

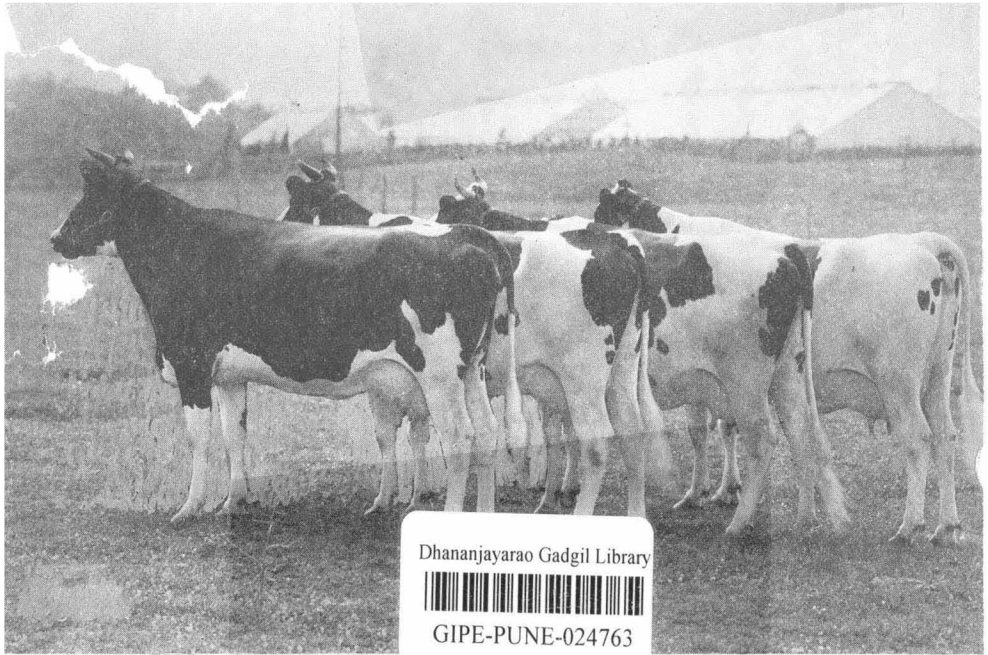
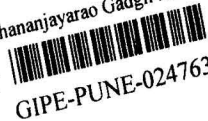
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III. Further Studies of the Influence of Different Levels of Fat Intake upon Milk Secretion

L. A. Maynard, J. K. Loosli, and C. M. McC

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CONTENTS

	PAGE
First experiment, 1938-39	3
Results	6
Second experiment, 1939-40	8
Results	10
Discussion of results	14
Summary	17
References	18

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III. FURTHER STUDIES OF THE INFLUENCE OF DIFFERENT LEVELS OF FAT INTAKE UPON MILK SECRETION

L. A. MAYNARD, J. K. LOOSLI, AND C. M. McCAY

Experiments described in previous publications from this laboratory (Maynard and McCay, 1929, 1932; Maynard, McCay, and associates, 1934; and Maynard, Gardner, and Hodson, 1939) showed that the replacement of one-half or more of the fat in a 6- or 7-per-cent-fat concentrate mixture by an isodynamic amount of starch resulted in lowering of the milk and fat yield of dairy cows. Comparison of concentrate mixtures containing 4 and 7 per cent fat (Maynard and coworkers, 1934) showed a consistent advantage for the higher fat level, but the difference could not be shown to be statistically significant. When soybeans were compared with soybean oil meal in concentrate mixtures containing approximately 3 and 6 per cent fat, the higher fat level resulted in the production of additional milk and butterfat (Maynard and coworkers, 1939). In the above-cited experiments, the low-fat mixture was obtained by solvent extraction of a high-fat supplement and incorporating this with a basal concentrate mixture. The question thus arose as to whether this finding would hold also for differences in fat levels brought about by extraction of the fat by pressure methods. It seemed desirable to eliminate the minor possibility that the previous results had been due to some undesirable residue or other harmful effect of the solvent procedure.

In the present experiments, therefore, the lower fat levels used were obtained by the inclusion of feeds from which as much of the oil as possible had been removed by either the hydraulic or the expeller method.

Two experiments involving a comparison of levels of approximately 3 per cent and 7 per cent of fat in the concentrate mixtures, carried out in different years, are reported. In the first experiment, two groups of cows, one on each level were fed continuously for a period of 14 weeks. In the second experiment the same rations and fat levels were studied by the double-reversal system. The two experiments are described separately.

FIRST EXPERIMENT, 1938-39

In this experiment a total of 16 cows were employed, 8 in each group.

The following concentrate mixtures were prepared, using the analyses of the individual ingredients as a basis in such a way that the high-fat mixture contained about 7 per cent fat and the medium-fat mixture about 3 per cent:

<i>High-fat mixture</i>	<i>Medium-fat mixture</i>
660 pounds barley	660 pounds barley
360 pounds wheat	360 pounds wheat
220 pounds beet pulp	220 pounds beet pulp
240 pounds soybean oil meal (high fat)	210 pounds soybean oil meal (low fat)

160 pounds linseed oil meal (high fat)	150 pounds linseed oil meal (low fat)
220 pounds cottonseed oil meal (high fat)	200 pounds cottonseed oil meal (low fat)
100 pounds corn germs	50 pounds corn-germ oil meal
20 pounds bone meal	110 pounds starch
20 pounds salt	20 pounds bone meal
	20 pounds salt

The two rations contained the same ingredients except that in the medium-fat mixture starch was added in an attempt to equalize the protein content. Because of this adjustment the medium-fat mixture was slightly lower in digestible nutrients, and larger quantities were fed to compensate for this difference, as is detailed later. Dried beet pulp was also fed to the higher-producing cows in both groups in order to supply sufficient digestible nutrients.

The low-fat soybean oil meal was a hydraulic product made in the regular manner with a cooker temperature of 200°F. The high-fat soybean oil meal was a blend of this meal with the unextracted meal cooked at the same temperature. The low-fat linseed oil meal was the regular hydraulic material produced at a cooker temperature of 210°F., and the high-fat meal was a blend of this meal with flax cooked at the same temperature. The cottonseed oil meals and the corn-germ meal were expeller products.

The timothy hay fed was cut in early bloom. It was fairly fine, contained about 10 per cent of clover, and corresponded to a U. S. no. 2 grade. The corn silage was well matured when cut and carried a fair number of ears. It was good-quality silage.

The analyses of the feeds used are given in table 1. The data for total digestible nutrients were calculated from average digestion coefficients.

TABLE 1. ANALYSES OF THE FEEDS USED

Feed	Crude protein	Carbohydrates		Ether extract	Digestible crude protein	Total digestible nutrients
		Crude fiber	Nitrogen-free extract			
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
High-fat concentrate mixture....	20.46	7.02	51.53	7.05	16.7	81.1
Medium-fat concentrate mixture..	19.74	7.43	54.73	3.11	16.1	76.5
Timothy hay.....	8.43	31.51	38.98	1.56	3.0	50.0
Corn silage.....	2.58	5.52	13.08	0.71	1.0	14.8
Dried beet pulp.....	8.5	18.8	60.2	1.0	4.6	71.6

The pertinent data concerning the cows used in this experiment are presented in table 2. As a basis for making up the groups for the rations to be compared by the continuous system, a number of animals, all negative to the tuberculin and the abortion tests and otherwise healthy, were provisionally selected, and their production was recorded during a preliminary period of three weeks. In so far as available, these cows were selected by pairs, which, it was hoped, might prove alike in production during the preliminary period and thus be divided between the two experimental rations. During this preliminary period, the regular herd ration was fed along with the hay and silage to be used in the experiment. On the basis of the rec-

ords obtained, two groups were selected according to the principles set forth by Maynard and Myers (1918) and Maynard (1931). Two groups of eleven cows each, the two groups having substantially the same average production of milk and fat, were thus obtained and assigned to the experimental rations by lot. As the experiment progressed, however, an udder injury necessitated the elimination of one animal, and her pair-mate in the other group was removed to balance the two groups in terms of yield at the start. Four other cows, two from each group, were removed because one cow died from a nail puncture of the heart and another cow dried up in the course of the experiment. A study of previous production of the latter cow indicated that she was not a persistent producer. The cows paired with these two were also eliminated in order to balance the two groups. These removals left 16 cows, 8 in each group, as shown in table 2, which completed the experiment satisfactorily. The elimination of animals from the groups disturbed the original equalization somewhat. In terms of yields of fat and fat-corrected milk, the final grouping favored the high-fat group slightly, but in terms of total milk production, the medium-fat group was favored. These differences were not large, as is indicated in table 2. The adjustments which were made after the groups were originally selected illustrate the hazards of the continuous system, a system which in other respects has advantages over the double-reversal procedure.

TABLE 2. COWS USED IN THE EXPERIMENT, THEIR STAGE OF LACTATION AND GESTATION AT THE BEGINNING OF THE EXPERIMENT AND THEIR PREVIOUS PRODUCTION

Group	Cow	Breed	Age			In milk	In gestation	Average daily production 3 weeks prior to beginning of experiment			
			Years	Months	Days			Days	Milk	Fat	Fat	Fat-corrected milk
							Pounds	Per cent	Pounds	Pounds	
High-fat concentrate mixture	Bettie	Holstein	3	6	107	0	46.9	3.07	1.440	40.4	
	Mead	Holstein	3	8	80	0	55.1	3.30	1.818	49.3	
	Pontiac	Holstein	9	1	101	0	61.4	3.30	2.026	54.9	
	Bluett	Ayrshire	3	1	49	0	40.0	4.02	1.608	40.1	
	Della	Jersey	5	2	36	0	53.2	5.23	2.782	63.0	
	Eva	Holstein	7	0	60	0	78.8	3.47	2.734	72.5	
	Gloria	Holstein	5	3	39	0	85.9	4.15	3.565	87.8	
	Marie	Jersey	6	7	42	0	36.4	5.03	1.830	42.0	
Average							57.21	3.95	2.226	56.25	
Medium-fat concentrate mixture	Burke	Holstein	6	4	221	0	54.1	3.25	1.758	48.0	
	Hilda	Holstein	2	6	100	0	53.7	3.20	1.718	47.2	
	Hope	Holstein	8	6	101	0	55.9	3.02	1.688	47.7	
	Barmaid	Ayrshire	3	3	53	0	39.7	4.30	1.707	41.5	
	Canary	Holstein	8	9	58	0	80.2	3.50	2.807	74.2	
	Polly										
	Dora	Guernsey	7	1	54	0	61.2	4.27	2.613	63.7	
	Opal	Holstein	7	0	56	0	75.4	3.60	2.714	70.9	
Rhythm	Jersey	5	0	42	0	41.4	5.65	2.339	51.6		
Average							57.70	3.85	2.168	55.60	

All of the cows had passed the peak of their production before the experiment started. While some had been in lactation for a considerable time, none of them had been bred, and thus a regular yield performance,

subject only to the normal drop with advancing lactation, was to be expected.

The cows were fed in accordance with the Morrison Standard recommendations for good cows. The ration of each cow was recalculated every seven days and adjusted according to her production of fat-corrected milk during the preceding week and according to her previous weight. The cows were weighed periodically. Aliquot samples of milk, taken at each of the three daily milkings, were composited for seven days and then analysed for fat by the Babcock method. Each cow received approximately one pound of timothy hay and three pounds of corn silage for each 100 pounds of body weight. The concentrate mixture was fed at such a level that it furnished one pound of total digestible nutrients for each 3.6 pounds of four-per-cent fat-corrected milk produced. To compensate for the difference in digestible nutrients, 1.06 pounds of the medium-fat mixture was fed for each pound of the high-fat mixture. Some variations from the above rules were necessitated by fluctuations in the individual appetite of some cows, and by other factors.

RESULTS

The experiment was continued for a period of 14 weeks. One cow in each group went "off feed" for one or two days, with resulting temporary drops in milk yield. The influence of this drop on the production was slight and was substantially alike in both groups; thus the validity of the data was not seriously affected. Actual feed-intake records were kept, adjustment being made for feed refused. The average daily intakes of total digestible nutrients are given in table 3, along with the theoretical requirements as calculated from the Morrison Standard. From these data it is seen that all but three cows consumed slightly more nutrients than their theoretical requirements. This was in accordance with the plan to

TABLE 3. AVERAGE DAILY INTAKE OF NUTRIENTS IN RELATION TO REQUIREMENTS BY MORRISON STANDARD AND TO FAT SECRETED

Group	Cow	Total digestible nutrients			Fat intake per pound of fat secreted
		Requirement by Morrison Standard	Actual intake	Intake per pound of fat produced	
High-fat concentrate mixture.	Bettie	23.9	24.3	16.2	1.00
	Mead	25.0	25.8	15.0	0.95
	Pontiac	27.2	28.9	14.9	0.94
	Bluett	20.7	22.4	15.6	0.94
	Della	25.4	24.5	7.1	0.59
	Eva	33.7	35.5	13.9	0.80
	Gloria	35.8	36.3	12.5	0.72
	Marie	18.4	18.6	11.0	0.72
	Average.		26.3	27.0	13.3	0.83
Medium-fat concentrate mixture.	Burke	23.8	24.2	16.6	0.66
	Hilda	23.7	24.1	14.8	0.59
	Hope	23.2	24.3	17.9	0.71
	Barmaid	21.6	22.6	14.4	0.57
	Canary	33.4	34.8	13.2	0.49
	Folly Dora	26.5	25.9	11.1	0.40
	Opal	30.9	28.7	11.1	0.40
	Rhythm	20.5	20.6	10.2	0.41
	Average.		25.4	25.6	13.7	0.53

avoid any possibility that a lowered production might result merely from a lack of a sufficient intake of total digestible nutrients. Of these three cows, two, Della and Folly Dora, were "off feed" at one time. This may be a factor in the lower intake shown. The other cow (Opal) frequently refused to consume her allowance of the timothy hay. As an average, both groups consumed more than their theoretical requirements, indicating that they were probably adequately fed during the experiment. The theoretical requirements were slightly greater for the high-fat group, and they also received a somewhat larger intake of nutrients in relation to their requirements than did the cows in the medium-fat group.

In view of the liberality of the theoretical requirements used, it is not believed that the somewhat more liberal feeding of the high-fat group could be considered a factor in their higher production, although one might expect it to be reflected in the gain in body weight. That this was so can be seen in table 4, where the average production of milk, fat, and fat-corrected milk, and the change in body weight of the cows are tabulated. All of the cows in the high-fat group gained in weight, and four of the eight cows in the medium-fat group lost weight during the experiment. In calling attention to this difference in feed intake in relation to the requirements of the two groups of cows, the small difference between the two groups should be kept in mind.

The high-fat group received from the feed 83 per cent as much fat as they secreted (table 3), while the medium-fat group consumed only 53 per cent as much fat as they gave in the milk. It should be born in mind, of course, that ether extract is here involved and that the percentage figures would be considerably smaller in terms of true fat.

TABLE 4. AVERAGE DAILY PRODUCTION OF MILK, FAT, AND FAT-CORRECTED MILK, AND CHANGE IN WEIGHT DURING THE 14-WEEK EXPERIMENT

Group	Cow	Average daily milk	Average daily fat	Average daily fat-corrected milk	Gain in weight
High-fat concentrate mixture.		<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
	Bettie	46.5	1.501	41.1	35
	Mead	50.5	1.717	46.0	15
	Pontiac	55.6	1.936	51.3	120
	Bluett	37.3	1.434	36.4	24
	Della	46.0	2.473	55.5	35
	Eva	78.8	2.550	69.8	65
	Gloria	80.6	2.894	75.6	142
	Marie	29.9	1.691	37.3	28
Average.		53.15	2.024	51.62	
Per cent of preliminary production.		92.9	90.9	91.8	
Medium-fat concentrate mixture.					
	Burke	43.7	1.458	39.3	-13
	Hilda	50.2	1.626	44.5	110
	Hope	44.0	1.355	37.9	89
	Barmaid	36.4	1.573	38.2	148
	Canary	77.4	2.641	70.6	-12
	Folly Dora	51.9	2.337	55.8	-2
	Opal	68.9	2.583	66.3	-25
	Rhythm	34.7	2.010	44.0	35
Average.		50.90	1.948	49.60	
Per cent of preliminary production.		88.2	89.9	89.2	

The high-fat group produced more milk and fat during the experimental period than did the other group of cows (table 4). The production favored the high-fat group as follows: milk, 4.4 per cent; fat, 3.9 per cent; fat-corrected milk, 4.1 per cent. In view of the fact that during the preliminary period (table 2) the high-fat group produced less milk but slightly more fat and fat-corrected milk, the production during the experimental period is also given in percentage of the preliminary production (table 4). The high-fat group produced an average of 92.9 per cent as much milk, 90.9 per cent as much fat, and 91.8 per cent as much fat-corrected milk during the experimental period as that produced during the preliminary period. The medium-fat group produced an average of 88.2, 89.9, and 89.2 per cent as much milk, fat, and fat-corrected milk during the experiment as they produced during the preliminary period. The fat percentage of the two groups of cows was practically the same during the experimental period. Thus the increase in milk yield shown by the cows fed the high-fat mixture was accompanied by a slight decline in fat test.

Further consideration is given to the significance of the results on page 15.

SECOND EXPERIMENT, 1939-40

The same concentrate mixtures were used in a second experiment to test further the effect of different levels of fat intake on milk yield by the double-reversal procedure. It seemed desirable to repeat the 1938-39 experiment, using a different procedure, to obtain additional evidence on the problem. Ten cows were divided into two groups. Group A was fed the high-fat mixture and group B the medium-fat mixture. At the end of five weeks, the concentrate rations were reversed for five weeks and then shifted back to the original basis for a final period of the same length. The system of feeding is shown below.

FEEDING SYSTEM, SECOND EXPERIMENT

Group	Period 1	Period 2	Period 3
A.....	High-fat mixture	Medium-fat mixture	High-fat mixture
B.....	Medium-fat mixture	High-fat mixture	Medium-fat mixture

The timothy hay fed was rather stemmy and contained a small percentage of weeds and grasses, but was free from legumes. It was somewhat bleached and would probably correspond to a U. S. no. 3 grade. The corn silage was well matured but contained only a fair number of ears. The analyses of the feeds as actually fed in the second experiment are shown in table 5. The figures for digestible nutrients are based on average coefficients of digestibility. A comparison with table 1 shows that the two concentrate mixtures were slightly higher in protein and lower in fat than in the first experiment.

The essential data regarding the cows are given in table 6. All of the cows had reached the peak of their lactation before they were started on the experiment. Five of the cows had been bred when the experiment was started. Two of these (Susie and Rosaline) were 22 weeks or more in gestation before the experiment was terminated, an undesirable feature but one which could not be avoided because no other cows were available.

Rosaline declined markedly in milk yield during the last few weeks of the experiment, presumably because of advanced gestation, and for that reason the data for this cow are of doubtful validity. One cow in group B sustained an udder injury during period 2 which resulted in the loss of the right rear quarter; thus the production data for this cow were discarded.

TABLE 5. ANALYSES OF FEEDS USED

Feed	Crude protein	Carbohydrates		Ether extract	Digestible crude protein	Total digestible nutrients
		Crude fiber	Nitrogen-free extract			
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
High-fat concentrate mixture....	22.06	6.75	50.95	6.72	17.4	82.6
Medium-fat concentrate mixture.	21.70	7.14	54.09	2.60	17.1	77.3
Timothy hay	5.74	28.09	41.19	1.48	2.7	46.9
Corn silage	2.39	6.67	16.32	0.55	1.3	18.7
Dried beet pulp	8.5	18.8	60.2	1.0	4.6	71.6

TABLE 6. COWS USED IN THE SECOND EXPERIMENT, THEIR STAGE OF LACTATION AND GESTATION AT THE BEGINNING OF THE EXPERIMENT, AND THEIR PREVIOUS PRODUCTION

Group	Cow	Breed	Age		In milk	In gestation	Average daily production during 4 weeks preceding start of experiment			
							Milk	Fat	Fat	Fat-corrected milk
			Years	Months	Days	Days	Pounds	Per cent	Pounds	Pounds
A.....	Belle	Holstein	3	3	196	31	62.42	3.10	1.935	53.99
	Echo	Holstein	2	8	87	0	55.51	3.67	2.037	52.76
	Dodo	Holstein	4	2	109	31	70.34	3.06	2.152	60.42
	Susie	Holstein	2	9	186	100	42.40	4.19	1.777	43.61
	Rosaline	Holstein	2	11	177	62	36.95	3.79	1.400	35.78
B.....	Mead	Holstein	4	9	92	0	65.06	3.54	2.303	60.57
	Hilda	Holstein	3	7	113	0	57.40	3.29	1.888	51.28
	Sooky	Holstein	3	10	52	0	74.19	3.19	2.367	65.18
	Mariam	Ayrshire	7	1	30	0	58.19	4.20	2.444	59.94

The general procedure of feeding and management was the same as in the first experiment. The ration for each cow was recalculated every seven days on the basis of her production of fat-corrected milk during the preceding week and her previous weight. One pound of the high-fat concentrate was fed for each 1.06 pounds of the medium-fat to compensate for the difference in total digestible nutrients. An attempt was made to feed each cow at a constant level in relation to her requirement throughout the experiment. Six of the cows were in milk with their first or second calf, and in order to insure a nutritive plane adequate for growth and milk production, these cows were fed at a level somewhat higher than the theoretical requirements based on body weight. Approximately 1 pound of hay and 3 pounds of silage were fed per 100 pounds of body weight. The hay, silage, and dried beet pulp were kept at a constant level during the experiment and the level of concentrate feeding was adjusted according to the production of fat-corrected milk.

RESULTS

The experiment was continued for fifteen weeks. Because of the relatively high plane of nutrition used there were periods when some of the cows refused small amounts of feed. A record was kept of feed not consumed in order to correct the intake data. At the start of the experiment Belle and Sooky refused to eat the experimental concentrate mixtures. Belle went "off feed" and dropped in milk yield from 64 to 40 pounds per day. Both cows were returned to the herd ration and gradually changed

TABLE 7. AVERAGE DAILY YIELD OF MILK, FAT, FAT-CORRECTED MILK, AND THE FAT PERCENTAGE DURING THREE FIVE-WEEK EXPERIMENTAL PERIODS

Group	Cow	Period	Average daily milk yield	Average fat percentage	Average daily fat yield	Average daily yield of fat-corrected milk
A.....	Belle	1. High-fat	<i>Pounds</i> 59.57	<i>Per cent</i> 3.06	<i>Pounds</i> 1.823	<i>Pounds</i> 51.17
		2. Medium-fat	61.01	2.96	1.806	51.49
		3. High-fat	60.92	3.12	1.898	52.84
		Average of periods 1 and 3	60.24	3.09	1.860	52.00
		Gain on high-fat	-0.77*	0.13	0.054	0.51
A.....	Echo	1. High-fat	55.59	3.79	2.107	53.84
		2. Medium-fat	51.23	3.84	1.966	49.98
		3. High-fat	51.40	3.94	2.025	50.93
		Average of periods 1 and 3	53.49	3.86	2.066	52.39
		Gain on high-fat	2.26	0.02	0.100	2.41
A.....	Dodo	1. High-fat	73.16	2.88	2.107	60.87
		2. Medium-fat	69.95	2.85	1.994	57.89
		3. High-fat	66.50	3.01	2.001	56.02
		Average of periods 1 and 3	69.83	2.94	2.054	58.74
		Gain on high-fat	-0.12*	0.09	0.060	0.85
A.....	Susie	1. High-fat	43.92	4.17	1.831	45.03
		2. Medium-fat	41.38	4.19	1.732	42.53
		3. High-fat	40.49	4.47	1.809	43.33
		Average of periods 1 and 3	42.20	4.31	1.820	44.18
		Gain on high-fat	0.82	0.12	0.088	1.65
A.....	Rosaline	1. High-fat	35.34	3.81	1.345	34.31
		2. Medium-fat	33.11	3.97	1.316	32.98
		3. High-fat	29.10	4.25	1.236	30.18
		Average of periods 1 and 3	32.22	4.00	1.290	32.24
		Gain on high-fat	-0.89*	-0.03*	-0.026*	-0.74*
B.....	Mead	1. Medium-fat	63.83	3.45	2.202	58.56
		2. High-fat	61.34	3.39	2.079	55.72
		3. Medium-fat	55.60	3.34	1.855	50.07
		Average of periods 1 and 3	59.71	3.40	2.028	54.31
		Gain on high-fat	1.63	-0.01*	0.051	1.41
B.....	Hilda	1. Medium-fat	64.61	3.25	2.103	57.39
		2. High-fat	63.37	3.39	2.148	57.57
		3. Medium-fat	62.39	3.15	1.966	54.45
		Average of periods 1 and 3	63.50	3.20	2.034	55.92
		Gain on high-fat	-0.13*	0.19	0.114	1.65
B.....	Sooky	1. Medium-fat	72.16	3.09	2.228	62.28
		2. High-fat	67.88	2.98	2.022	57.48
		3. Medium-fat	64.44	2.90	1.868	53.80
		Average of periods 1 and 3	68.30	3.00	2.048	58.04
		Gain on high-fat	-0.42*	-0.02*	-0.026*	-0.56*
B.....	Mariam	1. Medium-fat	58.84	3.95	2.325	58.41
		2. High-fat	57.21	4.06	2.321	57.70
		3. Medium-fat	49.08	4.06	1.992	49.51
		Average of periods 1 and 3	53.96	4.00	2.158	53.96
		Gain on high-fat	3.25	0.06	0.163	3.74
		Average gain on high-fat	0.63	0.06	0.064	1.21

*Lower yield on the high-fat mixture.

to the experimental mixtures the following week. The effect of this upon the final results is considered later. The other cows behaved in a substantially normal manner throughout the test.

The data for the average yields of milk, fat, and fat-corrected milk by periods are presented in table 7.

The two groups produced an average of 0.6 pound more milk and 1.2 pounds more fat-corrected milk on the high-fat mixture. Five of the cows produced less milk, and two cows (Rosaline and Sooky) produced less milk and less fat on the high-fat mixture. Explanations can be obtained by examining figures 1 and 2. As noted earlier in this report, it is considered that the production data for Rosaline do not afford a reliable comparison of the influence of the rations fed because of an abnormally rapid decline in milk yield during the latter part of the experiment, which was

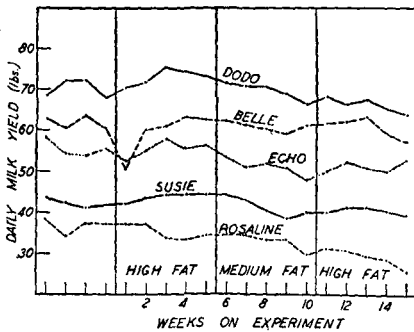


FIGURE 1. AVERAGE DAILY PRODUCTION OF MILK, BY WEEKS, OF THE COWS IN GROUP A

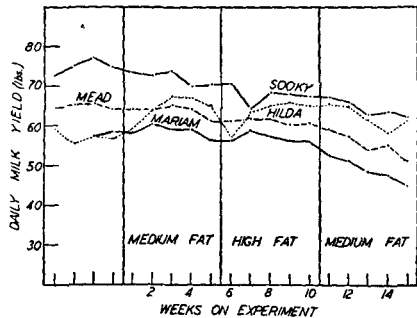


FIGURE 2. AVERAGE DAILY PRODUCTION OF MILK, BY WEEKS, OF THE COWS IN GROUP B

probably due to the stage of gestation. This decline is easily apparent in figure 1 and may explain her failure to show an advantage for the high-fat mixture. The drop in milk production experienced by Belle as the result of going "off feed" when she was first started on the test can also be observed in figure 1. This "off feed" period was obviously responsible for Belle's failure to show an average increase in milk yield when the data are considered for the five-week periods. The data for the three-week periods (table 8) are therefore considered more reliable for this cow.

The average daily milk production of the cows in group B is shown in figure 2. Sooky and Hilda showed marked temporary drops in milk yield for one week during the high-fat period. Because of this variation, both cows produced an average of less milk during the five-week high-fat period than they did during the medium-fat periods. On the basis of the last three weeks of each period, however, they produced more milk. It is not possible to account for this temporary drop in milk yield on the basis of the feed records, because the cows were not "off feed" and they showed no important digestive upset. Sooky refused small quantities of feed at this time, but it is not thought that this explains in full the decline in milk yield.

The changes from the high-fat to the medium-fat mixtures were made abruptly, and therefore the question arose as to whether the effect of one

diet carried over into the following period, or if the change in ration resulted in a temporary effect only. For this reason the data are also shown on the basis of averages of the last three weeks of the five-week periods. Calculations made on this basis, as described in detail by Maynard and McCay (1932) are shown in table 8. From these data it can be observed

TABLE 8. GAIN IN THE AVERAGE DAILY YIELD OF MILK, FAT, AND FAT-CORRECTED MILK DURING THE HIGH-FAT PERIODS, AS COMPARED WITH THE MEDIUM-FAT PERIODS

Group	Cow	Gain in milk yield		Gain in fat percentage		Gain in fat yield		Gain in yield of fat-corrected milk	
		Five weeks	Three weeks	Five weeks	Three weeks	Five weeks	Three weeks	Five weeks	Three weeks
A.....	Belle	<i>Pounds</i> -0.77*	<i>Pounds</i> 0.79	<i>Per cent</i> 0.13	<i>Per cent</i> 0.03	<i>Pounds</i> 0.054	<i>Pounds</i> 0.041	<i>Pounds</i> 0.51	<i>Pounds</i> 0.92
A.....	Echo	2.26	3.65	0.02	-0.05*	0.100	0.109	2.14	3.09
A.....	Dodo	-0.12*	1.13	0.09	0.09	0.060	0.090	0.85	1.79
A.....	Susie	0.82	2.58	0.12	0.05	0.088	0.130	1.65	2.99
A.....	Rosaline	-0.89*	-1.08*	-0.03*	-0.03*	-0.026*	-0.061*	-0.74*	-1.35*
B.....	Mead	1.63	2.37	0.01	-0.02*	0.051	0.064	1.41	1.91
B.....	Hilda	-0.13*	1.91	0.19	0.20	0.114	0.186	1.65	3.55
B.....	Sooky	-0.42*	0.87	-0.02*	-0.08*	-0.026*	-0.033*	-0.56*	-0.18*
B.....	Mariam	3.25	4.09	0.06	0.10	0.163	0.222	3.74	4.96
Average gain		0.63	1.81	0.06	0.03	0.064	0.083	1.21	1.97

*Lower yield on the high-fat mixture.

that when the cows are considered as a group, the average response was an increase in milk and fat yields when the high-fat mixture was fed, on

TABLE 9. WEIGHTS OF COWS BY PERIODS, SECOND EXPERIMENT

Cow	Period	Weight
Belle.....	1. High-fat	<i>Pounds</i> 1,390
	2. Medium-fat	1,385
	3. High-fat	1,500
Echo.....	1. High-fat	1,160
	2. Medium-fat	1,130
	3. High-fat	1,250
Dodo.....	1. High-fat	1,400
	2. Medium-fat	1,400
	3. High-fat	1,450
Susie.....	1. High-fat	1,190
	2. Medium-fat	1,260
	3. High-fat	1,300
Rosaline.....	1. High-fat	1,290
	2. Medium-fat	1,285
	3. High-fat	1,360
Mead.....	1. Medium-fat	1,440
	2. High-fat	1,400
	3. Medium-fat	1,440
Hilda.....	1. Medium-fat	1,270
	2. High-fat	1,300
	3. Medium-fat	1,400
Sooky.....	1. Medium-fat	1,280
	2. High-fat	1,320
	3. Medium-fat	1,340
Mariam.....	1. Medium-fat	1,175
	2. High-fat	1,175
	3. Medium-fat	1,200

the basis of both the five- and the three-week periods. There was no appreciable difference in fat percentage, indicating that the milk yield was primarily affected by the difference in fat content of the concentrate mixture. These data show that the increase in production which occurred on the high-fat mixture was not just a temporary increase, since the differences in favor of the high-fat mixture are more consistent and larger, on the average, for the last three weeks than for the period as a whole.

The application of Student's method to the nine pairs of values representing the yields of fat-corrected milk (table 7) show odds of 53:1 favoring significance. A similar calculation based on the last three weeks of each experimental period show odds favoring significance of the gains for the high-fat mixture of 117:1.

The weights of the cows by periods are shown in table 9. All of the cows increased in body weight during the experiment.

The intakes of digestible nutrients and fat in relation to the nutrient requirements and fat yields are tabulated in table 10. An attempt was made to keep the intake of nutrients constant for each cow in relation to her requirements during the entire experiment. This was not fully realized, and certain cows were fed at a slightly higher level during the latter

TABLE 10. AVERAGE DAILY INTAKE OF TOTAL DIGESTIBLE NUTRIENTS BY PERIODS, IN RELATION TO THE REQUIREMENTS BY MORRISON STANDARD AND TO FAT SECRETED, AND AVERAGE DAILY FAT INTAKE IN RELATION TO FAT SECRETED, SECOND EXPERIMENT

Cow	Period	Total digestible nutrients			Fat intake per pound of fat produced
		Requirement by Morrison Standard	Actual intake	Intake per pound of fat produced	
		<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
Belle.....	1. High-fat	27.1	31.8	17.4	0.88
	2. Medium-fat	27.2	32.1	17.8	0.53
	3. High-fat	28.4	33.1	17.4	0.89
Echo.....	1. High-fat	26.4	31.0	14.3	0.75
	2. Medium-fat	25.0	30.5	15.5	0.46
	3. High-fat	26.1	30.5	15.1	0.78
Dodo.....	1. High-fat	30.4	34.8	16.5	0.86
	2. Medium-fat	29.4	33.9	17.0	0.51
	3. High-fat	29.3	34.0	17.0	0.87
Susie.....	1. High-fat	23.7	27.2	14.9	0.75
	2. Medium-fat	23.5	27.0	15.6	0.47
	3. High-fat	24.0	27.2	15.0	0.76
Rosaline.....	1. High-fat	21.0	23.2	17.2	0.87
	2. Medium-fat	20.6	23.0	17.5	0.53
	3. High-fat	20.1	21.5	17.4	0.89
Mead.....	1. Medium-fat	29.9	31.7	14.4	0.46
	2. High-fat	28.7	33.0	15.9	0.86
	3. Medium-fat	27.2	31.8	17.1	0.54
Hilda.....	1. Medium-fat	28.4	30.6	14.6	0.47
	2. High-fat	28.6	31.9	14.9	0.81
	3. Medium-fat	28.3	32.0	16.0	0.51
Sooky.....	1. Medium-fat	30.1	32.5	14.6	0.44
	2. High-fat	28.7	30.8	15.2	0.79
	3. Medium-fat	27.7	31.7	17.0	0.53
Mariam.....	1. Medium-fat	28.0	29.0	12.5	0.37
	2. High-fat	27.8	28.7	12.4	0.65
	3. Medium-fat	25.3	28.0	14.1	0.42

part of the experiment. Several of the cows were fed at a level somewhat above the requirements as calculated from the Morrison Standard. Most of the cows were young and still making body growth. They were purposely fed as high a level as they would consistently consume. When the composite samples of the feeds used were analyzed they proved to be richer in digestible nutrients than had been estimated, and as a result the calculated intakes appear to have been higher than anticipated. There is no evidence, however, that the cows were not fed at least as well during the medium-fat concentrate periods as during the high-fat periods. Any advantage that may have occurred seems to have favored the medium-fat mixture. The fact that production favors the high-fat mixture, although the cows were fed in excess of their requirements, makes the effect of the additional fat even more significant.

DISCUSSION OF RESULTS

The results of the two experiments show an advantage in production of both milk and fat favoring the high-fat mixtures. The gains in yields for the high-fat mixtures for the two experiments are summarized in table 11.

TABLE 11. AVERAGE DAILY GAIN IN PRODUCTION DURING THE HIGH-FAT PERIODS IN COMPARISON WITH THE MEDIUM-FAT PERIODS

Year	Milk	Fat	Fat	Fat-corrected milk
	<i>Pounds</i>	<i>Per cent</i>	<i>Pounds</i>	<i>Pounds</i>
1938-39.....	2.25	-0.02*	0.076	2.02
1939-40.....	0.63	0.06	0.064	1.21

*Lower yield on the high-fat mixture.

In both experiments the cows produced more milk per day when they were fed the concentrate mixture of higher fat content. No appreciable change was noted in the fat percentage, but the total fat produced per day was increased as a result of the higher milk yields. The fat-corrected milk is probably the best single measure of the product, and an increase of more than one pound a day is indicated on the basis of the two experiments. It should be particularly noted that the two experiments carried out in different years and using different procedures showed advantages for the high-fat mixture, in agreement with previous experiments in this Laboratory.

The value of an experiment of the continuous type depends upon the selection of two groups of cows with the ability to produce similarly under the same feeding conditions. In any single experiment it is impossible to be certain that this condition has been fully achieved. For that reason, the experiment was repeated using the double-reversal procedure in which each cow is fed both diets, and she thus serves as her own control. Although both procedures are subject to certain objections, they tend to supplement each other.

Another measure of the reliability of the results of any experiment is the uniformity of the responses of the individuals in the groups. In the second experiment the responses of the individual cows were studied.

Considering all of the cows for the full 15-week experiment, there was an average gain of 0.6 pound of milk, 0.06 pound of fat, and 1.2 pounds of fat-corrected milk, on the high-fat mixture. On the basis of five-week periods the response of the individuals was not uniform regarding milk production. Only four of the nine cows produced more milk; seven produced more fat, and seven produced more fat-corrected milk on the high-fat mixture. Reasons for the lack of uniformity have been given.

Because of the experimental procedure used in the first experiment, a comparison of the responses of the individual cows is not possible. It is interesting to note, however, that as a group the cows fed the medium-fat mixture declined more rapidly in production than did the other cows. During the 14-week experimental period, the high-fat group produced an average of 93 per cent as much milk, 91 per cent as much fat, and 92 per cent as much fat-corrected milk per day as they produced during the preliminary period. Similar calculations for the medium-fat group give figures of 88, 90, and 89 per cent, respectively, for the production of milk, fat, and fat-corrected milk, in comparison with the preliminary daily yield.

In the first experiment the cows fed the high-fat mixture produced an average of 4.4 per cent more milk, 3.9 per cent more fat, and 4.1 per cent more fat-corrected milk than did the cows fed the medium-fat mixture. For the second experiment, the cows produced 1.1 per cent more milk, 3.4 per cent more fat, and 2.4 per cent more fat-corrected milk on the high-fat mixture. The two experiments show a consistent advantage for the 7-per-cent-fat concentrate mixture in comparison with a level of 3 per cent fat.

The results of the two experiments here reported agree with the earlier findings from this Laboratory (Maynard and McCay, 1929, 1932; Maynard and coworkers, 1934, 1939). To make possible a comparison of the experiments conducted by Maynard and coworkers since 1928, the average data from each experiment are shown in table 12. A total of 105 cows were used in nine different comparisons. Three experiments with 56 cows were of the continuous type and of 12 to 14 weeks' duration. Six double-reversal experiments, using 49 cows, were conducted also. Concentrate mixtures as low as 0.7 per cent of fat and as high as 7.5 per cent have been used. In all experiments except one, more milk and fat were produced as a result of feeding the high-fat concentrate mixtures. In every experiment the cows fed the high-fat mixture produced more fat-corrected milk. In three tests the fat percentage was lower on the high-fat mixture; in seven tests it was slightly higher, but the difference was usually small, which indicates that the milk yield was primarily affected.

It is recognized that the drop of one pound of milk is of greater importance in the case of a cow that produces 20 pounds per day than it is for a cow that gives 80 pounds. To take this into account, the gains in the yields of fat-corrected milk for the various experiments are expressed on a percentage basis in table 13. The number of cows used and the response of the individuals are shown in columns 3, 4, and 5 of this table. In the six double-reversal experiments only 6 of the 49 cows studied failed to show an increase in production when the high-fat mixture was fed. When comparison was made between concentrate mixtures containing 1 per cent of fat and those containing 6 to 7 per cent, the increase in yield of fat-cor-

rected milk amounted to 9 to 10 per cent of the total yield of the cow. In later studies, when concentrate mixtures having smaller differences in the fat content were compared, the gains in production varied from 0.6 to 7.2 per cent of the total production. From the double-reversal experiments, pairs of data are available that can be studied by Student's method. The odds favoring significance of the observed differences are shown in column 7 of table 13. The odds in three of the six double-reversal experiments are not considered statistically significant, either because the number of observations were very limited, or because of the wide differences between

TABLE 12. SUMMARY OF THE AVERAGE DAILY GAIN IN THE YIELD OF MILK, FAT, AND FAT-CORRECTED MILK, AND IN FAT PERCENTAGE DURING HIGH-FAT PERIODS IN COMPARISON WITH LOW-FAT PERIODS

Year	Fat in concentrate mixtures fed	Cows	Experiments		Average daily gain in—			
			Duration	Type	Milk	Fat	Fat	Fat-corrected milk
	<i>Per cent</i>	<i>Number</i>	<i>Days</i>		<i>Pounds</i>	<i>Per cent</i>	<i>Pounds</i>	<i>Pounds</i>
1928-29.....	0.7 and 5.8	4	85	Double-reversal	2.82	0.12	0.145	3.30
1929-30.....	3.1 and 6.1	3	90	Double-reversal	0.34	0.11	0.062	1.07
1930-31.....	1.0 and 7.5	2	105	Double-reversal	4.40	-0.19*	0.119	3.54
1930-31.....	3.2 and 7.5	9	105	Double-reversal	1.57	0.22	0.149	2.87
1931-32.....	4.1 and 6.6	20	91	Continuous	-0.06*	0.20	0.073	0.97
1932-33.....	4.2 and 7.2	20	84	Continuous	0.76	-0.07*	-0.001*	0.27
1936-37.....	3.4 and 6.3	10	105	Double-reversal	0.50	0.01	0.028	0.62
1937-38.....	3.1 and 6.3	12	105	Double-reversal	1.09	0.11	0.088	1.73
1938-39.....	3.1 and 7.1	16	98	Continuous	2.25	-0.02*	0.076	2.02
1939-40.....	2.6 and 6.7	9	105	Double-reversal	0.63	0.06	0.064	1.21
Total.....		105						

*Lower yield on the high-fat mixture.

TABLE 13. PERCENTAGE OF GAIN IN PRODUCTION OF FAT-CORRECTED MILK ON THE HIGH-FAT MIXTURE, AND THE SIGNIFICANCE OF THE OBSERVED GAINS

Year	Fat in concentrate mixtures fed	Cows showing—		Total cows	Average gain in fat-corrected milk	Odds favoring significance of differences
		Gain in yield of fat-corrected milk	Loss in yield of fat-corrected milk			
Double-reversal experiments						
	<i>Per cent</i>	<i>Number</i>	<i>Number</i>	<i>Number</i>	<i>Per cent</i>	
1928-29.....	0.7 and 5.8	4	0	4	9.0	>216:1
1930-31.....	1.0 and 7.5	2	0	2	10.4	
1930-31.....	3.2 and 7.5	9	0	9	7.2	>9999:1
1929-30.....	3.1 and 6.1	2	1	3	2.4	
1939-40.....	2.6 and 6.7	7	2	9	2.3	6:1
1937-38.....	3.1 and 6.3	11	1	12	3.7	53:1
1936-37.....	3.4 and 6.3	8	2	10	2.8	<285:1
Total.....		43	6	49		21:1
Continuous experiments						
1931-32.....	4.1 and 6.6	..	..	20	2.7	
1932-33.....	4.2 and 7.2	..	..	20	0.6	
1938-39.....	3.1 and 7.1	..	..	16	4.5	
Total.....				56		

the responses of the individuals. In the other three tests the observed differences were highly significant, even though the number of observations were rather small. When Student's method is applied to all 49 cows used in the double-reversal experiments, the odds are greater than 200,000:1 that the observed advantages for the high-fat concentrate mixtures were significant.

Statistical analyses of the continuous experiments have been made in various ways. None of the methods used in treating the data were satisfactory because of the wide variations among the yields of the individuals and the resulting large standard deviation within the groups. In all of the continuous experiments, involving 56 cows, a definitely greater production was obtained on the high-fat concentrate, thus supporting the results of the double-reversal experiments. To the writers, the concordance of the results summarized in tables 12 and 13 seem impressive. It should be mentioned, however, that in the work of others the findings of this Laboratory have sometimes been substantiated and sometimes not.

Horn and Muhl (1937) observed that the addition of 35 per cent of ground soybeans to a basal concentrate mixture produced a somewhat greater increase in milk and fat yield than did the incorporation of an equivalent amount of extracted ground soybeans. Williams, Cannon, and Espe (1939) reported that the addition of cracked soybeans decreased the milk yield slightly but increased the butterfat production and the fat percentage. When these workers fed soybean oil, milk production increased, but the fat percentage and the total fat yield decreased. Gibson and Huffman (1939) reported that the addition of soybean oil to a ration low in fat resulted in an increase in milk production, but these workers have more recently stated that in a later experiment they did not confirm their previous results. Monroe and Krauss (1940) have reported no significant differences in milk and fat production when concentrate mixtures containing 4.9, 3.5, and 2.8 per cent of fat were compared. Details of the latter study have not yet been published. In a very brief statement, Schubert and Wells (1940) reported no increase in milk yield when they replaced solvent-extracted soybean oil meal with soybeans as a supplement to barley for dairy cows. Details of this study, involving 11 cows for 6 weeks, are lacking.

These findings emphasize the need for further study, particularly to ascertain whether fat per se, some specific fatty acid, or some non-fat component of the "ether extract" has been responsible for the results obtained in this Laboratory. These possibilities and others have been discussed in a previous publication (Maynard and coworkers, 1939). Some of them are now under active investigation in this Laboratory.

SUMMARY

Two studies are reported comparing the effect on the milk production of dairy cows of concentrate mixtures containing 3 and 7 per cent of fat. Differences in the fat level were obtained by including feeds from which fat had been removed in varying degrees by either the hydraulic or the expeller process. In a continuous experiment involving two groups of eight cows each, the group fed the high-fat mixture produced 4.4 per cent more milk, 2.0 per cent more fat, and 4.1 per cent more fat-corrected milk than

did the group fed the concentrate mixture containing only 3 per cent of fat. In the second experiment, in which nine cows were studied by the double-reversal procedure, an average of 1.1 per cent more milk, 3.4 per cent more fat, and 2.4 per cent more fat-corrected milk was produced during the high-fat periods.

A summary is also presented of the previous experiments on this problem conducted at the Cornell University Agricultural Experiment Station during the past twelve years.

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