THE EFFECT OF FEEDING ON MILK COMPOSITION*

I. THE FFFECT OF LEVEL OF FEEDING UPON THE SOLID-NOT-FAT CONTENT OF MILK

By

Eiichi UEYAMA and Yoshitsune HIROSE

Animal Feeding Laboratory, Faculty of Agriculture
Hokkaido University, Sapporo, Japan

For a long time, butterfat has been considered the most important constituent of milk. Recently, attention has been focused on the solid-not-fat (SNF) content of milk. The reason for this is because less emphasis is now being placed on butterfat in human nutrition and greater importance is being placed on the SNF content, especially the protein content of milk. A recent trend, therefore, in the pricing of milk is to estimate the value of other constituents rather than on the butterfat percentage which has long been the established method of payment. Thus, protein and SNF are being considered in a new light. If, in the future, milk is sold on the basis of either protein or SNF, it would be desirable for dairymen to know the effect of feeding on these milk constituents.

The authors previously reported that the content of each milk constituent varied with the season of year as well as the lactational stage of cows[8]. The level of feeding for cows seemed to be the most important factor of this seasonal effect. BURT[4] and ROOK[13] reported in their reviews that the SNF content of milk was markedly affected by a plane of energy nutrition.

The present experiment was conducted to determine the effect of level of feeding for lactating cows on milk yield and milk composition, especially on the SNF content, under winter feeding conditions.

EXPERIMENTAL PROCEDURE

Experimental Animal Six Holstein cows from the Second Research Farm of Hokkaido University were used in this experiment. The cows were divided into two groups, three cows each, according to their lactational stage and the experiment was commenced on different dates as shown in Table 1. The cows were milked twice a day, at 6 : 30 AM and 4 : 00 PM.

* This experiment was supprted by Scientific Research Funds from the Ministry of Educaton.

TABLE 1. Experimental Animals

Group	Cow no.	Date of birth	Date of calving	Beginning date of experiment	Ending date of experiment
	613	5-28-'58	7-29-'60	11-8-'60	3-8-'61
I	610	6-27-'57	8-18-'60	"	"
	598	5-28-'55	8-21-'60	"	"
	590	1-17-'54	11- 9-'60	12-8-'60	4-8-'61
II	614	9-14-'58	11-21-'60	"	"
	540	11-28-'47	12- 3-'60	"	"

Experimental Period and Feeding Program The experiment consisted of four periods. The cows in both groups were fed during each period according to the feeding schedule shown in Table 2. To minimize the influence of the lactational stage, the cows received the same feeding treatment in both the first and the fourth periods. The average values obtained from these two periods

TABLE 2. Feeding Schedule

Period	Treatments
1	Basal ration (mainly roughage at a level of 2.5% of body weight on air dry basis)
2	Basal ration + Concentrate mixture (at a rate of 1 kg. to 4 kg. of milk yield)
3	Basal ration + Concentrate mixture (at a rate of 1 kg. to 2 kg. of milk yield)
4	Basal ration

were designated as the response of cows to the basal ration. Each period consisted of 1 month. Data of the last 7 days of each period were used for comparison.

As shown in Table 3, orchard grass hay, corn silage, mangel, sugar beet pulp and the concentrate mixture were used as feedstuffs. The concentrate mixture consisted of cracked rye 37%, linseed oil meal 25%, barley bran 35%, calcium carbonate 2%, and salt 1%.

Each cow received the basal ration, mainly consisting of roughage, approximately at a level of 2.5% of body weight on an air dried basis in both the first and the fourth periods. A cow, 500 kg. of body weight, was given 4.5 kg. of orchard grass hay, 23 kg. of corn silage, 13 kg. of mangel and 1 kg. of sugar beet pulp daily as a basal ration. The amount of concentrate feeding in either the second or third period was adjusted every week according to milk

TABLE 3. Feedstuffs

Feedstuff	Crude protein* (%)	Gross energy* (Cal./kg.)
Concentrate mixture	16.34	3,711.4
Corn silage	1.90	1,013.0
Mangel	2.26	435.8
Orchard grass hay	6.25	4,049.6
Sugar beet pulp	7.88	3,918.5

* Averages of four periods

yield of cow. An average daily milk yield of one week was used for calculation of the amount of concentrate for the following week. Each cow was individually fed twice a day in a stall with a stanchion. One half of the daily allowance of feed was given at AM feeding and the other half at PM feeding. Water was supplied *ad libitum.*

Data Collected and Analytical Method Daily records of milk yields were maintained. Body weight and heart girth of each cow were measured at the beginning of the experiment and every 10 days thereafter. Two composite samples of 6 consecutive milkings were collected from the last 7 days of each experimental period for determinations of milk constituents. GERBER's method was used for butterfat test. AOAC methods[1] were used for the determinations of total solid and protein. Lactose content was determined by LANE-EYNON method[6]. A digestion trial was conducted to determine the amounts of nutrient intake of cows during the last 7 days of each period. The chromogen index method[12] was applied for the digestion trial. The methods of SNEDECOR[15] were used for statistical analyses of data and the significances of these results were tested by DUNCAN's Multiple Range Tests[7].

RESULTS AND DISCUSSION

Body Measurement As shown in Table 4, the body weight and the heart girth increased by increasing the feeding level except during period 2. Because of the individual difference in cows, the differences in both body weight and heart girth between periods were not significant.

Milk yield and Production of Milk Constituent Table 4 shows that an increase in the level of feeding caused an increase in milk yield and production of butterfat, protein, and SNF in milk. The differences in milk and milk constituents between periods were highly significant.

Nutrient Intake The average daily intake of TDN and DCP per cow in each

TABLE 4. Body Measurements, and Yields of Milk and Milk Constituents

Period	Basal	2	3
Body Weight (kg.)	498.8 a)	494.7 a)	500.5 a)
Heart girth (cm.)	184.3 a)	183.8 a)	185.5 a)
Milk yield (kg./day)	10.20 a)	12.61 b)	14.32 c)
Butterfat production (g./day)	2,485 a)	3,096 b)	3,403 c)
Protein production (g./day)	1,914 a)	2,461 b)	2,845 c)
SNF production (g./day)	5,534 a)	7,068 b)	8,044 c)

Note: Values followed by the same superscript are not significantly different ($P<0.05$), based on DUNCAN's Multiple Range Tests.

period, determined by digestion trials, are presented in Table 5. The average nutrient requirements, based on N. R. C. Feeding Standards for dairy cattle[5], and percentage ratios of actual intake against standard requirements are also shown. The differences of nutrient intake between periods were highly significant. There were highly significant differences in the ratios of DCP intake of requirements between periods. The ratios of TDN intake of requirements in both the second and the third periods were significantly higher ($P<0.01$)

TABLE 5. Nutrient Intake and its Ratios to NRC Feeding Standards

Period	Besal	2	3
TDN intake (kg./cow/day)*	6.84 a)	8.79 b)	9.67 c)
TDN requirement by NRC Feeding Standards (kg./cow/day)	7.15	7.93	8.43
Percentage ratio of intake to Standards (%)	96 a)	111 b)	114 b)
DCP intake (g./cow/day)	499 a)	908 b)	1,218 c)
DCP requirement by NRC Feeding Standards g./cow/day	760 a)	870 b)	942 c)
Percentage ratio of intake to Standards (%)	66 a)	104 b)	129 c)

Note: Values followed by the same superscript are not signigcantly different ($P<0.05$) based on DUNCAN's Multiple Range Tests.

* TDN intake was calculated by using the following equation,

$$\text{TDN intake} = (\text{Gross energy intake} - \text{Energy excreted in feces}) \times \tfrac{1}{4}$$

Gross energy in feeds and in feces were determined by using a bomb calorimeter, and TDN values were obtained as 4 Cal. of the digestible energy equal 1 g. of TDN[2].

than that in the basal period. No significant difference in the ratios of TDN was observed between the second and the third periods.

Milk Composition The effects of feeding levels on the milk composition are presented in Table 6. By increasing the feeding level of cocentrate, the content of each milk constituent tended to go up, with the exception of butterfat content. The butterfat content was lowest in period 3. It has been reported by

TABLE 6. Milk Composition

Period	Basal	2	3
Total Solid (%)	11.28 a)	11.57 a)	11.49 a)
Butterfat (%)	3.49 a)	3.55 a)	3.43 a)
Protein (%)	2.72 a)	2.82 b)	2.88 b)
Lactose (%)	4.20 a)	4.28 a)	4.25 a)
SNF (%)	7.77 a)	8.02 b)	8.06 b)

Note: Values followed by the same superscript are not significantly different ($P<0.05$), based on DUNCAN's Multiple Range Tests.

many workers that the butterfat content was decreased when cows received high concentrate rations such as in the case of the third period in this experiment[13]. There were no significant differences in total solid, butterfat and lactose content of milk between the three periods. The cows produced milk containing significantly higher protein ($P<0.05$) and SNF ($P<0.01$) in both the second and the third periods than in the basal period. The protein and the SNF content of the milk in the third period were slightly higher than those in the second period, but these differences were not significant. The results concerning the protein and the SNF contents of milk observed in this experiment are in agreement with other workers.[3,9,10,14] HOLMES *et al*[10] reported that by increasing the ratios of energy feeding against the prescribed feeding standards, the SNF content of milk was increased when cows were fed at the level of, or above the feeding standards. This increase in the SNF content was due mainly to an increase in the protein fraction. No such increase in SNF, or protein content was observed when the ratios of protein feeding to the feeding standards were increased. In this experiment, there was no significant difference in the SNF content of milk between the second and the third periods in spite of the significant difference in the ratios of protein feeding to the feeding standards. These results may indicate, as suggested by BURT[4], that the SNF content of milk is not affected by the feeding levels of protein when cows are fed protein at the level of, or above the feeding standards. It has been reported that a considerable decline was observed in SNF content of milk when cows were fed adequate amounts of energy in a continuous negative nitrogen balance[4] It is possible to assume that the underfeeding of protein in the basal period caused the cows to produce milk of lower SNF content as well as the underfeeding of energy. The results concerning the changes in protein content along with that in SNF content of milk observed in this experiment, are in agreement with the report of HOLMES *et al*[10]. These results are of considerable interest in relation to the nutritive value of cow milk.

Although the level of energy feeding seems to affect the SNF content of milk, the biochemical, or physiological mechanisms which induce these changes in milk composition are not well known. ROOK and LINE[14] reported that the significant increases in total volatile fatty acids and α-amino N concentrations of blood plasma were observed by an increase in the plane of energy nutrition for lactating cows along with an increase in the SNF and the protein content of milk. From these results, they proposed the following hypotheses: (a) An increase in the plane of energy nutrition increases the amount of acetate absorbed from the rumen and, consequently, the plasma acetate concentration in peripheral blood. This change, in turn, increases the rate of mammary synthesis of both lactose and protein. To maintain isotonicity of the mammary secretion with blood plasma, an increase in the synthesis of lactose will produce an increase in the output of water and therefore in the yield of milk. Since the percentage increases in yields of lactose, protein and water will be of the same order, and no significant change in the milk content of lactose or protein will occur. (b) An increase in the plane of energy nutrition increases the amount of propionate absorbed from the rumen, which in milking cows gives rise to a small increase

TABLE 7. Efficiency of Feed Utilization to Milk Production

Period	Basal	2	3
Efficiency of feed utilization* to milk production (%)	23.54 a)	23.08 a)	22.49 a)

Note: Values followed by the same superscript are not significantly different ($P<0.05$), based on DUNCAN's Multiple Range Tests.

* Efficiency of feed utilization to milk production was calculated by using the following equation,

$$\text{Efficiency} = \frac{\text{Energy secreted in milk}}{\text{Digestible energy intake}} \times 100$$

Energy in milk was calculated by using the equation reported by LOFGREEN and OTAGAKI[11].

Digestible energy intake was determined by a digestion trial.

in plasma amino-acid concentration. This, in turn, produces a small specific increase in protein synthesis, additional to (a), and therefore an increase in the protein content of the milk secreted. The control of plasma amino-acid levels by the portal blood supply of propionate could be achieved in the liver through the intermediary of the Krebs's cycle.

Further work will be needed to clarify these mechanisms.

Efficiency of Feed for Milk Production The proportion of the energy converted from the digestible energy of feed to milk in each period was calculated and presented in Table 7. By increasing the level of feeding, the efficiency of feed utilization for milk production tended to decline. These differences, however, were not significant.

SUMMARY

Six Holstein cows were used in this experiment to determine the effect of the levels of feeding upon the milk yield and upon the milk composition, especially the SNF content.

Cows received three levels of feeding as follows: Period 1: basal ration, consisted mainly of roughages, at a level of 2.5% of body weight on air dry basis; Period 2: basal ration + concentrate mixture at a rate of 1 kg. to 4 kg. of milk produced; Period 3: basal ration + concentrate mixture, 1 kg. to 2 kg. of milk produced; and period 4: basal ration. Cows consumed 96%, 111% and 115% of TDN requirements, and 66%, 104% and 129% of DCP requirements according to the NRC Feeding Standards in the periods of basal, 2 and 3 respectively.

There were no significant differences in the body weight and the heart girth between periods, although these measurements tended to increase by increasing the level of feeding.

The increase in feeding levels caused significant increases in the yields of milk and milk constituents.

The total solid, butterfat and lactose content of milk were not significantly affected by the level of feeding. The increase in the level of feeding raised the SNF and the protein content of milk significantly. The changes of SNF content of milk, therefore, were mainly due to the changes in protein content.

The efficiency of feed utilization for milk production was not significantly different between periods.

REFERENCES

1) Association of Official Agricultural Chemists.: *Official Methods of Analysis.* 9th ed. Washington, D. C. 1960.

2) BRODY, S., PROCTER, R. C., and ASHWORTH, U. S.: Growth and Development, with Special Reference to Domestic Animals. XXXIV. Basal Metabolism, Endogenous Nitrogen, Creatinine and Neutral Sulphur Excretions as Function of Body Weight .Mo. Agr. Exp. Sta. Res. Bull., 220: 24. 1934.

3) BURT, A. W. A.: The Effect of Variations in Nutrient Intake upon the Yield and Composition of Milk. I. Variations in Amount and Type of Concentrates Fed in Winter Rations. J. Dairy Res., 24: 283. 1957.

4) BURT, A. W. A.: The Influence of Level of Feeding during Lacation upon the Yield and Composition of Milk. Dairy Sci. Abstr., 19: 435. 1957.

5) Comittee on Animal Nutrition.: III. Nutrient Requirements of Dairy Cattle. Natl. Acad. Sci. Natl. Research Council Publ., 464. 1958.

6) Department of Agricultural Chemistry, Tokyo University.: *Jikken Nogei-Kagaku.* Asakura Publ. Co., Chiyoda-Ku, Tokyo. 1953.

7) DUNCAN, D. B.: Multiple Range and Multiple F Tests. Biometrics, 11: 1. 1955.

8) HIROSE, Y., UEYAMA, E., NAGAO, Y., and HOSHINO, S.: Variations in the Chemical Composition of Milk with Particular Reference to the Solid-Not-Fat during Lactations. Res. Bull. of Farms, Fac. of Agr., Hokkaido Univ., 12: 141. 1964.

9) HOLMES, W., REID, D., MACLUSKY, D. S., WAITE, R., and WATSON, J. N.: Winter Feeding of Dairy Cows. IV. The Influence of Four Levels of Concentrate Feeding in Addition to a Basal Ration of Grass Products on the Production Obtained from Milking Cows. J. Dairy Res., 24: 1. 1957.

10) HOLMES, W., WAITE, R., MACLUSKY. D. S., and WATSON, J. N.: Winter Feeding of Dairy Cows. I. The Influence of Level and Source of Protein and on the Level of Energy in the Feed on Milk Yield and Composition. J. Dairy Res., 23: 1. 1956.

11) LOFGREEN, G. P., and OTAGAKI, K. K.: The Net Energy of Blackstrap Molasses for Lactating Dairy Cows. J. Dairy Sci., 43: 220. 1960.

12) REID, J. T., WOOLFOLK, P. G., RICHARDS, C. R., KAUFMANN, R. W., LOOSLI, J. K., TURK, K. L., MILLER, J. I., and BLASTER, R. E.: A New Indicator Method for the Determination of Digestibility and Consumption of Forages by Ruminants. J. Dairy Sci., 33: 60. 1950.

13) ROOK, J. A. F.: Variations in the Chemical Composition of the Milk of Cow. Part I. Dairy Sci. Abstr., 23: 251. 1961.

14) ROOK, J. A. F., and LINE, C.: The Effect of the Plane of Energy Nutrition of the Cow on the Secretion in Milk of the Constituents of the Solid-Not-Fat Fraction and on the Concentrations of Certain Blood-Plasma Constituents. Brit. J. Nutrition, 15: 109. 1961.

15) SNEDECOR, G. W.: *Statistical Methods.* 5th ed. Iowa State College Press, Ames, Iowa. 1956.