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INFLUENCE OF DIETARY FAT AND SHORT-TIME STARVATION ON THE COMPOSITION OF SOW-MILK FAT*)

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It is well known (*Deuel* 1955) that the amount and type of fat in the diet of ruminants can affect the amount and particularly the composition of the milk fat. The amounts of linoleic and linolenic acid in milk fat seem, however, to be very little influenced by feeding high levels of these acids (*Hilditch & Jaspersson* 1943, *Tove & Mochrie* 1963), which is claimed to be indicative of the efficiency and completeness of hydrogenation of unsaturated fatty acids by the rumen microflora.

The effect of dietary fat on the composition of the milk fat, with reference to the polyunsaturated fatty acids in particular, has been less extensively studied in monogastric animals and man. *Söderhjelm* (1953) gave diets containing sesame oil, cod-liver oil, or corn oil to women during part of the nursing period. The polyunsaturated fatty acids were determined spectrophotometrically. It was concluded that milk fat is rapidly influenced by the fat of the food. By giving fat rich in polyunsaturated fatty acids the amount of these acids increased in the milk.

Hallanger & Schultze (1957) also found spectrophotometrically that feeding vegetable oils to rats caused an increase in polyunsaturated acids in milk fat.

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The fatty-acid composition of sow's milk has only recently been the subject of more extensive studies (*DeMan & Bowland* 1963, *Lindberg & Tollerz* 1964), in which gas-liquid chromatography has been used. *DeMan & Bowland* fed to sows a basic diet containing crude fat 4.2 % and also the basic diet supplemented by stabilized tallow 15 %. The high amount of added tallow raised the fat level in the milk and influenced the fatty-acid composition of the milk fat.

Salmon-Legagneur (1963) fed to sows a diet with a high linoleic-acid content obtained by addition of corn oil 10 %. A linoleic-acid-poor diet was used as control diet. When the corn oil was fed during pregnancy alone or during the lactation period alone or when none was given, the sow-milk fat contained 14.1 %, 22.0 % and 6.2 %, respectively, of linoleic acid. Accordingly, the linoleic acid is stored in the depots during pregnancy and can then be released into the sow's milk during lactation. Polyunsaturated fat was determined spectrophotometrically.

In our earlier study (*Lindberg & Tollerz* 1964) we also found that the linoleic-acid content of the food influences the linoleic-acid content in the sow-milk fat. As the linoleic acid is a polyunsaturated fatty acid, its content in the food will increase the body's need of vitamin E and is thus an important causal factor in manifestations of vitamin-E deficiency in animals and man (reviews, *Dam* 1962, *Horwitt* 1962). We therefore decided to study more closely the relationship between the linoleic acid in the food and that in the sow-milk fat. We were further interested in finding out whether there would also be a relationship between the linolenic-acid content of the milk fat and that of the food.

The fat in the first few days' milk seems to resemble the depot fat more than does the fat in later milk. When deficient calories are fed to a lactating woman (*Insull et al.* 1959) or to cows (*Smith & Dastur* 1938), the milk-fat pattern also comes closer to the composition of depot fat. The effect of short-time starvation upon the fatty-acid composition of sow-milk fat was therefore investigated in two experiments.

MATERIAL AND METHODS

Diets.

Six different diets were used (Table 1). The gestation diet A and the lactation diet B, which were also used in the previous investigation, were commercially available mixtures.

Diets F, G, H, and I were prepared at the laboratory; diet F was obtained by adding 6.3 % cottonseed oil and diet G by adding 6.3 % linseed oil to diet B. Diets H and I contained 5 % and 16.7 % cottonseed oil, respectively. The diets were given twice a day in such quantities that the troughs were only exceptionally cleared of all the food. This arrangement meant ad-lib. feeding, and any changes in the sows' appetite could be easily discovered. Water was accessible separately.

Table 1. Composition of the diets (per cent by weight) fed to the sows. Adequate amounts of Ca, P, and trace elements were added.

	Diets					
Ingredients	A*)	B*)	F	G	H	I
Barley	33	44	41	41	39	34
Oats	37	28	26	26	39	34
Wheat bran	15	5	5	5		
Skim milk powder					17	15
Oilseed meal, fish and meat meal	10	20	19	19		
Alfalfa leaf meal	5	3	3	3		
Cottonseed oil			6.3		5	16.7
Linseed oil				6.3		

*) The figure may vary between ± 5 % of absolute amount of each ingredient. Guaranteed to contain no less than 3.0 I.U. of vitamin A, 0.2 I.U. of vitamin D, 2.0 γ of vitamin B_2 and 4.5 γ d,l-alfatocopheryl acetate per g of mixture.

Animals and methods.

The sows in the study belonged to the Swedish Land Breed or were crosses between this and the English Large White Breed. They had their first litters. Milk was obtained by stripping a teat while the sow was normally nursing her litter. No artificial stimulation of milk-release was used. A milk volume of 1 to 3 ml was usually obtained. All the sows appeared to be in good health during the experimental period. Some of them showed poor appetite for about a day following the addition of oil to their food.

From the age of 3 or 4 weeks the sucking-pigs had free access to food in troughs separated from the sows.

The effect of the cottonseed oil in diet F and of the linseed oil in diet G on the fatty-acid composition of the milk fat was studied each in one sow (nos. 10 and 13). The respective oil was in each case added to the basic diet B during two parts of the lactation period. The times of diet changes and milk-sampling are shown in Tables 3 and 4. In milk from sow no. 10, polyunsaturated fatty acids were determined and total fatty acids were then calculated.

The effect of a larger amount of cottonseed oil in the diet upon the content of the linoleic acid in the milk fat was tested in one sow (no. 17) after the end of a starvation experiment (see below). The 5 % cottonseed oil content in diet H was changed to 16.7 % (diet I). After one week on this diet, milk samples were taken from the sow on three consecutive days.

Two sows (nos. 17 and 18) were used for the starvation experiments. Diet was withdrawn for about 30 hours but water was available. Milk samples were taken before, during and after the starvation period (Tables 6 and 7). Sow no. 18 became rather nervous and uneasy when she had no food, and it was difficult to obtain milk from her. Fewer samples were therefore taken from her than from sow no. 17.

The two sows were given diet H from 6 and 13 days, respectively, before farrowing. Weighed lipids and weighed methyl esters were determined in milk from sow no. 17 but not from no. 18.

Methods for extraction of lipids, preparation and identification of methyl esters and calculation of their composition, and determination of polyunsaturated fatty acids (PFA) and total fatty acids (TFA) have been described elsewhere (*Lindberg & Tollerz* 1964, *Lindberg, Bingefors et al.* 1964). The gas-liquid chromatography (GLC) was done with a 2-metre, 5 mm ID standard column P with 20 wt-% polydiethylene-glycol succinate on 60/80 mesh chromosorb. Column temperature 208°C. Carrier gas (He) inlet pressure 1 kg/c. cm, flow rate 100 ml/min. Sample volume 0,3—1 μl.

The fatty acids are numbered according to chain length (number before colon) and double-bond content (number after colon). Thus, linoleic acid is C 18:2 and linolenic acid C 18:3.

The following acids were determined: C 14:0, C 16:0, C 16:1, C 18:1, C 18:2 and C 18:3. They represent more than 95 % of all fatty acids in sow-milk fat.

The individual fatty acids are, as earlier, expressed as area per cent of the total area for all fatty acids as determined by GLC. These values correspond closely to the weights of the methyl esters (*Brenner et al.* 1959).

Weighed lipids (WL), weighed methyl esters (WME), TFA, and PFA are expressed as per cent by weight of milk and dry substance, respectively.

The errors of the methyl-ester, fat-content, and PFA analyses and the methods of their determinations are reported elsewhere (*Lindberg & Tollerz* 1964; *Lindberg, Bingefors et al.* 1964). The statistical treatment of the material was made by conventional methods. The significance levels of $0.05 > P > 0.01$, $0.01 > P > 0.001$, and $P < 0.001$, found by the t-test, are indicated by *, **, and ***, respectively.

RESULTS

A. Dietary-fat analyses.

The employed diets were analyzed for fatty-acid composition and fat content (Table 2). With respect to its fatty-acid pattern, cottonseed oil resembles on the whole diet B, and so the addition

Table 2. Fatty-acid composition of diets and oils and polyunsaturated fatty acids and weighed methyl esters of diets. Diets F and G were prepared by adding 6.3 % cottonseed and linseed oil, respectively, to diet B, and diets H and I by adding 5 % and 16.7 % cottonseed oil in a basic diet.

Fatty acid	Diets						Oils	
	A	B	F	G	H	I	cotton-seed	lin-seed
C 14:0	1.0	0.8	0.9	0.3	0.7	1.0	1.0	0.1
C 16:0	19.2	19.6	25.8	10.0	25.6	26.1	27.0	6.8
C 16:1	1.2	0.9	0.7	0.7	0.5	0.6	0.6	0.5
C 18:0	1.7	2.1	2.0	2.8	1.7	2.0	2.1	3.2
C 18:1	20.7	22.2	17.0	17.8	21.2	17.8	16.6	17.1
C 18:2	50.6	47.3	51.2	22.7	49.3	51.6	51.9	14.1
C 18:3	5.6	7.1	2.3	45.7	1.0	0.8	0.8	58.2
PFA	1.72	1.24	4.79	6.13	3.92	10.69		
WME	2.8	2.3	7.8	8.3	6.8	18.5		
TFA	3.1	2.3	9.0	9.0	7.8	20.4		

of this oil to diet B has fairly little effect on the fatty-acid composition of the food. The dietary fat (TFA) is thus increased from 2.3 % to 9.0 % with an approximately similar fat composition. An exception is the linolenic acid which is only sparcely present in cottonseed oil (0.8 %). By the addition of oil the linolenic-acid content therefore decreases from 7.1 % to 2.3 %. As this decrease by 4.8 %, is counterbalanced by an increase in linoleic acid by 3.1 % the relative amount of polyunsaturated fat remains virtually unchanged.

The fatty-acid composition of linseed oil deviates markedly from diet B, and thus causes a considerable rise in the content of linolenic acid in the dietary fat (from 7.1 % to 45.7 %) mainly at the cost of C 16:0 and linoleic acid.

B. Milk analyses.

The oil supplements to diet B obviously affects the fatty-acid composition of the milk. The most striking effects of the addition of cottonseed oil on the fatty-acid pattern is an almost twofold rise in the linoleic-acid content (Table 3) (from 11.7 % to 20.5 %), which is parallelled by a decrease of acids shorter than C 18 (from 50.3 % to 38.1 %), notably of C 16:1 (from 13.1 % to 6.6 %). The increase of linoleic acid in the milk fat shows that the dietary content of this acid has a much greater direct influence on the composition of the milk fat than have C 14, the C 16 acids and C 18:1.

Since the linoleic acid is the predominant polyunsaturated fatty acid, the rise of the PFA value will approximate the increase of the linoleic acid.

Although they are fairly sparse, the values for TFA show that the almost fourfold increase in dietary fat is not parallelled by any distinct great increase in the fat content of the sow's milk.

The addition of linseed oil raised the linolenic-acid content in the milk fat from 1.1 % to 18.3 % (Table 4), whereas the contents of the other fatty acids decreased to varying extents, with the exception of the linoleic acid which, although its level in the dietary fat fell from 47.3 % to 22.7 %, remained unchanged in proportion to the sow-milk fat. Accordingly, there is also an intimate relationship between the linolenic-acid content in the milk fat and that in the diet.

The fatty-acid composition of the milk fat shows a striking ability to adjust itself to the dietary changes, which will be most clearly illustrated by the linoleic and the linolenic acids. On day 19, the day after the addition of cottonseed oil, and on days 20 and 34, four and three days, respectively, after the addition of linseed oil (Tables 3 and 4), the adjustment to the new diet seems to be complete. Similarly, the milk-fat pattern characteristic

T a b l e 3. Analysis of milk from sow no. 10, given cottonseed oil. Day 0 is the day of farrowing.
[1]) Control sample in the statistical calculations.

	Diet	Exchange of diet day	Day of milk sampling	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	TFA	PFA	Sum of C 14 and C 16 acids	Sum of all C 18 acids
		(—2)												
	F (cotton-seed oil)		5	3.4	31.5	6.6	5.6	28.4	22.8	1.1	5.8	1.37	41.5	57.9
			7	3.5	33.7	7.8	5.4	23.9	23.7	1.4	7.8	1.96	45.0	54.4
			9	3.2	30.0	6.7	5.8	36.1	16.9	0.5	9.6	1.67	39.9	59.3
			11	2.8	27.2	4.8	7.1	41.5	15.8	0.4	—	—	34.8	64.8
		11												
	B		15	3.4	29.3	10.5	4.5	37.7	13.6	0.4	6.7	0.93	43.2	56.2
			17	4.6	36.9	13.5	3.8	29.8	8.7	0.6	8.4	0.78	55.0	42.9
		18												
	F		19	3.5	26.5	7.2	4.8	36.8	19.2	0.7	8.0	1.59	37.2	61.5
			21	2.8	27.5	5.7	5.1	34.7	22.5	0.9	—	—	36.0	63.2
			23	3.0	26.1	7.4	4.0	40.7	17.0	1.0	7.6	1.37	36.5	62.7
			26	3.5	24.0	6.4	5.1	32.4	26.4	1.5	7.0	1.95	33.9	65.4
		27												
	B		30	4.9	33.0	14.5	3.1	30.8	11.3	1.0	8.0	0.99	52.4	46.2
			36	3.2	33.8	13.9	2.9	32.8	12.0	0.5	—	—	50.9	48.2
			47	3.6	33.6	12.9	2.9	32.9	12.8	0.8	6.5	0.88	50.1	49.4
				*		***	**		***			***	***	***
Mean n=8	F			3.21	28.31	6.58	5.36	34.32	20.54	0.94	7.63 (6)	1.65 (6)	38.10	61.16
Mean n=5	B[1])			3.94	33.33	13.06	3.44	32.80	11.68	0.66	7.40 (4)	0.90 (4)	50.33	48.58
Mean (4 sows) (*Lindberg & Tollerz* 1964)	B			3.94	30.84	11.85	3.71	36.05	11.43	0.70	7.33 (3 sows)	0.83 (3 sows)	46.63	51.89

Table 4. Analysis of milk from sow no. 13, given linseed oil. Day 0 is the day of farrowing.
[1]) Control sample in the statistical calculations.

	Diet	Exhange of diet on day	Day of milk sampling	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	Sum of C 14 and C 16 acids	Sum of all C 18 acids
		0										
	B		5	5.0	31.2	17.2	3.1	28.9	11.2	1.0	53.4	44.2
			8	3.8	34.8	16.0	4.4	28.9	9.4	0.8	54.6	43.5
			12	2.6	28.7	8.0	5.9	40.3	12.4	1.1	39.3	59.7
			15	3.0	30.1	9.5	4.2	38.6	12.5	1.1	42.6	56.4
		16										
	G (linseed oil		18	2.8	23.0	6.9	4.0	44.5	10.6	7.4	32.7	66.5
			20	3.2	29.6	9.5	3.1	22.0	12.7	19.0	42.3	56.8
			22	2.4	22.3	6.5	3.4	39.0	9.5	16.5	31.2	68.4
		23										
	B		24	3.4	38.1	12.4	3.8	27.0	10.0	3.7	53.9	44.5
			26	3.9	33.7	14.7	2.2	32.4	10.7	1.1	52.3	46.4
			30	3.7	34.4	15.1	2.5	32.6	9.7	0.9	53.2	45.7
		31										
	G		32	3.6	34.3	10.7	2.6	29.3	10.0	8.2	48.6	50.1
			34	3.5	30.8	8.9	2.7	25.7	10.9	16.9	43.2	56.2
			36	2.7	28.0	7.8	3.0	21.7	13.3	22.5	38.5	60.5
			45	2.5	28.2	8.0	3.6	27.2	12.6	16.8	38.7	60.2
		46										
	B		50	3.3	31.5	14.5	2.5	33.8	11.2	1.6	49.3	49.1
Mean n = 5. Days 18 and 32 are excluded	G			2.86	27.78*	8.14**	3.16	27.12	11.80	18.34***	38.78**	60.42**
Mean n = 7. Day 24 is excluded	B[1])			3.61	32.06	13.57	3.54	33.64	11.01	1.09	49.24	49.28
Mean n = 3. Days 26, 30, and 50	B			3.63	33.20	13.43	2.40	34.27	10.53	1.20	50.26	48.40
Mean (4 sows) (*Lindberg & Tollerz* 1964)	B			3.94	30.84	11.85	3.71	36.05	11.43	0.70	46.63	51.89

of diet B was obtained within three days of the withdrawal of cottonseed oil on day 27 and of linseed oil on day 23.

The supplements of oil to the food did not seem to have any lasting effect on the fatty-acid composition of the milk fat. After the days of adjustment following the withdrawal of the oil, a milk fat is obtained which greatly resembles that obtained earlier by the same diet (*Lindberg & Tollerz* 1964) and which, for the sake of comparison, is also shown in Tables 3 and 4.

Feeding a diet containing 16.7 % cottonseed oil (diet I) for about one week resulted in a milk fat that contained 27.1 % (range 25.1—29.5, n=3) of linoleic acid, 9.6 % (range 8.7—10.7, n=3) of TFA, and 9.7 % (range 9.0—9.8, n=3) of WME. By this increase of the cottonseed oil supplement to the diet, the sow's ability to enriche the linoleic acid in the milk fat is thus accentuated.

Table 5. Linoleic-acid content in diets and in milk fat from sows given different diets.
[1]) Calculated from TFA and percentage of linoleic acid in diet fat.

Diet started on day ( ) Day 0 is the day of farrowing	Linoleic acid in			Number of	
	diet fat %	diet g/kg of dry substance[1])	milk fat %	sows	deter-minations (total)
C (0)	54.8	9	7.7	2	23
B (0)	47.3	11	11.5	4	28
G (+16)	23.2	20	11.8	1	5
E (—42)	43.3	28	16.4	1	3
D (—42)	45.7	29	20.8	1	3
H (—10)	49.3	38	19.8	2	10
F (—2)	49.7	46	20.5	1	8
I (+41)	51.6	105	27.1	1	3

Table 5 shows a survey of the amounts of linoleic acid in all diets used in this and the previous study as well as the linoleic-acid content produced in the sow-milk fat by the respective diet. On the whole, the linoleic-acid content obtained in the milk fat rises when the amount of linoleic acid in the diet is increased.

Starvation for about 30 hours caused a change in the composition of the sow-milk fat to the effect that the content of C 18:1, in particular, increased and the content of C 16:0 decreased (Table 6). C 18:0 also tended to increase. The milk fat was

Table 6. Sow no. 17. Effect of starvation on fatty-acid composition of milk.
[1]) Control sample in the statistical calculations.

Milk sampling			C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	weighed lipids	weighed methyl esters	Sum of	
day	hours after the beginning of starvation	hours after the end of starvation										C 14 and C 16 acids	all C 18 acids
9			2.6	31.8	3.2	9.9	31.5	19.5	0.6	8.0	6.4	37.6	61.5
12			2.2	29.9	3.2	10.0	37.5	15.8	0.7	9.6	8.1	35.3	64.0
18			4.0	35.2	6.0	5.5	29.9	17.8	0.6	6.7	6.2	45.2	53.8
30			4.4	39.9	4.0	5.7	22.0	22.6	0.6	7.1	6.4	48.3	50.9
33			4.1	34.1	5.7	5.5	32.5	16.5	0.6	9.0	8.0	43.9	55.1
37	0		3.3	33.7	3.6	5.7	27.1	24.9	0.8	8.7	8.3	40.6	58.5
	3		4.1	38.3	4.8	5.6	24.8	20.4	0.9	7.8	6.4	47.2	51.7
	7		3.8	34.7	4.0	6.5	28.0	21.5	0.6	9.2	8.2	42.5	56.6
	13		3.5	30.7	3.8	7.4	37.8	15.2	0.5	—	—	38.0	60.9
38	19		2.0	25.4	3.4	8.3	45.9	13.7	0.7	8.3	7.4	30.8	68.6
	25		1.9	26.3	3.4	7.8	46.1	13.3	0.5	9.1	8.0	31.6	67.7
	29	0	1.8	28.1	3.0	9.2	41.0	15.5	0.8	7.9	7.1	32.9	66.5
		7	3.2	35.0	3.2	6.9	31.8	18.7	0.5	8.8	7.9	41.4	57.9
39		20	3.7	37.1	4.6	6.0	29.1	17.9	0.7	8.5	8.1	45.4	53.7
		25	4.9	38.5	5.4	5.9	28.6	15.2	0.5	7.1	6.7	48.8	50.2
40		43	4.1	36.0	6.3	5.6	33.0	13.8	0.4	6.3	5.7	46.4	52.8
Mean/n=6/ before[1]) starvation			3.43	34.10	4.28	7.05	30.08	19.52	0.65	8.18	7.23	41.82	57.30
Mean/n=3/ Hours 19, 25, and 29 during starvation			1.90**	26.60***	3.27	8.43	44.33***	14.17	0.67	8.43 (3)	7.50 (3)	31.77**	67.60**
Mean/n=4/ after[1]) starvation			3.98	36.65	4.88	6.10	30.62	16.40	0.53	7.68	7.10	45.51	53.65

Table 7. Sow no. 18. Effect of starvation on fatty-acid composition of milk.
[1]) Control sample in the statistical calculations.

Milk sampling: day	hours after the beginning of starvation	hours after the end of starvation	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	Sum of C14 and C16 acids	Sum of all C18 acids
4			3.8	32.9	4.2	7.4	26.5	23.1	0.7	40.9	57.7
12			4.7	38.6	5.5	5.8	24.4	19.2	0.6	48.8	50.0
24			4.5	37.4	3.3	6.3	24.4	22.6	0.7	45.2	54.0
31	0		3.4	32.2	5.0	6.7	35.7	15.2	0.8	40.6	58.4
	3		2.8	32.2	2.5	8.6	27.0	25.4	0.7	37.5	61.7
	7		2.8	32.5	2.4	8.8	28.2	24.1	0.6	37.7	61.7
32	24		2.2	30.1	2.2	9.8	32.8	21.6	0.8	34.5	65.0
	30	0	1.8	29.5	2.3	10.7	35.3	19.0	0.7	33.6	65.7
33		18	3.1	34.5	2.7	6.7	27.7	23.9	0.6	40.3	58.9
		23	3.4	35.4	2.8	6.2	27.3	23.8	0.3	41.6	57.6
34		41	3.6	35.2	3.9	5.2	31.3	19.7	0.3	42.7	56.5
Mean/=4/ before[1]) starvation			4.10	35.27	4.50	6.55	27.75	20.03	0.70	43.88	55.03
Mean/=2/ Hours 24 and 30 during starvation			2.00	29.80*	2.25	10.25***	34.05	20.30	0.75	34.05**	65.35**
Mean/n=3/ after[1]) starvation			3.37	35.03	3.13	6.03	28.77	22.47	0.40	41.53	57.67

further affected so that the long fatty acids became more dominant at the cost of the shorter ones, C 14 and C 16 (Tables 6 and 7). Because of the difficulties in collecting milk-samples from sow no. 18, only a few analyses were made. Despite this, significant responses of the milk-fat composition to starvation were obtained in some acids.

The tendency of the changes in the fat was identical in sows nos. 17 and 18 for all the acids except linoleic acid.

DISCUSSION

The linoleic acid is essential, that is, it must be supplied in the diet in order to meet the requirements of the body. This holds not only for pigs (*Witz & Beeson* 1951) but also for many other animal species and for man (*Aaes-Jørgensen* 1961). The occurrence of biosynthesis of linoleic acid in the organism, including the udder tissue, has not been shown, but it is, nevertheless, possible that such a synthesis may occur, though on a very small scale. The linoleic acid is partly stored in the fat depots and partly conversed to arachidonic acid (*Olsson* 1959). Many details of the metabolism of linoleic acid are obscure.

According to the present concept of the biosynthesis of milk fat (*Folley & McNaught* 1961), the major portion of C 18 acids arises from preformed fatty acids in blood-plasma. Most of the C 16 and shorter acids are believed to be synthetized through a stepwise condensation of acetyl CoA units in the mammary gland. In non-ruminants, glucose is the essential substrate for these acetate units. It is probable that all the linoleic acid in the sow-milk fat arises from preformed linoleic acid in blood-plasma which in turn comes from the digestive tract or from the reserves of linoleic acid deposited in the organism.

The intimate relationship between the linoleic-acid content of the diet and that of the sow-milk fat is seen in Table 3, and is also evident from Table 5, which shows the amounts of linoleic acid per kg dry substance of the diets used in this and the previous study, together with the linoleic-acid content in the sow-milk fat with each diet. On the whole, the linoleic acid in the milk fat rises when the amount of linoleic acid in the diet is increased.

Diet G differs markedly from the other diets because of its high content of linolenic acid.

As regards the other diets, D and E were given for a longer period before farrowing than were the rest, with the result that linoleic acid was deposited in storage, and therefore some of the linoleic acid in milk fat can derive from the depots (*Salmon-Legagneur* 1963). It is worth mentioning that all the fat in diets D and E, as well as in diet C, is provided by grain, in diet C barley, in D oats, and in E oats 78 %, and barley 22 %. The oats diets as well as the cottonseed oils diets F and H provide approximately 20 % of linoleic acid in the sow-milk fat, whereas the barley diet C provides only 7.7 % and the equally linoleic-acid-poor diet B 11.5 %.

The fat content and the fatty-acid composition of Swedish cereals do not vary much within each genus (*Lindberg, Bingefors et al.* 1964, *Lindberg, Tanhuanpää et al.* 1964). Generally therefore, sucking-pigs of oat-fed sows receive much more linoleic acid in their nourishment than do sucking-pigs of barley-fed sows.

The drastic procedure of feeding to sow no. 17 diet I containing 16.7 % cottonseed oil shows that it is possible by dietary means to raise the linoleic-acid content to at least 27 %.

When sows were fed both a linoleic-acid-poor diet and such a diet supplemented with 10 % corn oil (*Salmon-Legagneur* 1963), their milk fat contained 6.2 % and 22.0 % dienoic acids respectively, that is, approximately linoleic acid. Corn oil contains about 58 % linoleic acid (*Doerschuk & Daubert* 1948), which equals about 60 g of linoleic acid per kg corn oil. The found linolenic-acid contents in milk fat fit in well with the results set out in Table 5.

A possible explanation of the relatively low yield of linoleic acid in the sow-milk fat when diet G was fed may be that the very high linoleic-acid content displases the linoleic acid.

During starvation the supply of linoleic acid from the digestive tract ceases. The linoleic acid in the sow-milk fat will then probably emanate from the preformed linoleic acid in the blood which comes from the fat depots and which reflects the high metabolism that occurs there. It has been shown that the transport of free fatty acids in the blood is greatly increased during starvation (*Fredriksson & Gordon* 1958).

In view of the relatively small number of fatty-acid determinations during starvation, the conclusions as regards some of the fatty acids must be drawn with caution. The tendency of the changes is consistent, however, in both sows for all the fatty acids, excluding the linoleic acid which behaves non-uniformly, probably because the fat depots of the two sows may differ in linoleic-acid content. Sow no. 18 would thus have the larger reserve.

The effect of starvation on the fatty acids other than the linoleic acid is characterized by a decrease in the sum of C 14 and C 16 acids, which may be regarded as a sign of reduced synthesis of milk fat via acetate units (*Folley & McNaught* 1961) when the supply of raw material from the intestine ceases. The acid C 18:1 increases markedly, which should be interpreted as evidence of a higher uptake of preformed C 18:1 from the blood. C 18:1 is the predominant fatty acid in the depot fat (*Hilditch* 1956).

It is surprising that the fatty-acid composition of the first few days' milk (*Lindberg & Tollerz* 1964) and in the milk fat during starvation deviates in the same manner from the fatty-acid pattern in the later milk. The same fatty acids increase and the same ones decrease relatively, except for the linoleic acid which, as earlier, behaves non-uniformly. This similarity could be suggestive of a causal relationship between starvation and the fatty-acid pattern in the first few days' milk. Although the sow's appetite is, as a rule, poor in connection with farrowing, other factors relating to farrowing and beginning lactation could probably play an important role here.

Tove & Mochrie (1963) obtained very interesting results in cows by injecting cottonseed oil intravenously, thus evading conversion of the food in rumen. The effect produced in their experiments with parenteral administration of cottonseed oil was essentially strikingly similar to that obtained by the oral administration used by us: The linoleic acid increased markedly, C 18:1 was virtually unchanged, and C 14 and C 16 acids decreased in both investigations. The results did not agree for C 18:0 alone, which in cows, unlike C 18:0 in sows, is one of the larger fatty acids. If the rumen is by-passed, the biosynthesis of milk fat in the cow will evidently react in the same way as in the sow to a supplement of cottonseed oil, that is, the linoleic acid is the only fatty acid in the cottonseed oil that is incorporated direct from the blood into the milk fat in considerable amounts. As regards the deposition of preformed fatty acids in the blood, it is possible that the cow's and the sow's udders behave in a similar way.

The fat content in the sow-milk fat shows no distinct reaction to the 6.3 % supplement with cottonseed oil to the food (Table 3). With a larger number of samples it probably would have been possible to show a small difference in the fat content. In this study, however, which mainly concerns the fat composition, this would have been of less interest. It can be noted that the rise in fat content (WME), when diet H containing 5 % cottonseed oil was supplemented with further cottonseed oil up to 16.7 % of the diet, is significant ($0.01 > P > 0.001$). It has been shown earlier that the fat level in sow's milk is affected by the content of fat in the diet. Supplements with corn oil, 10 % (*Salmon-Legagneur* 1963) and with tallow, 15 % (*DeMan & Bowland* 1963) and the increase of dietary fat from 2.8 % to 27.1 % (*Wilett & Maruyama* 1946) raised the fat content by 1.4 %, 2.2 %, and 3.5 % respectively. No change of diet was however made during one and the same lactation period.

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SUMMARY

The influence of cottonseed oil and of linseed oil upon the fatty-acid composition of milk fat was each studied in one sow. Each oil was added to the basic diet in an amount of 6.3 % for two periods of the lactation. As cottonseed oil has a fatty-acid composition that is similar to that of the basic diet, the supplement with this oil will, in general, increase the same kind of fat in the diet. The linoleic-acid content in the milk fat will be nearly redoubled (11.7 % to 20.5 %) when the cottonseed oil is added. The supplement with linseed oil (of which linolenic acid constitutes about 58 %) to the food raised the linolenic-acid level in the milk fat from 1.1 % to 18.3 %. The increase of linoleic and linolenic acid is counterbalanced by a decrease of shorter fatty acids (C 14 and C 16 acids). The fatty-acid composition of the milk fat adjusts itself to the dietary changes within two or three days.

By feeding a diet containing 16.7 % cottonseed oil to a sow, about 27 % linoleic acid was obtained in the sow's milk fat.

The influence of 30 hours of starvation upon the fatty-acid composition was studied in two sows. The content of C 18 acids rose during starvation and that of shorter acids (C 14 and C 16) diminished.

ZUSAMMENFASSUNG

Die Einwirkung der Diät-Fette und des kurzdauernden Hungern auf die Zusammensetzung vom Fett in der Saumilch.

Die Einwirkung des verfütterten Baumwolle-Samenöls und Leinöls auf die Zusammensetzung der Fettsäuren in der Milch, wurde jede für sich an einer Sau geprüft. Während zwei Laktationsperioden wurde von jedem Öl 6.3 % zur Basal-Diät zugesetzt. Da die Zusammensetzung der Fettsäuren im Baumwolle-Samenöl sehr ähnlich ist wie in der Basal-Diät, verursachte der Ölzusatz eine Erhöhung hauptsächlich des gleichen Öles in der Diät. Durch denselben Ölzusatz hat sich die Linolsäure im Milchfett beinahe verdoppelt (von 11.7 % bis 20.5 %). Durch Zusatz von Leinöl, das ca 58 % Linolensäure enthält, erhöhte sich die Linolensäure im Milchfett von 1.1 % auf 18.7 %.

Die Erhöhung der Linol- bzw. Linolensäure wurde durch die Verminderung der kürzeren Fettsäuren (C 14- und C 16-Säuren) gegenseitig ausgeglichen. Die Zusammensetzung der Fettsäuren im Milchfett, passt sich an das neue Futter binnen 2—3 Tagen nach Futterwechsel an.

Bei einer Sau, die an einer Diät mit 16.7 % Baumwolle-Samenöl gehalten wurde, wurden ca 27 % Linolsäure im Milchfett erhalten.

Die Einwirkung eines 30-stündigen Hungern auf die Zusammensetzung der Fettsäuren, wurde an zwei Sauen untersucht. Während des Hungerns hat sich der Gehalt an C 18-Säuren erhöht und der Gehalt an kürzeren Säuren (C 14- und C 16-Säuren) vermindert.

SAMMANFATTNING

Inverkan av dietärt fett och kort tids svält på suggmjölkfettets sammansättning.

Inverkan av tillsatser av bomullsfröolja och linolja på fettsyrasammansättningen i mjölkfettet studerades på vardera en sugga. Vardera oljan adderades till baskosten i en mängd av 6.3 % under två perioder av laktationen. Då bomullsfröoljan i sin fettsyrasammansättning mycket liknar baskosten, medför oljetillsatsen i stort sett en ökning av samma sorts fett i kosten. Genom denna oljetillsats nära fördubblades halten av linolsyra i mjölkfettet (från 11.7 % till 20.5 %). Tillsatsen av linolja, som innehåller c:a 58 % linolensyra, till kosten ökade linolensyrahalten i mjölkfettet från 1.1 % till 18.3 %.

Ökningen av linol- respektive linolensyrahalten kompenseras genom att halten av kortare fettsyror (C 14- och C 16-syror) minskar. Fettsyrasammansättningen i mjölkfettet anpassar sig inom 2 à 3 dagar efter foderbytena till de nya fodren.

Vid utfodring av en sugga med en kost innehållande 16.7 % bomullsfröolja erhölls c:a 27 % linolsyra i mjölkfettet.

Inverkan av 30 timmars svält på fettsyrasammansättningen undersöktes i två experiment. Halten av C 18-syror ökade medan halten av kortare syror (C 14- och C 16-syror) minskade.

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