with palmitic acid in the 2-position of the suoids or with stearic acid in the 1- and 3-positions of all the species that have been examined. Whether there is a pattern of distribution of the unsaturated acids would require the examination of many more species.

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