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THE EFFECT OF VARYING THE DAILY MILKING FREQUENCY ON THE MILK YIELD OF THE EWE AND EVIDENCE ON THE NATURE OF THE INHIBITION OF MILK EJECTION BY HALF-UDDER MILKING

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SOMMAIRE

Par deux expériences, on a déterminé l'effet de différentes fréquences de traite journalière sur la quantité de lait obtenue chez la Brebis.

Expérience 1. — Des demi-mamelles sont traites 1,2 ou 3 fois par jour, selon un plan expérimental en carré latin 3 × 3 (tabl. 2). Le groupe bleu, de 6 brebis (tabl. 1) est trait normalement ; pour le groupe blanc (6 animaux), la traite est suivie de deux injections d'ocytocine (5 UI × 2) pour extraire le lait résiduel.

Il n'y a pas de différence entre les deux groupes pour les quantités de lait et de matières grasses, quand les demi-mamelles sont traites 2 et 3 fois par jour (tabl. 3, 4, 5, 6), alors qu'une seule traite par jour provoque une réduction d'environ 20 p. 100.

Le groupe trait avec ocytocine a une production augmentée d'environ 30 p. 100 quelle que soit la fréquence des traites (tabl. 5, 6).

La quantité de lait produite par une demi-mamelle est influencée par la fréquence des traites de l'autre glande chez un même animal. Moins on trait l'une des mamelles, plus grande est la quantité produite par l'autre.

Expérience 2. — Sur deux groupes de 4 brebis (tabl. 7) on compare la traite 2 et 3 fois par jour, les mamelles étant comparées soit entre mamelles entières, soit entre demi-mamelles, dans un protocole en carré latin 4 × 4 (tabl. 8).

Pour les quantités de lait, les graisses, la matière sèche, il n'y a pas de différence entre les semi-mamelles traites 2 ou 3 fois par jour (tabl. 9). De plus, la quantité de lait produite par une demi-mamelle, pour une fréquence de traite donnée (2 ou 3), est comparable à celle obtenue du côté opposé trait 2 ou 3 fois par jour. Cependant, on observe une production réduite d'environ 20 p. 100 quand une demi-mamelle est traite seule après un intervalle de temps donné, par rapport à la quantité obtenue de la même demi-mamelle quand on la trait en même temps que l'autre moitié et après le même intervalle de temps (effet de la coïncidence) (tabl. 15). Il est possible que cette réduction observée quand les deux demi-mamelles ne sont pas traites ensemble soit due à l'inhibition de l'éjection du lait. Cette hypothèse semble confirmée par le fait que si on injecte de l'ocytocine, les quantités de lait obtenues sont les mêmes, que les demi-glandes soient traites simultanément ou non.

INTRODUCTION

Evidence on the effect of varying the frequency of daily milking is derived from both survey and experimental data. HANSSON and BONNIER, (1947) have pointed out that in the former the results are biased in favour of the more frequent milking routines. The latter reports are derived from whole lactation or short term studies employing various experimental techniques : monozygous twins, and whole and half udder milking routines (see review by ELLIOTT, 1958).

In very general terms one can summarize these data based on cattle trials as shewing that when the frequency of daily milking is increased from twice to thrice, there is a subsequent and usually immediate response in milk yield. The increases quoted in various reports vary from 6-40 p. 100. One suspects that the increase becomes smaller as the experimental design becomes better. There is general agreement that once-a-day milking of dairy cows causes a reduction of milk yield of some 50 p. 100.

There is only one report on the effect of a change in milking frequency on the yield of sheep (GAAL 1957). Ewes yielded 20 p. 100 more milk when milked thrice. This experiment was carried out under commercial conditions and it may well be that the results are biased in favour of the group milked thrice. In view of lack of information on this subject in ewes, it was decided to carry out the following investigations.

EXPERIMENT I

Materials and Methods

A first experiment into the effect of different milking frequencies was carried out on twelve mutton breed ewes. The sheep, all in the first month of lactation, had been separated from their lambs within six hours of parturition. All the ewes had suckled lambs during the previous year and none had been milked during any earlier lactation. Details of the experimental animals are given in table 1. The twelve ewes were ranked in order of previous yield and then divided into pairs in the rank order. The ewes of each pair were then randomly allocated to one of two groups, hereafter referred to as the blue and white groups. Both groups were milked twice a day for seven days and then six ewes, again selected at random, were allocated to the treatment sequences of a balanced 3 × 3 Latin square designated Capital, and the remaining six ewes to the sequences of a second balanced Latin square (Cursive), as shewn in table 2. It is noted that the treatment definitions of A and *a*, B and *b* C and *c* respectively, were similar for whole sheep and differed only in respect of the half udder to which treatments were applied. Each period lasted eight days — the readings of the first day of each period being discarded in an attempt to eliminate the carry-over effects of residual milk from treatment to treatment. Total experimental time was 32 days, made up as follows :

(1 pre-treatment × 7 days) + (3 treatment periods × [1 discard + 7 treatment days]) = 32 days.

The ewes were machine milked using equipment described elsewhere (MORAG, GIBB and FOX, 1967). The sheep were brought into the parlour for milking and offered concentrates in the milking stands. The teat cups were then applied and when the milk flow had ceased the udders of the white group of ewes were vigorously massaged and then machine-, and hand-stripped. In the blue group residual milk was removed by two injections of 5 i. u. oxytocin (1) which were painlessly administered through a semi-permanent nylon cannula which had been inserted in the jugular vein five days prior to the experiment. Udder washing and fore-milking were not practised. The milking times were 05.00, 13.00 and 21.00 h, at 09.00 and 21.00 h and at 21.00 h for the thrice-, twice- and once-a-day milking routines. All half udders were milked at 21.00 h wich was ths only half udder coincidental milking during the three periods of the Latin square. Udder half-milk samples were taken at every milking and analysed for fat by a modified method of Gerber as described by MACDONALD (1959). (Fat samples were not taken for the first four days of the pre-experimental week).

The ewes were housed on slats in a closed barn illuminated by day and night. The ewes were offered water, grassnuts and hay *ad lib.* between milkings and were offered 3 kg of concentrates (2) per day milking. This daily ration of concentrates was divided into a number of meals equal to the number of milkings which the ewe received on any one day.

(1) P. O. P. Purified oxytocin principle-manufactured by Armours Pharmaceutical Co. Ltd.

(2) Soya 20 p. 100, fish meal 20 p. 100, rolled barley 60 p. 100, with 5 kg. bone flour and 3 kg. A + D^3 pre-mix per ton.

TABLEAU I

Détails sur les animaux expérimentaux
(Expérience 1)

TABLE I

Details of Experimental Animals
(Experiment 1)

Ewe number	Breed (1)	Age in years	Days after lambing	Mean daily yields of left and right udder halves during week prior to Latin Square (g.)
Blue group (with oxytocin)				
B_1	C. B.	3	18	846 854
B_2	D. H.	5	15	1040 1187
B_3	D. C. B.	3	18	968 1092
B_{11}	D. H.	6	19	832 946
B_{12}	D. C. B.	3	19	743 730
B_{13}	H. B.	7	16	822 622
White group (without oxytocin)				
W_1	C. B.	6	18	1041 1069
W_2	D. C. B.	4	15	978 499
W_3	D. C. B.	3	17	869 807
W_{11}	H. B.	7	18	632 615
W_{12}	P. D.	3	19	674 584
W_{13}	P. D.	3	21	707 615

(1) D. H. Dorset Horn.
P. D. Polled Dorset Horn.
H. B. Half-bred (Border Leicester × Cheviot).
C. B. Cross-bred (Dorset Horn × Half-bred).
D. C. B. Dorset Cross-bred (Dorset Horn × Cross-bred).

TABLEAU 2

Plan expérimental
(Expérience 1)

TABLE 2

Experimental Design
(Experiment 1)

Capital square

Ewes	Periods		
	1	2	3
B_1 and W_1	A	B	C
B_2 and W_2	C	A	B
B_3 and W_3	B	C	A

Cursive square

Ewes	Periods		
	1	2	3
B_{11} and W_{11}	*a*	*b*	*c*
B_{12} and W_{12}	*b*	*c*	*a*
B_{13} and W_{13}	*c*	*a*	*b*

Treatment definitions

	Left 1/2 udder	Right 1/2 udder
Treatment A	3 × daily milking $T_{3(2)}$(*)	2 × daily milking $T_{2(3)}$
Treatment B	2 × daily milking $T_{2(1)}$	1 × daily milking $T_{1(2)}$
Treatment C	1 × daily milking $T_{1(3)}$	3 × daily milking $T_{3(1)}$
Treatment *a*	2 × daily milking $T_{2(3)}$	3 × daily milking $T_{3(2)}$
Treatment *b*	1 × daily milking $T_{1(2)}$	2 × daily milking $T_{1(2)}$
Treatment *c*	3 × daily milking $T_{3(1)}$	1 × daily milking $T_{1(3)}$

(*) This designation describes the milking frequency on an udder half by the first number, and the milking frequency on the *opposite* udder half by the second (bracketed) number.

TABLEAU 3

(Expérience 1)
Sources de variations, carrés moyens et moyennes hebdomadaires des quantités de lait et de matière grasse par demi-mamelle dans le groupe Bleu (avec ocytocine) (g/jour)

TABLE 3

Sources of variance mean squares and means of the weekly half udder yields of milk and fat in the BLUE group (with oxytocin) expressed as g/day. (Experiment 1)

		Capital Square				Cursive Square			
		Milk		Fat		Milk		Fat	
Source of variance	*d.f.*	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*
Half udder	2	14 119	33 793	23.61	60.29	109 474	48 656	4.74	160.62
Periods	2	6 669	13 683	65.89	138.34	12 892	772	106 10	10.66
Treatments	2	71 102	112 889	336.88	172.92	34 313	83 678	7.53	164.2
Error	2	3 553	1 931	4.15	10.91	10 771	4 141	6.50	1.02
	8								
Means									
$1\times$daily milking		831 $T_{1(3)}$	880 $T_{1(2)}$	46.27 $T_{1(3)}$	53.22 $T_{1(2)}$	659 $T_{1(2)}$	532 $T_{1(3)}$	34.10 $T_{1(2)}$	40.81 $T_{1(3)}$
$2\times$daily milking		1 062 $T_{2(1)}$	1 249 $T_{2(3)}$	65.14 $T_{2(3)}$	66.70 $T_{2(3)}$	853 $T_{2(3)}$	766 $T_{2(1)}$	47.75 $T_{2(3)}$	43.97 $T_{2(1)}$
$3\times$daily milking		1 123 $T_{3(2)}$	1 170 $T_{3(1)}$	64.05 $T_{3(2)}$	66.02 $T_{3(1)}$	678 $T_{3(1)}$	856 $T_{3(2)}$	45.80 $T_{3(1)}$	42.41 $T_{3(2)}$

TABLEAU 4

(Expérience 1)
Sources de variations, carrés moyens et moyennes hebdomadaires des quantités de lait et de matière grasse par demi-mamelle dans le groupe BLANC (sans ocytocine) (g/jour)

TABLE 4

Sources of variance mean squares and means of the weekly half udder yields of milk and fat in the WHITE group (without oxytocin) expressed as g/day. (Experiment 1)

		Capital Square				Cursive Square			
		Milk		Fat		Milk		Fat	
Source of variance	*d.f.*	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*
Half udders.........	2	69 610	120 015	507.97	729.50	100 819	47 197	222.79	115.86
Periods	2	6 789	3 193	63.20	10.22	4 776	5 056	16.84	35.08
Treatments	2	29 228	14 430	173.04	47.17	13 056	15 415	11.75	151.32
Error	2	281	9 149	8.08	18.89	158	5 365	1.94	22.28
	8								
Means									
1 × daily		695 $T_{1(3)}$	629 $T_{1(2)}$	36.75 $T_{1(3)}$	35.71 $T_{1(2)}$	575 $T_{1(2)}$	504 $T_{1(3)}$	34.78 $T_{1(2)}$	26.60 $T_{1(3)}$
2 × daily milking		884 $T_{2(1)}$	730 $T_{2(3)}$	51.42 $T_{2(1)}$	38.37 $T_{2(3)}$	621 $T_{2(3)}$	644 $T_{2(1)}$	36.46 $T_{2(3)}$	40.37 $T_{2(1)}$
3 × daily milking		839 $T_{3(2)}$	762 $T_{3(1)}$	47.59 $T_{3(2)}$	43.51 $T_{3(1)}$	705 $T_{3(1)}$	598 $T_{3(2)}$	38.73 $T_{3(1)}$	36.48 $T_{3(2)}$

The blood of the ewes in the blue group was effectively anti-coagulated by the intravenous administration of 700 μg. of Malayan viper. *Ancistrodon rhodostoma* (BOIE) venom, given intravenously through the cannula every third day.

The experiment was carried out at Lane End Farm, University of Reading, from April 10th to May 14th 1964.

Results

The weekly yields of left and right udder halves of milk and fat in the blue and white groups were analyzed separately according to the following model:

$$Y_{ijk} = \mu + H_i + P_j + T_k + \varepsilon_{ijk}$$

When μ = the mean daily yield in a treatment period
H_i = the effect due to the ith half udder $i = 1, 2, 3$
P_j = the effect due to the jth period $j = 1, 2, 3$
T_k = the effect due to the kth treatment $k = 1, 2, 3$

The half udder treatment means for the two latin squares and the two groups with the relevant standard errors are given in tables 3 and 4. The milk yields of the udder halves during the pre-experimental week are given in table 1. It is noted that in tables 3 and 4 the means for the three milking frequencies are qualified by the milking frequency on the other half udder of the ewe. The mean udder yields of milk and fat in the blue and white groups, *regardless* of the milking frequency on the other side

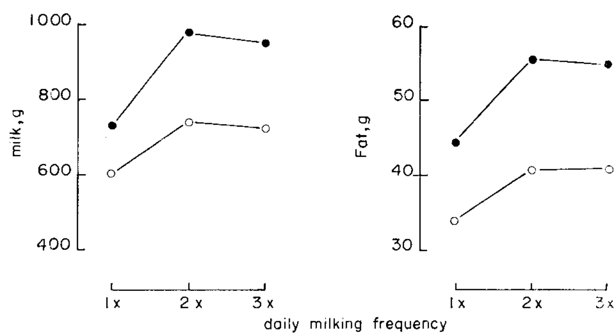

FIG. 1 — *Quantité journalière de lait et de matière grasse par demi-mamelle traite 1, 2 ou 3 fois par jour*
• Groupe Bleu ○ Groupe Blanc
(Expérience 1)

FIG. 1. — *Daily yield of milk and fat of half udders when milked once, twice or thrice-a-day, g.*
• Blue group ○ White group
(Experiment 1)

of the udder, have been calculated and appear in table 5. The effect of the milking frequency on the opposite side of the ewe is given in table 6. No standard errors are given in tables 5 and 6; this is because the treatment means are composed of estimates derived from different latin squares and thus no meaningful standard error could be calculated.

Discussion

The experimental results presented shew that there is no difference between the yield of milk or fat when a ewe is milked twice or three times a day. (see table 5 and fig. 1). This would appear to be true whether or not the residual milk was removed at milking (compare the means in tables 3 and 4). None of the communications of comparisons between twice and thrice daily milkings, including a trial carried out on a large number of ewes (GAAL, 1957), reported that the milk yield did not increase in response to the extra daily milking. Furthermore, the drop in milk yield following a change to a single daily milking — 24 p. 100 and 18 p. 100 in the blue and white groups respectively — was far smaller than the 50 p. 100 that one would expect on the basis of cattle experiments. (CLAESSON, HANSSON, GUSTAFSSON and BRANNANG, 1959).

TABLEAU 5

Quantités journalières de lait et de matière grasse par demi-mamelle traite 1, 2 ou 3 fois par jour
(Expérience 1)

TABLE 5

Daily yield of milk and fat of half udders when milked once, twice or thrice a day
(Experiment 1)

	Blue group	
Milking frequency	Milk, (g)	Fat, (g)
1×	725	43.60
2×	982	55.89
3×	956	54.57
	White group	
Milking frequency	Milk, (g)	Fat, (g)
1 ×	601	33.45
2 ×	738	41.65
3 ×	726	41.58

(see also fig. 1)

The experiment provided a further demonstration of the galactopoeitic effect of the oxytocin removal of residual milk in the ewe as described by DENAMUR and MARTINET, 1961 and MORAG and FOX, 1966. During the three weeks of the latin square the blue group (oxytocin) yielded 29 p. 100 more milk and 32 p. 100 more fat than did the white group (without oxytocin).

The effect on the yield of a half udder of the milking frequency on the other side is seen in table 6 and figure 2. *It would appear that the less frequently the opposite side is milked the higher the yield becomes.* A possible explanation to this, could be that it is due to some obscure intra-udder compensatory mechanism such as had been suggested in other contexts in cattle by GARRISON and TURNER (1936) and by GRIFFIN (1966).

TABLEAU 6

Quantités journalières de lait et de matière grasse par demi-mamelle quand celle du côté opposé est traite 1, 2 ou 3 fois par jour (Expérience 1)

TABLE 6

Daily yield of milk and fat of half udders when OPPOSITE half udders milked once, twice or thrice a day (Experiment 1)

	Blue group	
Milking frequency on *opposite* half	Milk, (g)	Fat, (g)
1 ×	919	55.30
2 ×	880	51.00
3 ×	866	47.76
	White group	
Milking frequency on *opposite* side	Milk, (g)	Fat, (g)
1 ×	749	43.50
2 ×	660	38.64
3 ×	659	34.54

(see also fig. 2)

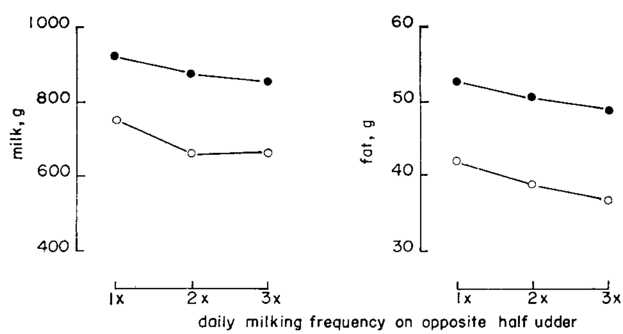

FIG. 2. — *Quantité journalière de lait et de matière grasse par demi-mamelle quand le côté opposé est trait 1, 2 ou 3 fois par jour*
• Groupe Bleu ○ Groupe Blanc
(Expérience 1)

FIG. 2. — *Daily yield of milk and fat of half udders when opposite half udders are milked once, twice or thrice-a-day, g*
• Blue group ○ White group
(Experiment 1)

In view of the inability to demonstrate the expected response to a third daily milking and in order to clarify the effect of application of different milking frequencies to the half udders of the same ewe a further experiment was initiated.

EXPERIMENT 2

Materials and Methods

The effect of twice and thrice-a-day milking estimated by half and full udder techniques was investigated using 8 mutton breed ewes (see table 7). The 8 ewes were ranked in order of their previous yield and were then divided in the rank order into two yield blocks of 4 ewes each. The ewes of each block were then randomly allocated to the treatment sequences of a 4 × 4 Latin square (see table 8). Each period lasted 7 days and the readings of the first day of each period were discarded in an attempt to eliminate carry-over effects of residual milk. Total experimental times was 28 days made up :

$$4 \text{ periods} \times (1 \text{ discard} + 6 \text{ treatment days}) = 28 \text{ days}$$

TABLEAU 7

Détails sur les animaux expérimentaux (Expérience 2)

TABLE 7

Details of Experimental Ewes (Experiment 2)

Ewe number	Breed*	Age in years	Days since lambing	Mean daily 1/2 udder yield over previous 10 days, (g)
High yielding block				
1	D.H.	2	38	Right 924 Left 903
2	D.H.	2	40	Right 1297 Left 1364
3	D.H.	2	41	Right 956 Left 993
4	D.H.	2	41	Right 1324 Left 1352
Low yielding block				
11	D.H.	5	42	Right 683 Left 740
12	C.B.	2	39	Right 753 Left 770
13	H.B.	7	38	Right 613 Left 554
14	D.H.	4	42	Right 710 Left 684

* D.H. Dorset Horn.
H.B. Half-bred (Border Leicester × Cheviot)
C.B. Cross-bred (Dorset Horn × Half-bred).

Milking was carried out in the parlour described above. Ewes not scheduled to be milked at any particular hour were kept in the yard out of earshot of the pulsators until the milking session was over. The ewes to be milked were brought into the parlour and offered concentrates in the milking stands. The teat cups were then applied and when the milk flow had ceased the udders were vigorously massaged and then machine-, and hand-stripped. Udder washing and fore-milking were not practised. Milking times were at 0.800, 16.00 and 24.00 and at 12.00 and 24.00 h on the thrice and twice-a-day milking routines respectively. The fat and total solids content of daily composite samples were carried out by the modified method of Gerber (MACDONALD, 1959) and by the method of GOLDING (1934), respectively.

Feeding, housing and general management were as described in the previous experiment.

TABLEAU 8

Plan expérimental (Expérience 2)

TABLE 8

Experimental Design (Experiment 2)

Ewe numbers	Periods			
	1	2	3	4
1 and 11	A	B	C	D
2 and 12	B	C	D	A
3 and 13	C	D	A	B
4 and 14	D	A	B	C

Treatments	Left 1/2 udder	Designation	Left 1/2 udder	Designation
A	Milked 2×a day	$T_2 : (3)$	Milked 3×a day	$T_3 : (2)$
B	Milked 3×a day	$T_3 : (3)$	Milked 3×a day	$T_3 : (3)$
C	Milked 3×a day	$T_3 : (2)$	Milked 2×a day	$T_2 : (3)$
D	Milked 2×a day	$T_2 : (2)$	Milked 2×a day	$T_2 : (2)$

A and C are referred to as the staggered routines.
B and D are referred to as the coincidental routines.

Results and Discussion

The average daily half-udder yields for each period of milk, fat, total solids and solids-not-fat were analyzed according to the following model :

$$Y_{iklm} = \mu + S_i + H_{ij} + P_k + T_{lm} + \varepsilon_{iklm}$$

when μ = the mean daily yield of a half udder in a period

S_i = the effect due to the ith. ewe i = 1, 2... 8

H_{ij} = the effect due to the jth. half udder of the ith. ewe j = 1,2

P_k = the kth. period k = 1, 2, 3, 4

T_{lm} = the effect due to the lth. treatment of two or three times a-day milking and the mth. treatment of two or three times-a-day milking on the other side of the udder l = 1, 2 and m = 1, 2.

TABLEAU 9

(Expérience 2)

Moyennes basées sur l'analyse des périodes avec une erreur à 42 degrés de liberté

TABLE 9 *Means based on period analysis with an error of 42 d. f.* (Experiment 2)

	Milk g/day ½ udder	Fat g/day ½ udder	Total solids g/day ½ udder	Solids-not-fat g/day ½ udder	Difference between milkings at midnight and at other times, g/day**
Experimental means					
$T_{2:3}$*	744.1	38.09	125.03	86.36	173.18
$T_{3:3}$	787.9	40.00	129.85	89.85	36.52
$T_{3:2}$	748.8	39.41	126.95	87.55	201.97
$T_{2:2}$	777.1	42.19	128.05	85.91	32.65
Calculated effects					
$\frac{1}{2}(T_{2:3} + T_{2:2})$	768.4	39.71	128.40	88.70	119.25
$\frac{1}{2}(T_{3:3} + T_{3:2})$ (Main effect)	760.6	40.14	126.54	86.14	102.92
$\frac{1}{2}(T_{3:3} + T_{2:3})$	766.0	39.05	127.44	88.15	104.85
$\frac{1}{2}(T_{2:2} + T_{3:2})$ (Secondary effect)	763.0	40.80	127.50	86.73	117.31
$\frac{1}{2}(T_{2:3} + T_{3:2})$	746.4	38.75	125.99	86.98	187.58
$\frac{1}{2}(T_{3:3} + T_{2:2})$ (Interaction)	782.5	41.00	128.95	87.88	34.59

* The left number describes the treatment on the measured half udder, whilst the right number describes the milking routine on the opposite side of the same ewe (see table 8). On treatments $T_{2:3}$ and $T_{3:2}$ only the midnight milking is coincidental.

** Calculated as :

(i) In half udders milked twice daily :

$$2 \times (\text{Mean yield over 6 days at } 24.00 - \text{mean yield at } 12.00)$$

(ii) In half udders milked thrice daily :

$$3 \times \left(\text{Mean yield over 6 days at } 24.00 - \left[\frac{\text{mean yield at } 8.00 + \text{mean yield at } 16.00}{2}\right]\right)$$

TABLEAU 10

Sources de variations et carrés moyens des moyennes du tableau 9 (Expérience 2)

TABLE 10 *Sources of variance and mean squares of means in table 9.* (Experiment 2)

	d.f.	Milk	Fat	Total solids	Solids-not-fat	Difference between midnight and other milkings
Ewes	7	420 223	1318.0	11 948	38 623	789 663
Half udders in ewes	8	10 506	29.5	3 81	1 884	23 945
Periods	3	48 208	176.9	1 786	2 677	3 967
Treatments	3	7 312	45.4	65	150	4 975
Error	42	6 068	13.2	122	3 209	127 084
	63					

The means and relevant standard errors are given in tables 9 and 10. During the handling of the field data it was noticed that the midnight yield were often higher than the day time yields. The differences between the yield at midnight and the other milkings, corrected for the differences in interval lengths (see footnote table 9), were therefore also subjected to analysis according to the above model. (The fat yields could not be analyzed in this way as the fat content had been determined in *daily* composites).

The data of this experiment confirm the findings of the previous experiment and shewed that a change from two to three daily milkings had no effect on the yield of milk in the ewe. Furthermore, there was a suggestion (significant only at a level of 10 p. 100) that a non coincidental milking routine had caused a reduction in milk yield. Only the *water* phase was actually affected as the yield of total solids shewed no such trend (see interactions means for milk and total solids in table 9). The reduction in yield at a non-coincidental milking as compared to a coincidental was highly significant (see interaction means for the difference between milkings at midnight and at other times in table 9).

Examination of the data from individual ewes shewed that the slope of the lactation curve was a characteristic of each ewe and that the decline was independent of treatment. This is shewn in table 11. and figure 3 which compare the slope of the daily yield *within* each period with that *between* periods in individual ewes. The linear

TABLEAU II

Relation entre les pentes des moyennes de production laitière journalière, au cours de l'expérience 2. Pentes « entre périodes » et « intra périodes » (Expérience 2)

TABLE II

Relationship between the « b » values of between and within period slopes of mean daily milk yields (Experiment 2)

Period	Within Periods					Between Periods
	1	2	3	4	Mean	
Ewe						
1	12.71	18.71	— 0.24	4.17	35.35	6.45
11	7.47	— 16.01	— 6.34	7.29	— 7.59	— 56.80
2	— 17.74	— 7.10	— 23.49	29.71	— 18.62	— 92.14
12	26.51	— 12.90	— 17.70	— 6.83	— 10.96	— 58.08
3	51.27	— 11.30	12.29	7.67	59.93	45.54
13	8.06	— 7.56	— 14.36	9.14	— 4.72	— 37.72
4	— 3.86	— 54.63	8.03	— 40.93	— 91.39	125.35
14	2.99	0.44	— 11.03	— 10.03	— 19.21	— 16.20

relationship of the plots in the figure illustrates this point clearly. Now the model used for the analysis takes out bias due to time as a « period » effect (with 3 degrees of freedom) and is based on the assumption that the decline in yield with the advance of lactation is uniform in all subjects. As this was not so in these data, they were reanalyzed using the following linear model ; (for general method see Cox, 1958, 1962) :

$$Y_{iklm} = \mu + S_i + H_{ij} + b_i(k - 2.5) + T_{lm} + \varepsilon_{ijklm}$$

when b_i is the regression of yield of time in the *i*th. ewe (other nomenclature as in the previous model).

This model takes out the bias as an individual ewe « slope » effect with 8 degrees of freedom. The decline in yield with time for the 16 half udders had previously been plotted out, and it was seen that the slopes of the decline of the two half udders in any one ewe were similar, and for this reason the regressions were calculated on a ewe rather than a half udder basis.

The covariance means and the relevant standard errors are shewn in table 12. It can be seen that the similarity between the yields to twice- and thrice-a-day milking remains as in the previous analyses. The reduction in milk (that is of the water phase) on the staggered milking routines has, however, disappeared. This indicates that the reduction shewn in the earlier analysis was due entirely to a spurious latin square effect and was not, in fact, of biological origin.

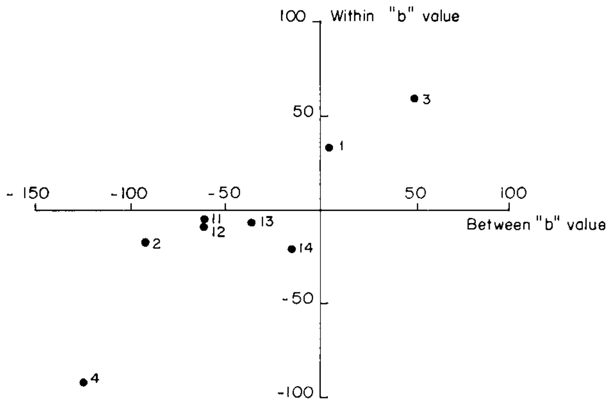

FIG. 3. — *Relation entre les pentes des moyennes de production laitière journalière Pentes « intra-périodes » et « entre périodes » pour chaque brebis* (3 : numéro de la brebis) (Expérience 2)

FIG. 3. — *Relationship between the « b » values of between and within period slopes of mean daily milk yields for individual ewes schewing ewe numbers* (Expériment 2)

An additional set of 64 analyses were carried out on the differences in yield between the midnight and daytime yield of milk in each half udder period, according to the following model :

$$Y_{ij} = \mu + D_i + T_j + \varepsilon_{ij}$$

μ = the mean difference between the midnight and the daytime yield in an udder half.

D_i = the effect due to *i*th. day $i = 1, 2, \ldots 6$

T_j = the effent due to *j*th. time of day $j = 1, 2$.

The bias in favour of the midnight milking was significant ($P < 0.01$) in 32 cases, that is *in all cases that the daytime milkings were non-coincidental and non-significant in the 32 cases when both day and night milkings were coincidental.*

TABLEAU 12

Moyennes dérivées de l'analyse des pentes avec une erreur à 37 degrés de liberté
(Expérience 2)

TABLE 12

Covariance means derived from slope analysis with an error of 37 d. f.
(Experiment 2)

	Milk g/day ½ udder	Fat g/day ½ udder	Total solids g/day ½ udder	Solid-Not-Fat g/day ½ udder	Difference between milkings at midnight and at other times, g/day**
			Experimental means		
$T_1 : {}_3$	759.6	38.64	127.07	87.80	212.58
$T_3 : {}_3$	764.0	39.82	127.07	87.24	53.88
$T_3 : {}_2$	764.4	39.96	128.99	89.00	241.38
$T_2 : {}_2$	769.8	41.26	126.71	85.64	82.84
			Calculated effects		
$1\frac{1}{2}$ ($T_2 : {}_3 + T_2 : {}_2$	764.2	39.89	128.03	88.12	147.63
$1\frac{1}{2}$ ($T_3 : {}_3 + T_3 : {}_2$	767.1	39.95	126.89	86.72	147.71
(Main effect)					
$1\frac{1}{2}$ ($T_3 : {}_3 + T_2 : {}_3$	761.8	39.23	127.07	87.52	133.23
$1\frac{1}{2}$ ($T_2 : {}_2 + T_3 : {}_2$	767.1	40.61	126.89	87.32	162.11
(Secondary effect)					
$1\frac{1}{2}$ ($T_2 : {}_3 + T_3 : {}_2$	762.0	39.30	128.03	88.40	226.98
$1\frac{1}{2}$ ($T_3 : {}_3 + T_2 : {}_2$	766.9	40.54	126.89	86.44	68.36
(Interaction)					

* The left number describes the treatment on the measured half udder, whilst the right number describes the milking routine on the opposite side of the same ewe (see table 8). On treatments $T_2 : {}_3$ and $T_3 : {}_2$ only the midnight milking is coincidental.

** Calculated as : (i) In half udders milked twice daily :-

$$2 \times [\text{Mean yield over 6 days at 24.00} - \text{mean yield at 12.00}]$$

(ii) In half udders milked thrice daily :-

$$3 \times [\text{Mean yield over 6 days at 24.00} - \left[\frac{[\text{mean yield at 8.00} + \text{mean yield at 16.00}]}{2}\right]$$

As half udder techniques have been widely used in cow studies, a check was made to see if a similar effect was produced by the non-coincidental milking of half udders in cattle. Data taken from an earlier half-udder experiment by ELLIOTT (1958) were investigated and a similar effect to that shewn in the present work, albeit of less magnitude, was observed. (see MORAG, 1966).

A suggested explanation for the effect of non-coincidence of milking based on a reanalysis of the data of Experiment 1

The reduction in half udder milk yield at a non coincidental milking could possibly be due to an inhibition of ejection for reasons which are quite obscure. It can be argued that if this was so there should be no reduction when half udders are milked non-coincidentally with the aid of an exogenous oxytocin. To test this hypothesis the

TABLEAU 13

Source of variance and mean squares of means in table 12

TABLE 13

Sources de variations et carrés moyens des moyennes du tableau 12

	d.f.	Milk	Fat	Total solids	Solids not fat	Difference between midnight and other milkings
Ewes	7	as in table 10				
Half udder in ewes	8					
Slopes	8	43692	108.60	1015.8	529.3	12753
Treatments	3	217	16.74	15.7	24.2	110904
Error	37	1925	8.25	8.3	46.7	4129
	63					

original data of Experiment 1 were analyzed for differences between the yield of milk at 21.00 h and the other milkings in the blue and the white groups. Analysis of the first week's results gave the difference between two *coincidental* milkings, and any bias that appeared can only be attributed to some diurnal effect. The analysis carried out on the differences during the periods of the latin squares (*i. e.* during the 2nd, 3rd and 4th experimental weeks) deals with the above bias plus the effect of non-coincidence of milking. (All yields of milk during periods in which half udders were milked only once-a-day have, of course, been discarded from these analyses).

Table 14 shews that in both the blue and white groups there was a significant bias in milk yield in favour of the *morning* milking, (the difference in fat yield was significant only in the blue oxytocin group) during the first week, when all milking was coincidental. This is in general agreement with the hypothesis of SEMJAN (1962) that the rate of milk secretion in the ewe is higher during the night. One is, however, unable to discern any diurnal effect of the mechanism of ejection, as did Semjans

TABLEAU 14

Sources de variations, carrés moyens, facteurs de correction et moyennes générales des différences journalières dans les quantités de lait et de matière grasse entre les traites à 21 h et 9 h dans les groupes BLEU et BLANC de l'expérience 1

TABLE 14

Sources of variance, mean squares, correction factors and grand means of the daily differences in yields of milk and fat between the milking at 21 00 h and 09 00 h in the BLUE and the WHITE groups of Experiment 1

Sources of variance	Blue group (oxytocin)				White group (without oxytocin)			
	d.f.	Milk	*d.f.*	Fat	*d.f.*	Milk	*d.f.*	Fat
Half udders (H-U)	11	10 655	11	70.8	11	11 268	11	34.1
Ewes	5	21 275	5	121.2	5	15 166	5	46.8
H-U in Ewes	6	2 443	6	28.8	6	8 019	6	23.5
Days	6	75 091	2	19.3	6	6 607	2	19.8
Error	66	5 854	22	23.2	66	4 755	22	14.2
Correction factor	1	828 257	1	1.5	1	458 281	1	23.2
Grand mean (g)		— 99g		— 2.7g		— 73.8g		— 1.1g

TABLEAU 15

Sources de variations, carrés moyens, facteurs de correction et moyennes générales des différences hebdomadaires dans les quantités de lait et de matière grasse pour les traites faites en coïncidence bilatérale (21 h) *ou non dans les groupes BLEU et BLANC de l'expérience 1*

TABLE 15

Sources of variance, mean squares, correction factors and grand means of the weekly differences in yield of milk and fat between the coincidental (21 00 h) and the non-coincidental milkings in the BLUE and WHITE groups of Experiment 1

Source of variance	Blue group (oxytocin)			White group (without oxytocin)	
	d.f.	Milk	Fat	Milk	Fat
Ewes	5	327 046	65 462	3 428 302	633 616
Periods corrected for ewes	2	86 410	57 259	1 294 146	298 033
Treatments	3	634 629	37 793	104 927	5 579
Error	13	98 706	36 479	431 292	52 200
Correction factor	1	2 446 860	721 621	71 390 162	11 592 600
Grand mean, g		319g	173g	1 725g	695g

since the differences in yield between the evening and morning milkings in both the blue and white groups appear to be similar.

Table 15, however, presents a different picture. During the periods of the latin square there was a significant bias in the yields of milk and fat in favour of the *evening* i. e. coincidental milking. The reduction in yield at a non-coincidental milking discerned in Experiment 2 is thus also clearly demonstrated by this further analysis of data from the first experiment. These data do not only confirm this finding *but also present strong evidence that the reduction in yield at a non-coincidental milking is at least partially due to an inhibition of milk ejection.* This can be deduced since the bias in favour of a coincidental milking, although still significant, *became far smaller when oxytocin was given at all milkings.* This is seen by comparing the grand means in the blue (oxytocin) and the white (without oxytocin) groups (table 14).

The two experiments described in this paper consistently shew that there is no increase in milk yield when ewes are milked thrice daily either with or without the aid of oxytocin. It would appear that this is an important species characteristic, when one compares the lack of response in the ewe with the many reports of an increase in milk yield from a third daily milking derived from cow studies. An additional species characteristic is the relatively small reduction in milk yield caused by a change from two to a single daily milking, which was far smaller than that reported in cows.

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SUMMARY

Two experiments were carried out to determine the effect of different daily milking frequencies on the milk yield of the ewe.

In the first experiment ewe half-udders were milked once, twice or thrice daily, using a 3 × 3 Latin square design. One group of six ewes was milked as in normal practice whilst another group 6 ewes was milked with the aid of oxytocin. Within each group the milk and fat yields of udder halves milked twice and thrice were identical, whilst a single daily milking caused a reduction of some 20 p. 100. The group milked with the aid of oxytocin out-yielded the other ewes by over 30 p. 100 on all milking frequencies. The yield of a given udder half was shewn to be influenced by the milking frequency on the other udder half : the less frequently the other side was milked the greater the yield of the given gland.

The second experiment compared twice and thrice daily milking on a whole and a half udder basis in eight ewes using a 4 × 4 Latin square design. The yields of milk, fat and total solids of half udders milked thrice was again found to be identical to that of half udders milked twice. Furthermore the yield of an udder half on a given milking frequency were similar when the opposite side was milked twice or thrice daily. A reduction of over 20 p. 100 in yield was however, detected when a half-udder was milked alone after any given interval (non-coincidentally) as compared to the yield of the same udder half when milked together with to opposite gland (coincidentally) after the same interval. It was suggested that this reduction in yield, when a gland was milked noncoincidentally, was due to an inhibition of milk ejection. Support for this was found in that when oxytocin was given at both coincidental and non-coincidental milkings the yields were similar.

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