A STUDY OF DIURNAL RHYTHMS IN MILK AND FAT PRODUCTION IN THE COW.

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TABLE OF CONTENTS

PART I

DIURNAL RHYTHMS IN MILK AND BUTTERFAT PRODUCTION

I N T R O D U C T I O N

When cows are milked under commercial conditions milk yields are normally greater in the morning than in the evening, mainly because a longer time interval precedes the morning milking. In addition the percentage of fat in the milk is generally lower in the morning and higher in the evening. The alternation of high milk yields of low fat percentage, with lower milk yields of higher fat percentage, form a diurnal rhythm. This will depend partially on the length of time between morning and evening milkings, for the difference in yield and fat percentage is reduced as the time intervals approach equal length.

There is left in the udder after a normal milking an appreciable quantity of milk of high fat percentage which has been termed "residual milk". In a hypothetical case if the volume and fat percentage of this milk remained constant after each milking, then the yield obtained from the udder would represent synthesis, and any diurnal rhythm would be caused solely by synthesis. However, neither the amount, nor the fat percentage of the residual milk remains constant at morning and evening milkings. Thus the diurnal rhythm may be attributed to two general causes, firstly synthesis, and superimposed on to this a diurnal variation in residual milk.

The differences in milk and fat yield between morning and evening milking constituted the general field of this investigation and the following general objectives were formulated in an attempt to achieve a clearer understanding of this problem.

1. To measure differences in the rate of synthesis in alternate night and day periods.
2. To measure the amount and fat content of the residual milk in the udder after normal milk ejection and removal had been completed.

REVIEW OF LITERATURE

It is not intended to review the broad field of literature concerning milk secretion and ejection, but to cover the following aspects.

1. To examine the literature to find what differences in milk yields and fat percentage between morning and evening milkings are thought to occur.

2. To examine possible causes of the differences defined above.

It is suggested that workers in this field have not given sufficient consideration to the secretion of water in relation to the milk solids. The variations in yield and composition which occur between the quarters of an udder have also been neglected.

The osmotic pressure of milk remains remarkably constant over the normal range of milk yield and composition, Davis and MacDonald (1953). Osmotic pressure involves an equilibrium between water and solutes. It would be of interest to know whether this equilibrium is maintained by water entering or water leaving the lumen of the alveolus, because this would give a clearer understanding of changes in fat percentage, which is the ratio of $\frac{\text{fat} \times 100}{\text{milk}}$.

There is a tendency to regard fluctuations in percentage composition as a direct result of a particular set of conditions, for example, plane of nutrition, and to ignore the possibility of the osmotic pressure equilibrium influencing composition, for instance, the entry of additional water into the alveolus to achieve osmotic pressure equilibrium, with a consequent fall in percentage composition.

Many of the studies of milk yield and fat percentage have been made of samples from the combined yield of the four separate quarters of the udder. This has the disadvantage of obscuring the differences in yield between quarters demonstrated by Crossman et al. (1950), and also the differences between quarters in the rise in fat percentage during milking shown by Johansson (1952a). Therefore the value of any future work in this field would be increased by separate examination of the milk from each quarter.

A. The differences in milk yield and fat percentage between morning and evening milkings.

(1) Fat Percentage.

The low fat percentages normally occurring at the morning milking have been recognized for many years. Investigations made by Krull as early as 1905 have been confirmed by Bartlett (1929) and Edwards (1950).

(2) Milk Yield.

The difference between morning and evening milk yields depends largely on the difference in the time intervals between those milkings. This can be allowed for by dividing the yield by the length of time between milkings. This gives the yield per hour, which may differ from the rate of synthesis if residual milk varies between alternate milkings.

It was necessary to find out whether the yield per hour was likely to be the same in both intervals, or whether it was lower for the interval preceding the morning milking.

Bartlett (1929) and Edwards (1950) found the yield per hour was consistently lower for the interval preceding the morning milking but that it varied with the stage of lactation. On the other hand Korkman (1953) found equal yield per hour at both morning and evening milkings. Since these data were not collected with the particular aim of measuring the milk yield per hour for the two intervals, the accuracy of the estimate of the time intervals might not be satisfactory.

Although not decisive, the evidence presented by these three workers suggested that the yield per hour was lower in the long night interval.

The "night effect".

Campbell (1930, 1931, 1933) reported the existence of higher yields of milk and fat at night than in intervals of the same length during the day. Termed the "night effect" this appears to have been widely accepted, and has been quoted by Johansson (1940), Edwards (1950) and Korkman (1953). Critical examination of Campbell's work casts some doubt on the validity of his conclusions.

(a) The night effect at unequal intervals between milkings.

Campbell's results were obtained from cows milked at alternate 9 and 15 hour intervals throughout lactation. The following criticisms are made of his experimental technique.

The intervals of 6.30 a.m. to 3.30 p.m. and 6.30 a.m. to 9.30 p.m. alternated in periods of several weeks' duration. But Bartlett (1929), subsequently confirmed by Edwards (1950), showed changes over the lactation in the ratio of morning yield to evening yield. Thus Campbell's results could have been confounded by stage of lactation.

The periods of long night interval tended to coincide with the periods when the stock were housed. This is evident from figures 1 - 6 Campbell (1931). This also may have confounded the results.

The change in routine from a long night interval to a long day interval, and back again, was achieved by altering the time of the evening milking, and keeping the morning milking constant. Thus any low yields recorded as a result of abnormal let down would be expected at the 9.30 p.m. milking, tending to inflate the following morning yield, and thus the yield per hour for the interval preceding that milking.

It is possible to obtain evidence of inflated morning yields by comparing the ratio of morning to evening yields with the ratio of the respective time intervals. It has been shown that the yield per hour in the interval preceding the morning milking is less than in the interval preceding the evening milking which results in the ratio $\frac{\text{a.m. yield}}{\text{p.m. yield}}$ normally being less than the ratio $\frac{\text{a.m. time interval}}{\text{p.m. time interval}}$.

When the ratio $\frac{\text{a.m. yield}}{\text{p.m. yield}}$ is greater than the ratio $\frac{\text{a.m. time interval}}{\text{p.m. time interval}}$ it is regarded as evidence of inflated morning yields due to the change in the evening milking routine. Such evidence may be found for three of the six cows in Table I Campbell (1931) which is reproduced below.

Table 1

Ratio of milk yield to milk yield

(after Campbell 1931)

Cow	Milking Hours: 6.30 a.m. and 3.30 p.m.	Milking Hours: 6.30 a.m. and 9.30 p.m.
Cherry 10	1 to 1.73	1 to 1.35
Rockrose 19	1 to 1.82	1 to 1.29
Rockrose 5	1 to 1.63	1 to 1.36
Rockrose 9	1 to 1.87	1 to 1.57
Fillpail 8	1 to 1.56	1 to 1.41
Duchess 7	1 to 1.61	1 to 1.49
Ratio of time intervals	1 to 1.67	

The postulated night effect depends on a comparison of the results in columns one and two. Since the basis of the comparison, namely, the results in column 1, is questioned there is inadequate evidence of greater milk production in a long night interval than in a long day interval.

(b) The night effect at equal 12 hour intervals.

Campbell (1933) reported as evidence of the night effect the milk yields for 6 cows over several weeks at two stages of lactation.

	6 a.m.	6 p.m.
Stage 1	4561.25	4186.00
Stage 2	3232.5	3296.00
Total	7793.75	7482.00

Whilst over the whole experiment the milk production at the 6 a.m. milking exceeded that at 6 p.m., in the second stage the 6 p.m. yield was consistently greater than the 6 a.m. yield. Thus it appeared unreasonable to conclude that, at 12 hour intervals there was greater milk production in the interval preceding the morning milking, and that this constituted a "night" effect.

The situation may be summarized as follows.

1. Lower fat percentages occurred at the morning milking after a long night interval.
2. The yield per hour under these conditions was probably less than in the short day interval.
3. The "night" effect postulated by Campbell has been disputed.

B. The possible causes of any difference between morning and evening milk and fat production have been examined as -

(1) Variation in ejection which caused differences in the amount of milk and fat left in the udder.

(2) Variation in the rate of milk synthesis.

1. Ejection.

Hammond (1913) used pituitary extracts to show that all the milk was not removed from the udder at any particular milking. The milk which remained in the udder was subsequently termed "residual milk". Johansson (1940) cited Krull as having suggested in 1950 -

> "That the cause of the comparatively low fat content of morning milk was not primarily a difference in secretion of fat in relation to milk serum, but that the emptying of the udder was less complete when the glands were more highly distended with milk after the long night interval."

Johansson (1940) tested this hypothesis using pituitary extracts to remove residual milk after each one of three milkings per day. He reasoned that if residual milk were the cause of differences in fat percentage then those differences should be removed when the udder is evacuated by the use of let down hormone at successive milkings. Unfortunately Johansson's results were inconclusive. His experiments might have offered more decisive results had there been two milkings per day instead of three. He merely concluded "It is quite possible that there is a diurnal variation in the rate of fat synthesis". No mention was made of any diurnal differences in the volume of milk synthesised.

Turner (1953) examined the same problem in a different way. He assumed no diurnal differences in synthesis, and accepted the lower fat percentages and lower yield per hour for the night interval reported by Edwards (1950) and Bartlett (1929). These he considered the result of the greater volume of residual milk left in the udder at the morning milking compared with the evening milking. The relationship was expressed as the regression of residual milk on total udder contents. He was able to show that the differences in morning and evening milk yields reported by Edwards (1950) were likely to be the result of variation in the amount of residual milk.

2. Synthesis.

Amongst other reasons it has been suggested by Johansson (1940) that different rates of synthesis may contribute to the differences in fat percentage between morning and evening milkings.

Turner (1953) has suggested that the rate of milk secretion remains constant for periods approaching 24 hours, but on the other hand Bailey (1954) in a preliminary note reported results which suggested the rate decreased after approximately 12 hours. This latter work appeared to be carefully executed and suggested that the rate of synthesis in a long interval was less than in a short interval. The effect of "night" was not investigated.

Plan of the Investigation.

The review of literature did not definitely show that the yield per hour in a long night interval was less than in a short day interval. However, after this was confirmed by an examination of the Massey College herd test data, it was decided to plan an investigation of the contribution of synthesis and ejection to this lower yield in the night interval.

1. Synthesis.

Turner (1953) assumed the rate of synthesis remained constant and that the lower yield per hour in the night interval was caused by a greater volume of residual milk remaining in the udder after the morning milking than after the evening milking. It was planned to milk cows at 12 hour intervals and as a check on the true rate of synthesis to eliminate any variation due to let down by superstripping them. This would show any difference in synthesis between the period 5 a.m. to 5 p.m. and 5 p.m. to 5 a.m., and thus give a test of the assumption that the rate of synthesis remained constant.

2. Ejection.

The quantity and fat percentage of residual milk would be examined in relation to primary yield in order to investigate the role of residual milk as a possible cause of diurnal differences in milk yield and fat percentage, and to find out whether the relationship of residual milk and primary yield varied between cows; and thus whether the diurnal differences in milk and fat yield in each cow would require separate explanation.

PRELIMINARY EXAMINATION OF MASSEY COLLEGE HERD TEST RECORDS

The review of literature did not provide conclusive evidence of a lower yield per hour in the long night interval than in the short day interval. The Massey College herd test data was used to clarify this point before proceeding with the main investigation.

The monthly herd test records collected by the Herd Improvement Association were examined with the following aims in view.

1. To search in the 1953/54 records of the "production per acre" experiment in which the milking interval equalled 12 hours for a difference between morning and evening milk yields. This had been suggested by an examination of the 1952/53 bulk milk records which showed some evidence of greater evening yields, contradicting Campbell (1932).

2. To investigate in the main Massey College herd, the claim made by Edwards (1950) and Bartlett (1929), that

the milk yield per hour was less in a 14 hour night interval preceding the morning milking.

Herd Improvement Association Records.

In compiling these records it was the practice of the testing officer to carry forward the odd tenths of a pound from the evening milking to be added to the tenths recorded at the morning milking, before rounding them off to the nearest pound. This inflated the yield per hour in the interval preceding the morning milking. In spite of this, results will be presented showing a lower yield per hour in that interval.

A continuous set of records from August to November was required and therefore only records of cows which had calved in or before August 1953 were used in this analysis.

(a) Milk Yield Data for cows milked at unequal intervals.

In the main Jersey herd 34 of the animals calved in or before August 1953; these were selected for the present analysis. The time intervals preceding the morning and evening milkings were estimated as 14.17 and 9.83 hours respectively. To give yield per hour the morning and evening milk yields were therefore divided by 14.17 and 9.83. The mean rate in the period preceding the evening milking was 1.075 lbs. per hour and preceding the morning milking 1.001 lb., a difference of 0.74 lb. per hour. Analysis of Variance for these data is given in Table 2, which shows

Table 2

Analysis of Variance of Milk Production data of the Main Jersey Herd

Source	df	S.S.	M.S.	F	Result
Cows	33	13,425.251	406.825		
Intervals	1	378.983	378.983	13.47	*
Months	3	1,281.098	427.033		
Cows x Months	99	3,942.827	39.827		
Cows x Intervals	33	502.489	15.227	.95	
Intervals x Months	3	84.403	28.134	1.75	
Error	99	1,588.368	16.049		
Total	271	21,203.919			

the lower yield per hour in the interval preceding the morning milking is statistically significant.

Turner (1953) had suggested that similar results put forward by Edwards (1950) were due to residual milk. It was concluded that a further investigation should be made of the part played by residual milk in producing these results.

(b) Milk Yield data for cows milked at 12 hour intervals.

The records of the cows in the "production per acre" experiment, in which the cows were to be milked as nearly as possible at 12 hour intervals were used in this analysis. After observing routine operations it was decided that the time intervals and the herd test data were sufficiently accurate for a preliminary analysis.

Twenty of the total number of cows in the herd had calved in or before August 1953 and their records were selected for analysis. The yields were not converted to rates per hour since the time intervals were equal.

The mean yields were -

Afternoon	- 14.75	lbs.
Morning	- 14.34	"
Difference	0.41	"

The herd test system of carrying over the fractions of a pound of milk from the evening to the morning milking would have reduced this difference of 0.41 lb. Also the greater evening milk yield appeared remarkably consistent and therefore although the difference between the means was non-significant as shown in Table 3, a more accurate investigation of this difference appeared desirable.

Table 3

Analysis of Variance of Milk Production data of the Production per acre experiment

Source	df	S.S.	M.S.	F	Result
Periods	1	6.782	6.782	<1.0	N.S.
Cows	19	920.544			
Months	3	51.244			
Periods x Cows	19	74.093	3.900	1.3	N.S.
Periods x Months	3	30.593	10.198	3.4	*
Cows x Months	57	177.331			
Error	57	171.032	3.001		
Total	159	1431.669			

Summary

For the cows milked at 10 and 14 hour intervals higher yields per hour were found in the 10 hour intervals preceding the evening milking. This made the ratio of $\frac{\text{p.m. milk yield}}{\text{a.m. milk yield}}$ greater than the ratio of the respective time intervals, which agrees with Bartlett (1929) and Edwards (1950). Turner (1953) considered that a greater volume of residual milk was left after the morning milking than after the evening milking. The excess of the morning residual milk over the evening residual milk was added to the secretion produced in the day interval and resulted in a higher yield per hour in that interval. This explanation could be tested by an examination of the relationship of residual milk to primary yield.

The greater evening yield found when the intervals between milkings were 12 hours was the reverse of the night effect reported by Campbell (1933). Although this greater evening yield was non-significant it was concluded that more accurate measurement was required.

EXPERIMENTAL METHODS

A. Residual Milk Estimation.

Milk ejection can be evoked in the udder by use of commercial pituitary extracts possessing oxytocic activity. In these experiments the Parke Davis preparation "Pitocin" was used, having a claimed concentration of 10 IU (oxytocic) per cc. Ten IU were considered satisfactory for the removal of the residual milk in the udder by Shaw (1942), Smith (1947), and Swanson and Hinton (1951) and by Brumby (1953).

Preliminary investigation of the removal of residual milk showed that occasionally a very small additional volume of milk was obtained by increasing the amount of Pitocin injected from 10 IU to 20 IU. Therefore in this work 10 IU were considered satisfactory for an estimate of the milk retained in the udder after normal ejection.

The milking routine prior to the collection of Residual Milk followed the normal pattern except that primary yield was collected in a herd test bucket until milk flow was negligible. Let down was not affected by the experimental technique and thus a valid estimate should have been obtained of the residual milk left after a normal milking.

After collecting the primary yield the cows were led to a crush pen in a separate building where one c.c.

of "Pitocin" was injected into the jugular vein. The animal was then immediately milked by machine; during the latter stages the claw was pulled downwards, and the udder vigorously massaged until milk flow was negligible.

A pilot experiment was carried out on the individual quarter milking machine used by McDowall (1946). The machine was found to be too large for accurate measurement of residual milk and it upset the normal ejection reflex at the primary milking. Therefore no attempt was made to collect yields of individual quarters.

B. Milk and Fat Recording

To ensure uniform fat distribution at all milkings, the milk was tipped from one bucket to another three times and then weighed to the nearest 1/10th of a pound. A sample was taken and from this the fat content was subsequently estimated in duplicate by the standard Babcock techniques, British Standards Institution. (1937)

C. Farm Organisation

Cows in the Massey College dairy herd were made available for this work. The herd was split into three units.

1. Friesians.
2. Main Jersey herd.
3. Jerseys on the "production per acre" experiment.

The order in which these cows were milked was as follows:-

Morning	Evening
1. Jerseys on "production per acre" experiment at 5 a.m.	1. Friesians.
2. Friesians.	2. Main Jersey herd.
3. Main Jersey herd.	3. Jerseys on "production per acre" experiment at 5 p.m.

The design of this routine allowed the Jerseys on the "production per acre" experiment to be milked at 12 hour intervals. However, the milking times varied when seasonal operations and unexpected disturbances made this necessary.

The Friesians and the main Jersey herd were organized on a commercial basis which limited the scope of experimental work.

The "production per acre" experiment, described by Riddet and Hyde (1954) was designed to study pasture utilization and the production of butterfat.

DIURNAL RHYTHMS IN MILK AND BUTTERFAT PRODUCTION

INTRODUCTION

In section A the difference between morning and evening milk and fat yield is described when the interval between milkings is 12 hours. Two experiments were carried out. In the first the cows were normally milked and therefore both milk synthesis and ejection could contribute to any difference in yield. In the second experiment the udders were evacuated by "pitocin" after each milking, thus eliminating any potential difference in let-down at morning and evening milkings and measuring only variation in synthesis. Examination of the results of both these experiments would allow not only the definition of any diurnal differences in yield when the interval between milkings was 12 hours, but also an assessment of the relative importance of synthesis and ejection in producing this result.

In section B normal milk yield was measured when the night interval between milkings was 14 hours and the day interval 10 hours. Turner (1953) had claimed that under these conditions any difference in yield per hour between day and night was caused by consistently more residual milk remaining in the udder after the morning milking. It was planned to test this view by relating these results to measurements of residual milk.

A. 12 HOUR INTERVALS BETWEEN MILKINGS

1. Milk yield at 12 hour intervals following normal ejection.

Experimental.

The yield of the cows in the production per acre experiment was measured without interfering with the normal routine of that experiment; except that a request was made for close observance of the 12 hour time interval between milkings. In spite of this request for exact timing a difference in time intervals resulted in the mean night interval being 8 minutes longer than the mean day interval.

Results

(a) Milk Yield.

The preliminary analysis of the herd test data on page 16 for these cows had shown a difference of 0.41 lb. between the afternoon and morning yield which was non-significant. The present experiment was designed to further investigate these differences.

Table 4

Mean Milk Yields for 30 cows over 4 days

Cow No.	Mean Yield lbs. P.M.	Mean Yield lbs. A.M.	Cow No.	Mean Yield lbs. P.M.	Mean Yield lbs. A.M.
1	14.0	13.5	16	15.7	14.4
2	10.1	9.2	17	16.2	15.4
3	11.0	10.6	18	12.8	13.2
4	12.1	12.1	19	13.1	12.8
5	14.5	14.7	20	13.5	13.2
6	14.7	13.8	21	16.4	17.0
7	14.1	13.7	22	19.1	17.1
8	15.2	15.1	23	13.2	12.1
9	13.1	13.8	24	12.5	11.7
10	14.1	14.2	25	12.7	13.0
11	6.3	6.2	26	11.1	10.5
12	18.5	18.3	27	14.8	13.8
13	11.4	11.9	28	13.6	12.4
14	19.7	18.4	29	10 .2	9.3
15	15.8	15.3	30	13.8	9.4
	Mean PM	13.76			
	Mean AM	13.19			
	Difference		0.57 lb.		

These data have been analysed by Analysis of Variance, Table 6.

The results in Table 4 show that the afternoon milk yield was 0.57 lb. greater than the morning, which is not only greater than in the preliminary analysis but also significant at the 9% level. (Table 6).

Table 5

The mean daily morning and evening bulk milk yields for 31 cows in the production per acre experiment.

Week ending	P.M.	A.M.
9.11.53	471 lb.	451 lb.
16.11.53	445	448
23.11.53	438	416
30.11.53	455	416
7.12.53	459	437
14.12.53	446	421
21.12.53	440	427
28.12.53	434	413
4.1.54	418	417
11.1.54	416	430
18.1.54	404	395
25.1.54	391	396
1.2.54	386	386
8.2.54	372	374
15.2.54	381	373
22.2.54	361	349
1.3.54	353	330
	7070	6879
Mean	415.9	404.6
diff	11.3	
	for 31 cows	

This difference of 0.57 lb. (Table 4) was supported by an examination of the record of the bulk milk produced by these cows at the morning and evening milkings, reproduced in Table 5. These records taken from the production per acre experiment were collected under routine conditions, when milking times were only approximately 12 hours apart, the mean day interval being slightly shorter than the mean night interval. However, in spite of the shorter time for secretion in the day interval the production in that time was still greater than in the night interval. Table 5 shows the mean daily production for the weeks when the time intervals were observed to be approximately 12 hours.

Table 6

Analysis of Variance of Milk Production of the 30 cows on the production per acre experiment.

Source	df	Sums Sqs.	MS	F	Result
Cows	29	1708.11			
Days	3	10.68			
Days x Cows	87	51.62			
Periods	1	19.55	19.55	6.63	p =0.09
Periods x Cows	29	52.97	1.83	2.18	**
Periods x Days	3	8.86	2.95	3.51	*
Error	87	73.37	0.84		
Total	239	1925.16			

The statistical test which has been used in Table 6 showed a low level of statistical significance for the difference between the mean milk production in the two periods. The interactions "Periods x Days" and "Periods x Cows" were both significant and therefore the appropriate test of significance for "periods" would not be using the usual test with "error" as the denominator. The most valid test was against the larger interaction as the denominator, but the low number of degrees of freedom for this interaction makes significance difficult to obtain but none the less it has been used. A more appropriate test might be to use a combination of Error and Interaction Mean Squares as denominator. However, the appropriate number of degrees of freedom are not known and although this procedure might have given a highly significant test it cannot be used.

These results show that the greater evening production could have occurred by chance alone 9 times in a hundred, that is, they were significant at the 9% level. The significant interaction between periods and days showed that the difference changes from day to day. This could be the result of differences in milking efficiency. The significant interaction "Periods x Cows" was of more interest because it showed that the diurnal rhythm differed between cows, and therefore the overall difference between morning and evening production required examination in each cow.

(b) Fat Yield.

Similar trends to those for milk yield were observed in differences between morning and evening fat production. Table 7 shows the mean fat production for each cow for the four day period and the difference between the mean morning and evening fat yields.

Table 7

Mean Fat Yields in lb. for 30 cows over 4 days.

Cow No.	Mean Yield lb. P.M.	Mean Yield lb. A.M.	Cow No.	Mean Yield lb. P.M.	Mean Yield lb. A.M.
1	.827	.708	16	.865	.719
2	.624	.528	17	.923	.746
3	.540	.478	18	.747	.724
4	.721	.660	19	.637	.597
5	.667	.670	20	.667	.592
6	.885	.775	21	.886	.913
7	.869	.702	22	.995	.727
8	.931	.871	23	.740	.575
9	.722	.708	24	.842	.677
10	.778	.716	25	.711	.691
11	.348	.326	26	.785	.626
12	1.023	.885	27	.940	.762
13	.635	.647	28	.793	.582
14	.961	.839	29	.570	.499
15	.848	.838	30	.777	.408

Mean P.M. 0.775
A.M. 0.673

Difference 0.10 lb.

The Analysis of Variance (Snedecor 1946) showed that in Table 8 the difference in Table 7 of 0.10 lb. of fat between the mean fat yield was highly significant.

Table 8

Analysis of Variance of fat production of 30 cows on the production per acre experiment.

Source	df	Sums Sqs	MS	F	Result
Cows	29	4.3216	.1490		
Days	3	.0776	.0258		
Days x Cows	87	.6365	.0073		
Periods	1	.6282	.6282	30.60	**
Periods x Cows	29	.4609	.0156	1.71	*
Periods x Days	3	.0629	.0209	22.5	**
Error	87	.8077	.00928		
Total	239	6.9954			

The difference between the mean morning and evening fat production was tested in Table 8 in the same way as in Table 6 for the milk yield data, but in Table 8 a highly significant result was obtained when tested against the larger interaction.

The significant interaction "Days x Cows" showed that the diurnal rhythm in fat production differed between days; this could have been caused by variation in milking efficiency. The significant interaction "Periods x Cows" showed that the diurnal rhythm differed between cows, but since fat is suspended in the milk the significant interaction for milk yield in Table 6 and fat yield in Table 8 may have common cause.

(c) Fat Percentage.

The mean fat percentage for morning and evening over the experimental period was -

Evening	5.65%
Morning	5.11%
Difference	0.54%

The influence of variation in let-down on fat percentage is discussed in Part II Section "E" where it has been shown that higher yields due to more complete evacuation of the udder result in a higher fat percentage at that milking. Conversely a lower fat percentage was found when yield was reduced by a poor let-down. It is possible that the higher fat percentage at the evening milking was caused by a consistently bigger let-down which would add more of the high fat percentage strippings to the primary yield. It is interesting to note that if the extra 0.10 lb. of fat were suspended in the extra 0.57 lb. of milk this milk would be 17.5% fat, which is not greatly above the fat percentage found in strippings. However there is no evidence to show that the extra yield of fat and milk was in the strippings.

The problem was to find a test for the hypothesis that a bigger let-down occurred at the evening milking. If there had been a bigger let-down there would have been more strippings added to the primary yield.

From the normal milking to milking variation in fat yield it was possible to estimate how much extra fat would be added by the let-down of an additional 0.57 lb. of milk. This relationship between fat yield and milk yield is discussed in Part II Section "E".

Table 9.

Analysis of Covariance to test the significance of the difference in fat yield between periods after allowance for the regression of fat yield (y) on milk yield (x).

Source	df	Errors of Estimate SSy'	df'	M.S.	F	Result
Total	239					
Cows	29					
Days	3					
Periods	1					
Days x Cows	87					
Periods x Cows	29					
Periods x Days	3					
Error	87	0.288	86	0.00335		
Periods + Error	88	0.428	87			
Difference for test-adjusted period means		0.140	1	0.140	41.79	**

Table 9 shows that the difference between the mean fat yields remained significant after allowance for the regression of fat yield on milk yield. It was possible that this relationship between milk yield and fat yield may show some departure from linearity, but it is not likely to be important in this analysis. It is concluded that let-down did not produce all the difference in fat yield between morning and evening milkings. However, this test can only show that let-down could not have produced all the difference, but does not show whether it produced part of the difference. This test would have given a more decisive result if the difference in fat yield had been non-significant after allowing for the extra milk yield, because then it would have been concluded that a difference in let-down had occurred and a difference in synthesis had not occurred.

2. Milk yield at 12 hour intervals following superstripping.

Experimental

The use of "Pitocin" as a technique for evacuation of the bovine udder has been discussed under the general heading of Experimental Methods. It has been assumed that the contractile elements in the udder showed uniform sensitivity to one c.c. of "Pitocin" at morning and evening milking and this gave uniform evacuation at both milking times. Thus differences in total yield were interpreted as differences in synthesis. The 10 Jersey cows made available from the main Massey College herd were milked in the same order, starting at 5 a.m. and 5 p.m. The length of the intervals between milkings were estimated from the time the cups were removed from each cow. Care was taken to prevent the feed conditions from influencing the results, and as far as possible the feed offered during the day period and the night period was similar. A ration of 4 lb. of commercial dairy meal was offered to each cow after each milking. The meal helped to maintain production and also allowed the cows to settle down to the new routine. The cows were allowed to graze irrigated pasture for approximately three-quarters of an hour after eating their meal. For the remainder of the day they were on medium quality grass, plus ample silage. This supplementary feed was made necessary by the dry summer of 1953/54.

Starting on 23rd February five days were allowed for the cows to become accustomed to the new conditions; then the injection routine was in operation from 28th February to 5th March and the return of normal let-down was observed from 5th March until 8th March.

Results

(a) Milk yield.

The mean night interval was 12.12 hours, and the day interval 11.89 hours, a difference of 14 minutes. In spite of the shorter day interval the yield of milk synthesised during the day was the greater. Therefore the difference of 0.28 lb. in mean yield, Table 10, between periods in these results could not have been caused by the uneven time intervals, rather it may have been reduced by the uneven time intervals.

Table 10

Mean milk yields at morning and evening for 6 superstripped cows for 6 days.

Cow	Morning	Evening
1	9.72	9.18
2	10.80	11.12
3	9.93	9.83
4	9.20	10.10
5	11.62	11.95
6	16.27	17.30
7	9.62	9.97
8	11.67	11.27
9	13.03	13.48
10	10.20	10.67
Mean	11.21	11.49
Mean Difference	0.28 lb.	

The relation between time and production has been examined in Table 11 which shows a positive relation between milk production and time over the short intervals involved in these data.

Table 11

Test of the significance of the difference in milk yield between periods, after allowing for the regression of fat yield (y) on time interval (x).

Source	df	Errors of Estimate SSy'	df'	M.S.	F	Result
Total	119					
Cows	9					
Days	5					
Periods	1					
Days x Cows	45					
Days x Periods	5					
Periods x Cows	9					
Error	45	19.864	44	0.451		
Periods + Error	46	26.1596	45			
Difference for testing Adjusted Period Means		6.2956	1	6.296	13.96	**

Table 12

Adjusted Mean Milk Yields

$\bar{x}$ = 12.003 lb.   b = 2.079

Period	Mean Time	x Dev from Exp. Mean	Product b.x	Mean Production Y	Adjusted Mean Production Y-bx
AM	12.116	+0.113	0.235	11.205	10.970
PM	11.890	-0.113	-0.235	11.490	11.725
Difference .755 lb.					

The additional 0.28 lb. of milk produced at the evening milking (Table 10) may have been influenced by the shorter time interval in the day period. Therefore this difference of 0.28 lb. was adjusted by Covariance in Table 11 for the regression of milk yield on time interval. Table 12 shows the difference of 0.7 lb. between the mean milk yields after this adjustment was made.

The pain and rough treatment associated with the "Pitocin" injections caused inhibition of normal let-down which resulted in retention of more residual milk. When the injections were completed, measurement of milk and fat yield was continued. By 8th March let-down appeared to have become approximately normal and no permanent effect could be observed.

(b) Fat Yield.

No significant difference was found in fat production between the morning and evening periods. Table 13 shows the mean yields.

Table 13

Mean fat yields at morning and evening for 6 superstripped cows for 6 days.

Cow	Morning	Evening
1	0.583 lb.	0.564 lb.
2	0.625	0.642
3	0.569	0.543
4	0.485	0.526
5	0.735	0.681
6	0.737	0.739
7	0.608	0.639
8	0.633	0.626
9	0.691	0.676
10	0.615	0.606
Mean	0.628	0.624
Mean Difference	0.004 lb.	

It was recognized that these results might have been influenced by the 14 minute difference in time interval, in the same way as the milk yield in Table 11. A Covariance analysis in Table 14 showed this difference in fat production to be non-significant after allowing for the regression of fat yield on time interval.

Table 14

Analysis of Covariance to test the significance of the difference in fat yield between periods after allowing for the regression of fat yields (y) on time interval (x).

Source	df	Errors of Estimate SSy'	df'	M.S.	F	Result
Total	119					
Cows	9					
Days	5					
Periods	1					
Days x Cows	45					
Days x Periods	5					
Periods x Cows	9					
Error	43	.05648	42	0.00134		
Periods + Error	44	.05653	43			
Difference for testing adjusted means for Periods		.00005	1	.00005	< 1	N.S.

In Table 14 the Error degrees of freedom have been reduced by Two in order to allow for two missing plots. In this Table the usual null hypothesis has been used in the statistical test. The hypothesis set up was that no difference existed between the mean fat production in the two periods, the test in Table 14 does not disprove this hypothesis nor does it prove that there was no difference between the mean fat yields. Therefore it is not possible to prove that the rate of fat synthesis remained constant throughout the 24 hours.

(c) Fat Percentage.

The evening fat percentages in Table 15 were below those for the morning, since fat yield in Table 14 remained constant and milk yield in Table 11 rose in the afternoon.

Table 15

Mean fat percentage at the morning and evening milking for 10 superstripped cows for 6 days.

Cow	Morning	Evening
1	6.01	6.13
2	5.79	5.77
3	5.74	5.50
4	5.13	5.21
5	6.34	5.71
6	4.53	4.28
7	6.33	6.41
8	5.44	5.56
9	5.31	5.01
10	6.04	5.68
Mean	5.67	5.52
Mean difference	0.15%	

The significance of the difference between the Mean fat percentages in Table 15 has not been tested since both Milk yield and fat yield have been tested in Tables 11 and 14 respectively. The separate analysis of fat yield and milk yield follows the approach of Cox (1953), although his dilution analysis has not been used.

DISCUSSION OF THE DIFFERENCE BETWEEN MORNING AND EVENING MILK AND FAT YIELDS IN COWS MILKED AT 12 HOUR INTERVALS

In the cows milked under the normal routine at 12 hour intervals the evening milk and fat yield was slightly greater than the morning yield. This is not in agreement with the "night" effect reported by Campbell (1933) who showed greater yields at the morning milking. In the review of literature critical examination of Campbell's results showed that even his own data did not conclusively demonstrate a "night" effect. This evidence taken in conjunction with the present results cast considerable doubt on the existence of such a "night" effect. Instead, it is suggested that, in cows milked under the normal routine, the slightly greater yields of milk and fat at the evening milking constituted a "day" effect.

It was not possible to decide whether the additional evening yield in these results was caused entirely by a higher rate of synthesis in the day interval, or by a more complete let-down at the evening milking. This latter alternative was supported by Korkman's (1953) discussion of differences in let-down between morning and evening milkings. The analysis of covariance in Table 9 showed that, even if there was any difference in let-down between milkings, it was unlikely to have caused all the difference in fat yield and fat percentage. Therefore it was suggested that synthesis almost certainly contributed to this result. This has been discussed in detail under the heading "Fat Percentage" on page 31.

In a separate experiment, described on page 33, variation in let-down was eliminated by use of "Pitocin" to evacuate the udder after each milking. Thus the milk obtained should have been synthesised in the interval since the preceding milking. A greater milk yield was also obtained at the evening milking under these conditions. The difference of 0.28 lb. was small, but when allowance was made for the regression of milk yield on time interval this difference in milk yield was increased to 0.76 lb., which is approximately the same as that obtained in the normally milked cows. This was regarded as further evidence that the small differences in milk yield, between morning and evening milkings in normally milked cows, are largely caused by differences in synthesis in night and day intervals of equal length.

It is not yet possible to associate these rhythmic differences in production with metabolic activity or with the alternate light and dark periods, although it would be of interest to test the differences between morning and evening yield when the photo period is artificially reversed. If there are any differences between morning and evening yield due to let-down, they would be very small.

The difference between the fat yield results in the normally milked and superstripped cows require further explanation. In the normally milked cows a greater fat yield was obtained at the evening milking, but in the superstripped cows the yield was the same at both milkings. The occurrence of greater milk yields in both experiments has already been discussed. In considering these results it is important to remember that the differences in milk yield are small, of the order of 2% of the daily yield and it seems unreasonable to speculate on the possibility of let-down causing a difference in fat yield in the normally milked cows and not in the superstripped cows.

The extra milk yield at the evening milking in the superstripped cows was caused by the secretion of more water in proportion to fat. It is of interest to note that Hillman et al. (1950) and Aschaffenburg et al. (1950) report smaller freezing point depressions in evening than in morning milk, though these occurred under abnormal husbandry conditions and therefore may have limited application. It would be of interest to indirectly measure the difference in osmotic pressure equilibrium of milk between morning and evening through the freezing point depression.

No significant interaction,between periods and cows, was observed in the superstripped animals where variation in let-down was eliminated. This result can be derived from the data in Table 11. In the normally milked cows, there was a significant interaction, Table 6. Since superstripping eliminated the interaction the differences between the normally milked cows in the way the greater evening yield was produced i.e. the interaction, could be attributed to the ejection mechanism.

These results show that Turner (1953) was unjustified in his assumption that the rate of milk synthesis was constant in both periods. His evidence showed that the rate of synthesis remained constant for periods as long as a 14 hour night interval, but these results show a diurnal change in the rate of synthesis which is a different kind of variation. A further point of importance will be to consider these diurnal variations in the rate of milk synthesis in experimental designs, as for example, in the work reported by Eisenreich and Mennicke (1950) and Bailey et al. (1954).

B. MILK YIELDS AT UNEQUAL INTERVALS BETWEEN MILKINGS

Introduction

The work described in this section was undertaken with the following aims:

1. To investigate differences between cows in the ratio of evening to morning milk yield, because if these differences were large they could be important in considering the usefulness of Turner's (1953) explanation of the lower rate of yield in a long night interval.

2. To obtain the average yield per hour in the long night and short day intervals and thus check the report of Bartlett (1929) and Edwards (1950) that the yield per hour was lower in the long night interval. It was proposed to relate the lower yield per hour, if it were confirmed, to the regression of residual milk on primary yield, in order to test the explanation of Turner (1953) that more residual milk was left in the udder after the morning milking than after the evening milking, thus causing the lower yield per hour in the long night interval.

Experimental

The production of 51 cows in the Massey College herd was recorded for 14 consecutive milkings from 11th February to 17th February 1954. It was not possible to superimpose a fixed milking time on the normal routine. The milking intervals were calculated from the average time at which milking started, which should be satisfactory since the cows were milked in approximately the same order and the time taken to milk the herd was almost constant. The herd and its management have been previously described under the heading "Experimental Methods".

1. Differences between cows in the evening to morning milk yield ratios.

From the evening and morning milk yields the ratio of evening to morning yield was calculated. Table 16 shows the mean ratio for each cow.

Table 16.

Mean Ratio of Evening to Morning milk yield for 51 cows for 7 days.

Cow Number	Ratio	Cow Number	Ratio
1	0.744	27	0.682
2	0.758	28	0.804
3	0.821	29	0.680
4	0.620	30	0.700
5	0.602	31	0.799
6	0.656	32	0.656
7	0.766	33	0.630
8	0.634	34	0.715
9	0.608	35	0.639
10	0.648	36	0.667
11	0.763	37	0.778
12	0.614	38	0.617
13	0.720	39	0.669
14	0.688	40	0.629
15	0.696	41	0.649
16	0.656	42	0.824
17	0.758	43	0.645
18	0.858	44	0.757
19	0.615	45	0.707
20	0.938	46	0.849
21	0.772	47	0.658
22	0.680	48	0.626
23	0.733	49	0.645
24	0.729	50	0.708
25	0.566	51	0.807
26	0.641		

General Mean 0.689

Interval preceding the morning milking	14.133 hrs.
Interval preceding the evening milking	9.867 hrs.

The differences between cows in these ratios was tested by Analysis of Variance (Table 17) which shows a significant difference between cows in the ratio of evening to morning yield.

Table 17.

Analysis of Variance of the ratios of evening to morning milk yields

Source	df	SS	MS	F	Result
Cows	50	2.19345	0.04387	1.48	* P ⟩ .05
Days	6	0.45708			
Missing plots	9				
Error	291	8.63857	0.0297		
Total	356	11.28910			

Variation in the individual ratios may have been increased by small morning yields resulting in very high ratios. This is a disadvantage inherent in the use of ratios. On completion of this analysis it became evident that use of the rate of yield per hour would overcome this disadvantage and at the same time give a greater amount of information; therefore in any future work the rate of yield would be analysed rather than the ratio of evening to morning yield.

Turner (1953) assumed no differences between cows in these ratios. It is evident that in these data at least, such an assumption was unjustified.

In discussing the significant interaction "Periods x Cows" in Table 6 for normally milked cows in relation to Table 11 for the superstripped cows where there was no significant interaction (though the result is not shown in the Covariance Table), it was suggested that let-down was the most likely cause of the significant interaction. It was not possible to formulate a similar argument for these results obtained from cows milked at 10 hour and 14 hour intervals because no cows were superstripped at these intervals. However, it seems likely that these differences between cows in the ratio of evening to morning yield could also be attributed to let-down differences between cows.

If let-down, and not synthesis, causes the differences between cows in the ratio of evening to morning yield, then it would be of interest to test the differences between cows of the regression of residual milk on primary yield.

Edwards (1950) has shown that the ratio of evening to morning yield would change with the stage of lactation, and therefore it might have contributed to the observed differences between ratios. The seasonal calving programme resulted in only limited differences between cows in the stage of lactation. When the stage of lactation was plotted against the mean ratio of evening to morning yield for each cow, no relationship could be distinguished. However, this did not constitute a satisfactory test of the influence of stage of lactation on the ratio of evening to morning yield, but these data did not allow use of a more decisive test.

Discounting the possibility of stage of lactation causing all the differences between cows in the ratio of evening to morning yield it is concluded that any explanation of any difference between intervals in the yield per hour require separate examination in each cow.

2. The rate of milk yield in the intervals preceding the morning and the evening milkings.

Turner (1953) examined the lower yield per hour at the morning milking, reported by Edwards (1950), by using the ratio of morning to evening yield. Differences between cows in these ratios have been demonstrated in the preceding pages. This cast doubt on the validity of Turner's (1953) method of explaining any lower yield per hour in the interval preceding the morning milking.

In this section the object was to decide whether any such lower rate of yield existed in the Massey College herd, and thus whether Turner's (1953) explanation was in fact necessary.

$$\text{The ratio of } \frac{\text{Mean evening yield}}{\text{Mean morning yield}} = \frac{8.304}{12.061} = 0.689$$

$$\text{The ratio of the time intervals} = \frac{9.867}{14.133} = 0.698$$

It is evident that any difference between the ratio of the milk yields and the ratio of the respective time intervals is negligible, that is, the rate of yield per hour is constant in the night and the day intervals.

The relation between residual milk and primary yield has been discussed in Part II. The "between cows" regression of residual milk on primary yield showed that residual milk increased with primary yield. If this occurred "within cows" more residual milk would be left after the morning milking when the yield is normally greater than the evening. This would cause the yield per hour at the morning milking to be lower than at the evening milking since more complete evacuation would occur at the evening milking and thus the ratio of evening to morning yield would be greater than the ratio of the respective time intervals. These results do not show such an increase in ratio for the ratio of the yields equals the ratio of the respective time intervals. There appear to be two possible explanations.

1. Residual milk was constant in volume at both milkings and the rate of secretion was constant. Under

these conditions there would be no "within cows" regression of residual milk on primary yield.

2. These results may not be repeatable. A possible source of error would be in estimating the time intervals although it is difficult to see how this would have occurred. It is surprising that differences in synthesis alone did not produce a ratio of evening to morning yield in excess of the ratio of the intervals. A lower yield per hour would be expected at the morning milking because, firstly, the diurnal rhythm in synthesis (Part I section "A") would lower the morning yield, and secondly, secretion would be inhibited in the long night interval, since Bailey et al. (1954) have given an indication that secretion rates may fall slightly after approximately 12 hours.

These results do not agree with those obtained by Edwards (1950) and Bartlett (1929) who both showed a higher rate of yield per hour in the short day period, which resulted in ratios of afternoon to morning yield being greater than that for the ratio of the time intervals. However, they do confirm Korkman's (1953) results. The data collected by Edwards, Bartlett and Korkman were not for the express purpose of measuring production in relation to time, therefore the time intervals may not be accurately estimated.

The discrepancy between these data and the herd test results.

The preliminary examination of herd test data showed significantly lower yield rates at the morning milking. The monthly herd test was done six days after the present data were collected. This again showed lower yield rates at the morning milking. Under the herd testing routine the fractions of a lb. above the round figure were carried forward to the morning milking, i.e. 12.75 lb. at the evening milking was recorded as 12 lb. and the three-quarters was carried forward to the morning yield. This would merely decrease the evening yield which in the herd test data has already been shown greater than the morning.

No explanation was apparent for lack of agreement between the experimental data and the herd test results. It will be of interest to attempt to repeat them. If this can be done it seems likely that some factor operated during herd test milkings which biased the results. For instance, it would not be unexpected to find the cows more thoroughly milked when the tester arrived for the first milking in the afternoon. If the discrepancy between the two sets of data can be substantiated the possibility would arise of a similar bias in the results reported by Edwards (1950) for herd test data.

Turner (1953) has based his explanation of the difference in yield per hour at morning and evening milkings on Edwards' data (1950). If these data are inaccurate Turner has explained a situation which in fact does not exist.

DISCUSSION OF DIURNAL RHYTHMS IN MILK AND FAT PRODUCTION

Any difference between morning and evening milk yields must be considered in relation to the length of the time interval over which the milk was produced. The belief that production is maximised when the intervals between milkings are approximately equal has resulted in a tendency towards a 12 hour day interval. This tendency is opposed by the need to restrict the working day to a reasonable length. In practice the day interval ranges from approximately 9 hours up to 12 hours. As this interval increases the night interval decreases by the same amount.

This investigation has been concerned with two sets of conditions. Firstly, the interval between milkings was 12 hours and therefore equal. A separate examination of milk yields was made when the day interval was 10 hours and the night interval 14 hours.

Production from the cows milked at equal intervals showed the evening milk and fat production to be slightly greater than the morning production. The greater evening milk production is substantiated by the bulk milk records for the same cows over the period November to February. This was the opposite of the greater morning milk production reported by Campbell (1933). This difference in production at 12 hour intervals was then examined in superstripped cows, where again greater evening milk production was found, though fat production was equal in both intervals.

It is suggested that the greater milk production at the evening milking was largely the result of a slightly higher rate of synthesis in the day interval, although there is as yet no evidence to show what changes occur in the rate of synthesis from one hour to another over a 24 hour cycle. The possibility of differences in let-down contributing to the greater afternoon yield has been considered.

Milk production was also measured when the day interval was 10 hours and the night interval 14 hours. These results show approximately equal yield per hour in both intervals; thus, at least, under certain conditions there is no difference in yield per hour on which to test the hypothesis put forward by Turner (1953).

It has been shown that the differences in yield per hour which occur at 12 hour intervals between milkings are not exhibited in the same way in each cow.

It has also been shown that the ratio of evening to morning milk yield differed in the cows milked at 10 and 14 hour intervals; thus the average yield per hour used by Turner (1953) conceals the individual differences between cows. Within each cow the yield per hour appears to depend on a combination of factors which will eventually require separate explanation in each cow.

A further aim of the work was to check another assumption made by Turner (1953) that the rate of synthesis remained constant. In view of the differences in yield found at 12 hour intervals in this work and the report by Bailey et al. (1954) of an inhibiting effect of a long interval on synthesis, it seems unlikely that synthesis does remain constant.

Thus:-

1. The lower yield per hour in the interval preceding the morning milking reported by Edwards (1950) and used by Turner (1953) has not been confirmed.
2. It has been shown that Turner (1953) has neglected the need for separate explanation in each cow of any difference in yield per hour between night and day intervals.
3. The assumption made by Turner (1953), that the rate of synthesis remained constant throughout a 24 hour period has been disputed.

THE RELATIONSHIP BETWEEN RESIDUAL MILK AND PRIMARY MILK YIELD

INTRODUCTION

Krull in 1905 suggested that some of the observed milking-to-milking variation in milk and fat yield could be attributed to the different amounts of milk left in the udder after a normal milking. This hypothesis and the work it stimulated has been discussed in the review of literature. The aim of the present investigation was to obtain estimates of the amount and composition of the residual milk and also of the relationship between residual milk and primary yield in the Massey College Dairy Herd. At a later date it was hoped to test Krull's hypothesis by relating this information to the morning and evening milk yields observed in the same herd.

EXPERIMENTAL

The technique used for residual milk collection has been described under the heading "Experimental Methods". Particular care was observed in obtaining normal let-down response at the primary milking, in order to obtain normal partition of the udder contents into the primary and residual fractions.

Residual milk was collected from 44 cows over the course of several weeks. These animals were selected at random and each one injected only once.

A. RESIDUAL MILK IN THE JERSEY HERD

The results are given in detail in Appendix 4. The Sums of Squares and Sums of Products from which the regression of Residual milk on Primary yield was calculated are given in Table 18.

Table 18

The relationship between residual milk (y) and primary yield (x)

Residual Milk		n = 44
Mean y	2.14 lb.	
Sums Sqs y	74.99	
Primary Yield		
Mean x	12.79 lb.	
Sums Sqs x	699.49	
Sums Products xy	149.96	
b.yx	0.214 **	
r.yx	0.655 **	

Table 19 shows the regression of residual milk on primary yield to be highly significant.

Table 19

Test of significance of regression of Residual Milk on Primary Yield

Source	df	SSy	MS	F	Result
Regression	1	32.15	32.15	31.52	**
Error	42	42.84	1.02		
Total	43	74.99			

These data can be alternatively analysed for the relationship between residual milk and the total udder contents. Table 20 shows the Sums of Squares and Sums of Products for the data analysed in this form.

Table 20

The relationship between Residual Milk (y) and Total Yield (x)

Residual Milk		n = 44
Mean y	2.141	
Sums Sqs y	74.99	
Total Yield		
Mean x	14.927	
Sums Sqs x	1074.41	
Sums Products		
xy	224.95	
b.yx	0.209**	
r.yx	0.793**	

Table 21 shows the regression of residual milk on total udder contents to be highly significant.

Table 21

Test of Significance of regression of Residual Milk on Total Yield.

Source	df	SSy	MS	F	Result
Regression	1	47.10	47.10	71.36	**
Error	42	27.89	.66		
Total	43	74.99			

From these data the following regression equations were derived,

Residual Milk = .21 Primary Yield - 0.6

Residual Milk = .21 Total Yield - 0.98

When the relationships between residual milk and primary yield and also between residual milk and total udder contents had been established, it was necessary to decide which form to use. Total udder contents equals primary yield plus residual milk, therefore these two regressions can be interpreted in a rather similar way. Turner (1953) has used the relation between residual milk and total udder contents as shown in Tables 20 and 21. He claimed "A dependence of residual milk on the total amount of milk in the udder at the start of milking seems most logical". He did not explain why this seemed most logical and in this work no sequence of cause and effect has been found suggesting preference for either method. Therefore the preference was decided on statistical grounds. Table 22 shows the correlations calculated in both forms.

Table 22

Residual Milk Correlations

Correlation between residual milk and primary yield	r = 0.655	df 42
Correlation between residual milk and total yield	r = 0.793	df 42

The relationship existing between residual milk and total yield can be written alternatively as residual milk and primary yield plus residual milk. The presence of residual milk in the total yield inflated the correlation between residual milk and total yield and therefore preference was given to the use of the regression of residual milk on primary yield. The regression of residual milk on total udder contents has been used to relate this analysis to that of Turner (1953). His regression coefficient (b = 0.16) does not differ significantly from the value obtained in these data where b = 0.21, as shown in Table 23.

Table 23

Test of significance of the difference between Turner's regression (1953) of residual milk on total yield and these data

Source	df	SSy	M.S.	F	Result
Difference due to regression	1	1.88	1.88	< 1	N.S.
Deviations from individual regressions (Error)	98	424.99	4.34		
Total	99	426.87			

Johansson (1952b) gives the correlation between primary yield and residual milk as r = 0.606, for 104 degrees of freedom. The present estimate is r = 0.655 for 42 degrees of freedom.

The results in Part II, Section "E", show considerable variation in the volume of residual milk left in the udder after milking is completed. The total udder content is relatively constant; any decrease in primary yield is accompanied by an increase in residual milk therefore variation in let-down would produce a negative correlation between residual milk and primary yield "within cows" which would contribute to the error variation (Table 19) in the "between cows" regression of residual milk on primary yield since this has a positive slope. Collection of extra data for each cow to give an average within cow regression would therefore increase the accuracy of this estimate.

It would be of interest to know why "between cows" more residual milk was left in the udder as the primary yield rose, for as yet no causal relationship has been established between primary yield and residual milk.

B. RESIDUAL MILK IN THE FRIESIAN HERD

11 cows were used in this experiment. The larger size of these animals, combined with their excitable disposition, presented practical difficulties with the limited assistance available. Whenever a large Friesian cow declined to enter the crush bail little could be done to force it in. Thus the sample of cows was not a random one. Residual milk was collected by the same technique as has been described for the Jerseys. The Friesian and Jersey cattle are milked in the same shed and since they are run on the same farm there are no important differences in the management of the two herds.

Greater amounts of residual milk were found in those cows having the highest primary yield, as was found in the Jersey breed. The method of analysis in Table 24 was the same as that used for the Jerseys in Table 18.

Table 24

The relationship between Residual Milk (y) and Primary Yield (x) in the Friesian breed.

Residual Milk		n = 11
Mean y	2.35	
Sums Sqs y	19.05	
Primary Yield		
Mean x	19.07	
Sums Sqs x	255.5	
Sums Products xy	50.26	
b.yx	0.197**	
r.yx	0.720**	

Table 25

Test of significance of the regression of residual milk on primary yield.

Source	df	SSy	MS	F	RESULT
Regression	1	9.89	9.89	8.6	*
Error	8	9.16	1.15		
Total	9	19.05			

From these data the following significant regression equation (Table 25) was derived:-

Residual Milk = 0.197 Primary Yield - 1.5

The difference between the slope of this regression and the one for the Jersey breed is not statistically significant as shown in Table 26.

Table 26

Test of significance of the difference between Jersey and Friesian regressions of residual milk on primary yield.

Source	df	SSy	M.S.	F	Result
Difference due to regression	1	0.06	0.06	< 1	N.S.
Deviation from individual regressions (Error)	51	52.00	1.02		
Total	52	52.06			

The difference in residual milk between the two breeds was tested by Covariance in Table 27 after allowing for the regression of residual milk on primary yield.

Table 27

Analysis of Covariance to test the difference in amount of residual milk between Jerseys - Friesians after allowing for the regression of residual milk (y) on primary yield (x).

Source	df	Errors of Estimate SSy'	df'	M.S.	F	Result
Total	54					
Breeds	1					
Error	53	52.054	52	1.0010		
B + E	54	60.052	53			
Difference		7.998	1	7.998	7.99	**

The difference between the adjusted means is shown in Table 28.

Table 28.

Calculation of residual milk in Jerseys and Friesians after allowing for the regression of residual milk (y) on primary yield (x). $\bar{x}$ = 14.044 lb. b = 0.210

Y_J = 2.141 - 0.210 (12.786 - 14.044) = 2.405 lb.

Y_F = 2.345 - 0.210 (19.073 - 14.044) = 1.289 lb.

Difference 1.12 lb.

It is evident that in the Friesians there is appreciably less residual milk in proportion to primary yield. In the succeeding discussion this difference in residual milk between the breeds is related to the difference in fat percentage of the milk of the two breeds.

C. THE BUTTERFAT PERCENTAGE OF RESIDUAL MILK

Table 29 shows that a positive correlation was found between the volume of the residual milk and the butterfat percentage of this milk, and also between the volume of primary yield and the butterfat percentage of the residual milk.

Table 29

The relation between the fat percentage of residual milk and other fractions of the udder contents.

Correlation between Fat Percentage of Residual Milk and	Jersey Correlation Coefficient "r"	df	Friesian Correlation Coefficient "r"	df
1. Volume of residual milk	0.631**	42	0.726*	9
2. Volume of primary yield	0.607**	42	0.499 NS	9
3. Fat percentage of primary yield	-0.103 NS	42	0.543 NS	9

Table 29 shows that the correlation between the fat percentage of residual milk and the fat percentage of the primary yield does not reach the usual significance level.

A high fat percentage in the residual milk is probably associated with a large rise in the fat percentage during milking, and thus the positive correlation between the fat percentage of residual milk and the volume of primary yield can be reconciled with the report by Johansson et al. (1952a) of a rise in fat percentage during milking which was greatest in cows with the largest primary yield. Johansson et al. (1952a) also showed that within a breed the volume of primary yield was more important than the fat percentage of the primary yield in producing this rise in fat percentage. The mean fat percentage of the Friesian residual milk (11.52%) was lower than the mean fat percentage of the Jersey residual milk (15.48%). This implies a lower rise in fat percentage in the Friesian breed during milking. Therefore it was suggested that between these breeds the fat percentage of the primary yield is more important than the volume of the primary yield in causing a rise in fat percentage. Alternative explanations for the difference between breeds might involve factors influencing the clustering of fat globules.

The positive correlation between the volume of residual milk and fat percentage of residual milk, requires careful interpretation because of the appearance of the volume of residual milk in both variables. The correlation is between residual milk lb. and $\frac{\text{residual fat lb.}}{\text{residual milk lb.}}$ Nevertheless it was suggested that some degree of association existed between the volume of residual milk and fat percentage of residual milk.

The correlation between the volume of residual milk and fat percentage of residual milk may be explained in terms of the hypothesis put forward by Whittlestone (1953) to account for the rise in fat percentage which occurs during milking. This depended on the fat globules clustering to form larger particles, which are partly filtered out in the udder by the fine ducts of the alveoli. Therefore the last milk to leave this region will be very rich in fat. Quite clearly Whittlestone considered the high fat milk was preferentially retained.

It may be possible to carry this argument further. Whittlestone (1953) regarded the fat as difficult to eject. It may be that the final fractions are not merely more difficult to eject but not normally ejected because of the difficulty of removing them from the alveoli. This would establish the fat content as a causal factor in the retention of residual milk. However, if this were the sole cause the fat percentage would rise as it becomes gradually more difficult to eject, until eventually a fat percentage is reached where ejection ceases, the final strippings would reach this constant fat percentage. Since this does not occur, the difficulty of ejecting this high fat milk cannot be regarded as the only reason for the incomplete evacuation of the milk in the udder.

However, the comparison between the Jerseys and the Friesians in the present data suggests it may be a contributory cause. This hypothesis would lead one to expect less residual milk in a breed with a low fat percentage in the residual milk. In fact this is supported in Table 28 by the smaller amount of residual milk in the Friesians (1.12 lb.) after adjusting them for the regression of residual milk on primary yield.

D. RESIDUAL MILK AT MORNING AND EVENING MILKINGS

The earlier sections of this Chapter dealt with the "between cows" regression of residual milk on primary yield. The higher yielding cows had a greater volume of residual milk.

This section is concerned with the relationship between residual milk and primary yield which exists "within cows", that is, the change in residual milk over the increase in primary yield from evening to morning milking. Turner (1953) has assumed no significant difference between the "within cows" and "between cows" relationships. The present aim is confined to an investigation of any difference between morning and evening residual milk which might be linked to the difference in yield per hour between morning and evening milkings. It has already been shown that if more residual milk were left after the morning milking then the yield per hour at this milking would be lowered.

1. The "between cows" residual milk data.

The data from which the general relationship was established was split into two groups, one collected at the morning milking, the other at the evening milking, with the aim of calculating the difference in residual milk between morning and evening milkings.

These data were collected from different cows, but Table 30 shows that the differences in residual milk need not have been caused by differences in primary yield because there was no significant difference between the daily production for the two groups.

Table 30

Mean daily milk yield in lb. for the months December, January, February, from monthly herd test records.

Morning Group	23.8 lb.
Evening Group	22.4 lb.
Difference	1.4 lb
(t = 1.02 37 df	N.S.)

Table 31

Mean residual milk and mean primary yield at morning and evening milkings.

Milking	Mean Primary Yield	Mean Residual Milk	Fat Percentage of Residual Milk
Morning group	14.57 lb.	2.32 lb.	17.3
Evening group	10.33 lb.	1.7 lb.	13.7
Difference		0.62 lb. (t = 2.76 ** 37 df)	

Table 31 shows the difference between the mean residual milks to be highly significant.

If it can be assumed that the levels of production for these two groups are comparable it would appear that greater amounts of residual milk of higher fat percentage are left at the morning milking.

Table 32

Analysis of Covariance to test the difference in amount of residual milk at morning and evening milkings after allowing for the regression of residual milk (y) on primary yield (x).

Source	df	Errors of Estimate SSy'	df'	M.S.	F	Result
Total	33	34.02	32	1.063		
Periods	1					
Error	32	33.21	31			
Difference for test of significance of adjusted means		0.81	1	0.81	0.762	N.S.

Table 32 shows the difference in residual milk between morning and evening was not significant after allowing for the "between cows" regression of residual milk on primary yield. Thus the difference in residual milk which would be expected within a cow between morning and evening milkings is of the same order as predicted by the "between cows" relationship. However, these data do not prove that the "between cows" and "within cows" relationships are similar.

2. The Difference on a "within cows" basis between morning and evening residual milk.

A further test was carried out on 8 cows with the sole aim of testing the statistical significance of the difference between the mean morning residual milk and the mean evening residual milk. The cows were autumn calvers selected from the Massey College Jersey herd. The trial was carried out in July when the milking intervals were 9¾ and 14¼ hours.

Appendix 5 gives the primary yield and residual milk for each cow at each milking. Two cows, numbers 3 and 4 were in oestrus when residual milk was collected; their let-down was abnormal, therefore these results were excluded from the analysis.

Table 33

Morning and Evening Mean Primary Yield and Residual Milk (4 estimates for each of 8 cows).

	Mean Primary Yield (lb.)	Mean Residual Milk (lb.)
A.M.	14.12	3.08
P.M.	11.06	1.69
	Difference	1.39
	(t = 3.015**	27 df)

Table 33 shows that the difference between the mean morning and mean evening residual milk was highly significant.

Examination of Appendix 5 shows considerable variation in the morning residual milk but there appeared to be no valid reason for the exclusion of any of these figures.

The significantly greater amounts of residual milk left after morning milking agree with results discussed in Section D.1.

Discussion of the difference in volume and fat percentage of residual milk at morning and evening milkings.

Taking both sets (D.1 and D.2) of results together the evidence suggests that a greater volume of residual milk is left at the morning milking when the primary yield is greater. The difference in residual milk appears to be of the same order as would be explained by the "between cows" relation in Table 18.

The fat percentage of the residual milk remaining after the morning milking was higher than the fat percentage of the residual milk remaining after the evening milking (Table 31) and therefore the fat percentage of the morning primary yield would be lowered. In addition there appeared to be more of this high fat percentage residual milk left after the morning milking; together these could explain the lower fat percentage of morning milk.

E. THE RELATIONSHIP BETWEEN RESIDUAL MILK AND PRIMARY YIELD AT 12 HOUR INTERVALS BETWEEN MILKINGS.

The aims of this investigation were -

1. To examine the difference between residual milk at morning and evening milkings at 12 hour intervals.
2. To examine differences between cows in the relation of residual milk to primary yield.
3. To determine the influence of variation in residual milk on milking-to-milking variation in milk and fat yield.

Experimental.

The six cows used in this work were from the herd of the "production per acre" experiment. These cows were not in calf, but in other respects were unselected animals. They were grazed and milked in the normal way with the herd, the interval between milkings being approximately 12 hours. Following the primary milking the residual milk was on ten occasions collected using the technique described under the heading Experimental Methods. The injection schedule was as follows:

Day	1		2		3		4	
Milking	AM	PM/	AM	PM/	AM	PM/	AM	PM/
Injection	x			x				x
	5		6		7		8	
	AM	PM/	AM	PM/	AM	PM/	AM	PM/ etc.
			x				x	

In this routine the effect of time was not confounded with yield and in addition a suitable period was allowed for the residual milk to return to normal after super evacuation.

1. Differences in Residual Milk at morning and evening milkings.

The mean evening residual milk was not significantly greater (Table 35) than the morning residual milk. Appendix 2 gives the individual results.

Table 34

Residual Milk after morning and evening milkings

Cow	PM	AM
1	4.40	3.98
2	2.74	4.16
3	1.42	1.86
4	2.80	1.38
5	1.08	1.30
6	2.68	4.08
Mean	2.79	2.52
Difference	.27 lb.	

Table 35

Analysis of Variance of the difference between morning and evening residual milk.

Source	SS	df	M.S.	F	Result
Cows	70.1	5			
Periods	1.12	1	1.12	0.439	N.S.
Error	135.25	53	2.55		
Total	206.47	59			

These results show no significant difference in the volume of residual milk at morning and evening when the interval between milkings was equal, whereas the results in Part I might have led to the conclusions that a very slightly greater volume of residual milk would be expected at the morning milking.

2. Differences between cows in the relation of residual milk to primary yield.

These data (Appendix 2) were analysed by Co-variance shown in Table 36 to examine the differences between cows in the relation of residual milk to primary yield.

Table 36

Analysis of Covariance to test the significance of the differences in residual milk between cows after allowing for the regression of residual milk (y) on primary yield (x)

Source	df	Errors of Estimate SSy'	df'	M.S.	F	Result
Total	59					
Cows	5					
Periods	1					
P x C	5					
Error	48	73.65	47	1.57		
Cows + Error	53	175.72	52			
Difference for testing adjusted Means		102.07	5	20.41	13.00	**

Table 36 above shows a significant difference between cows in the volume of residual milk after allowing for the regression of residual milk on primary yield. The interpretation of these results offered some difficulties because of the problem of obtaining estimates of the normal amount of residual milk. The treatment, which involved injections and a certain amount of rough treatment may have had a greater influence on let-down in some cows than in others, and could have contributed to the present result. On the other hand this variability in some cows and uniformity in others could have been quite a normal difference between cows.

The numbers in this experiment did not allow an examination of any possible effect of stage of lactation, level of production or of age, all of which may contribute to the observed difference between cows.

It is concluded that these results cast some doubt on the adequacy of Turner's approach (1953) to the differences in production between morning and evening milkings, because he has examined the average relation between residual milk and primary yield, and has ignored any differences which might exist between cows.

3. The influence of variation in residual milk on milking-to-milking variation in milk and fat yield.

The observed variation in primary yield from milking-to-milking could be due to both synthesis and letdown. From Table 36 the within cows, within periods regression of residual milk on primary yield has been calculated. The coefficient which equals -0.459 has been tested for significance in Table 37. This negative coefficient suggests that the udder contained a more or less constant volume of milk and that any decrease in primary yield was accompanied by a corresponding increase in residual milk. Conversely an increase in primary yield was accompanied by decrease in residual milk.

Table 37

Test of significance of the error regression of residual milk on primary yield from Table 36.

Source	S.S.	df	M.S.	F	Result
Regression	46.69	1	46.69	29.7	**
Error	73.65	47	1.57		
Total	120.34	48			

Although it is difficult to be certain that the treatment did not increase the normal range of variation in let-down, these results show the importance of let-down in producing variation in primary yield.

Maximum let-down would increase the volume of high fat percentage strippings in the primary yield and give a positive relation between the volume and the fat percentage of primary yield. Examination of this relationship would further test the hypothesis that day to day variation in milk yield was caused by variation in let-down.

This offered:

(a) A test of the hypothesis that let-down was the major cause of variation in primary yield.

(b) An estimate of the proportion of the variation in fat percentage which was due to variation in primary yield.

The interpretation of an analysis of the relation between the volume and the fat percentage of primary yield presented a difficulty. Fat percentage is $\frac{\text{Fat yield}}{\text{Milk yield}}$, and since milk yield was the other variable this would give an undefined degree of relationship between the two variables. Such an analysis would have been unsatisfactory.

Therefore, the relation between milk yield and fat yield was examined in data where the variation in milk yield was largely due to let-down. From this relationship between milk yield and fat yield it was possible to predict the changes in fat percentage of the primary yield which would accompany changes in the volume of the primary yield. If the regression of fat yield on milk yield differed significantly from a line passing through the origin then the fat percentage of the primary yield would vary with milk yield. The disadvantage of this analysis was that it would not be possible to predict what proportion of the variation in fat percentage was associated with variation in milk yield.

Table 38 shows the significant regressions of primary fat yield on primary milk yield for six cows, but in no case was a significant difference recorded between the slope of the regression line and the line drawn from the mean point to the origin.

Table 38

An indirect test of the significance of the relation between fat percentage and primary yield.

Cow No.	"b" Regression of Residual Milk on primary yield	Slope of the line joining the mean point to the origin	"t"	df	Result
1	0.0859	0.0609	1.61	8	N.S.
2	0.0894	0.0540	1.54	8	N.S.
3	0.0868	0.0610	1.43	8	N.S.
4	0.0784	0.0549	1.75	8	N.S.
5	0.1061	0.0716	1.77	8	N.S.
6	0.0519	0.0537	0.09	8	N.S.

The data in Appendix 1 was suitable for a similar analysis, derived from Table 9. In these results a highly significant difference was obtained between the regression of fat yield on milk yield and the line drawn from the mean value to the origin (t = 4.5** 86 df).

The regression equation is

fat yield = 0.088 (Milk yield) - 0.462.

The slope of the line drawn from the mean point to the origin was 0.054 which is less than the slope of the regression line. Therefore higher fat percentages are associated with the higher milk yields. It has already been shown that this form of analysis does not allow an estimate of the proportion of the variation in fat percentage which can be accounted for by the regression of fat percentage on primary yield. However, these results do show that fat percentage rises with primary yield, and since the last drawn milk is richer in fat than the first drawn milk it is suggested that at least part of the day to day variation in fat percentage is caused by variation in let-down.

This conclusion supports the results in Table 36 which showed that variation in primary yield was largely caused by let-down.

FINAL DISCUSSION

In the Jersey cows the volume of residual milk was approximately one fifth of the volume of the primary yield. The mean fat percentage of the residual milk was 15.5%. Any difference between morning and evening milkings in this reserve of milk and fat would produce a corresponding change in yield of milk and fat obtained at the normal morning and evening milking.

An hypothesis has been put forward which could partly explain the presence of residual milk in the udder of the cow. It was suggested that the high fat percentage of the residual milk may render it more difficult to eject, and thus the high fat percentage would itself contribute to the presence of residual milk. However, since residual milk probably occurs in pigs where the strippings are not higher in fat percentage, the high proportion of fat in strippings cannot be the sole cause of residual milk in the cow.

Residual milk can be obtained by injection of "Pitocin"; therefore it seems likely that at a normal milking insufficient oxytocic hormone is released to evacuate the udder. This balance between the pituitary and the volume of milk in the udder apparently results in the amount of hormone released being insufficient to completely evacuate the udder. In some cows a second ejection response causes a second "let-down". It would be of interest to measure the volume of residual milk under these conditions because there may be considerably less residual milk.

One of the aims of this work has been to examine the explanation put forward by Turner (1953) of the higher yield per hour in the short interval preceding the evening milking. This led to the measurements of residual milk which showed that high yielding cows had a greater volume of residual milk than low yielding cows. It was inferred from this relationship that more residual milk would be left in the udder after the morning milking following a 14 hour night interval than after the evening milking following a 10 hour night interval. An estimate of that difference in residual milk can be obtained from the regression of residual milk on primary yield, and thus an estimate of the difference it would produce between the yield per hour in the intervals preceding the morning and evening milkings. In the case of a cow milked at 10 and 14 hour intervals and secreting 1 lb. of milk per hour the estimated difference in residual milk could cause a difference in yield in those intervals of 0.1 lb. per hour. This is approximately the difference reported by Edwards (1950).

The regression of residual milk on primary yield was obtained from one record from each of 44 cows. This was a "between cows" regression. It has been shown how this was used to predict the volume of residual milk at morning and evening milkings "within cows". In doing this it would be necessary to assume the "between cows" regression was the same as the "within cows" regression. As yet there is no conclusive evidence to support this view.

It has been shown that cows vary in the manner in which they exhibit differences between morning and evening milk yields. This was demonstrated in the cows milked at 12 hour intervals by the significant interactions between periods and cows, and in the cows milked at 10 and 14 hour intervals, by the significant differences in the ratio of afternoon yield to morning yield. The regression of residual milk on primary yield was shown to differ between cows. This evidence showed that the difference between morning and evening yields required separate examination in each cow, and therefore cast doubt on the method used by Turner (1953).

A further problem involved in the use of a regression is the difficulty of obtaining a satisfactory range of primary yields. For instance, if residual milk and primary yield are measured at the normal milkings the primary yields would fall into two discreet groups, one around the average yield after the 10 hour interval and another group around the average yield after the 14 hour interval. The regression line joining these two groups of data would almost certainly be significant, but such data are unsatisfactory for calculation of a regression.

From this discussion it becomes evident that the use of a regression of residual milk on primary yield as a means of examining differences between morning and evening yields has limitations.

When all the data in this work had been collected it became evident that the major difficulty was to reconcile the equal yields per hour in both night and day intervals for cows milked at 10 and 14 hour intervals, with the claim by Edwards (1950) that higher yields per hour occurred in the day interval, especially since one aim had been to explain the very differences which were not found at 10 and 14 hour intervals.

The possibility or otherwise of these differences existing has been discussed. It has been supported by Table 10, that synthesis would be expected to produce a lower yield per hour in the night interval; also there is limited evidence to suggest more residual milk may be left after the morning milking, which would also tend to produce a lower yield per hour in the night interval, and this does not support the present results in which equal yield per hour was obtained in both intervals. Therefore it appears that at least under some conditions yields per hour can be equal in the 10 hour and 14 hour intervals.

Therefore the "between cows" regression of residual milk on primary yield has not been used to adjust the morning and evening yields. It seems possible that under these conditions the slopes of the "within cows" and "between cows" regressions may differ significantly.

It has been recognised for many years that the fat percentage of morning milk is lower than the fat percentage of evening milk. This could be due to the retention of more residual milk after the morning milking, and since this has a high fat percentage the primary yield would be low in fat percentage. Alternatively the larger volume of milk in the udder at the morning milking might produce a greater concentration of fat in the residual milk, and thus cause a low fat percentage in the morning primary yield. However, both these factors could operate together. An explanation of these low fat percentages will first require a satisfactory estimate of the difference in the amount of residual milk which remains in a cow after morning and evening milkings.

On completion of this work it was possible to review the explanation put forward by Turner (1953) of the supposed differences in milk yield per hour between night and day intervals. In the first place his acceptance of the differences reported by Edwards (1950) was disputed. It was suggested that the difference, if it exists, is considerably less than claimed by Edwards (1950).

Limitations have been found in the use of the regression of residual milk on primary yield in examining differences in residual milk between morning and evening milkings.

Turner's (1953) assumption that the rate of synthesis remained constant over a 24 hour period has been questioned.

Finally, if any difference in yield per hour is found between morning and evening milking it is suggested that it will require separate explanation in each cow.

SUMMARY

Milk and fat yield have been measured at alternate morning and evening milkings. When the time between milkings was 12 hours the night and day intervals were of equal length. Under these conditions slightly greater yields of milk and fat were obtained at the evening milking. These results do not agree with the "night"effect reported by Campbell (1930, 1931 and 1933). It has been shown that synthesis must have contributed to this greater evening production. The possibility of a greater let-down at the evening milking has been discussed. These differences between morning and evening production form a diurnal rhythm.

The limited investigation of milk yields at alternate 10 and 14 hour intervals showed a lack of agreement with other workers. The yield per hour was the same in both the short day and long night intervals. The disagreement between this work and previous reports can only be resolved by repeating the experiment.

At the same time as these results were being obtained a study was made of the amount and composition of the milk remaining in the udder after normal milking was complete. These results suggested that more milk would be left in the udder after the morning milking. If this reserve of milk in the udder was reduced at

the evening milking by more complete evacuation, the yield per hour in the day interval would be higher than in the night interval.

It has been suggested that the high fat percentage of residual milk is one of the causes of incomplete evacuation of the udder at a normal milking.

At the conclusion of this work, it is suggested that the differences between morning and evening milk and fat yield require more accurate definition when a long night period follows a short day period. If differences in yield per hour are found the effect of synthesis could be measured. Should this not account for all the difference in yield per hour, the influence of residual milk could be investigated.

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APPENDIX 1.

MILK AND FAT YIELD FOR 30 COWS MILKED AT 12 HOUR INTERVALS FROM 11/1 p.m. to 15/1 a.m.

Cow No.	11/1 p.m. Milk Lbs	Fat %	Fat %	12/1 a.m. Milk Lbs.	Fat %	Fat %	12/1 p.m. Milk Lbs.	Fat %	Fat	13/1 a.m. Milk Lbs.	Fat %	Fat %	13/1 p.m. Milk Lbs.	Fat %	Fat %	14/1 a.m. Milk Lbs.	Fat %	Fat %	14/1 p.m. Milk Lbs.	Fat %	Fat %	15/1 a.m. Milk Lbs.	Fat %	Fat %
1	13.4	6.40	0.8576	14.5	5.65	0.8193	13.5	6.00	0.8100	12.6	5.00	0.6300	14.7	5.70	0.8379	13.5	5.25	0.7088	14.2	5.65	0.8023	13.2	5.10	0.6732
2	9.5	6.35	0.6033	10.7	6.00	0.6420	9.3	6.05	0.5627	6.8	4.70	0.3196	12.3	6.20	0.7626	9.7	6.20	0.6014	9.1	6.25	0.5688	9.6	5.70	0.5472
3	11.3	4.75	0.5368	10.4	5.65	0.5876	10.8	5.00	0.5400	10.5	3.85	0.4043	11.7	4.90	0.5733	10.6	4.50	0.4770	10.2	5.00	0.5100	10.8	4.10	0.4428
4	11.8	6.40	0.7552	13.0	6.00	0.7800	11.5	5.35	0.6153	12.3	5.25	0.6458	12.2	5.65	0.6893	11.8	5.35	0.6313	12.9	6.40	0.8256	11.2	5.20	0.5824
5	14.8	4.95	0.7326	15.0	4.90	0.7350	14.5	4.60	0.6670	13.3	4.45	0.5919	14.6	4.20	0.6132	15.6	4.20	0.6552	14.1	4.65	0.6557	14.7	4.75	0.6983
6	15.2	6.65	1.0108	13.7	5.65	0.7741	15.0	6.05	0.9075	13.5	5.60	0.7560	14.4	5.55	0.7992	13.9	5.70	0.7923	14.2	5.80	0.8236	13.9	5.60	0.7784
7	14.7	6.95	1.0217	14.3	5.00	0.7150	12.9	5.50	0.7095	13.2	5.15	0.6798	14.6	6.15	0.8979	13.4	5.60	0.7504	14.2	5.95	0.8449	13/8	4.80	0.6624
8	15.8	6.30	0.9954	16.0	5.90	0.9440	15.4	6.70	1.0318	14.4	5.85	0.8424	13.9	4.60	0.6394	15.5	5.60	0.8680	15.8	6.70	1.0586	14.6	5.70	0.8322
9	13.6	5.95	0.8092	14.4	5.05	0.7272	13.2	5.85	0.7722	13.2	5.50	0.7260	13.1	4.20	0.5502	14.1	5.00	0.7050	12.6	6.00	0.7560	13.5	5.00	0.6750
10	13.4	5.60	0.7504	15.2	5.20	0.7904	14.2	5.50	0.7810	12.6	5.20	0.6552	14.2	5.00	0.7100	15.4	5.10	0.7854	14.4	6.05	0.8712	13.5	4.70	0.6345
11	6.2	6.10	0.3782	5.5	5.20	0.2860	6.5	5.90	0.3835	6.2	5.85	0.3627	6.1	4.80	0.2928	6.5	5.15	0.3348	6.3	5.35	0.3371	6.4	5.00	0.3200
12	19.1	5.60	1.0696	19.1	4.75	0.9073	17.4	4.90	0.8526	19.2	5.20	0.9984	18.0	5.65	1.0170	17.3	4.70	0.8131	19.4	5.95	1.1543	17.5	4.70	0.8225
13	11.0	5.80	0.6380	12.7	5.45	0.6922	11.0	5.60	0.6160	11.1	5.60	0.6216	12.0	5.35	0.6420	11.4	5.20	0.5928	11.5	5.60	0.6440	12.2	5.60	0.6832
14	21.7	5.20	1.1284	18.7	4.80	0.8976	17.5	4.95	0.8663	17.6	4.25	0.7480	20.6	4.20	0.8652	18.1	4.70	0.8507	18.9	5.20	0.9828	19.1	4.50	0.8595
15	14.0	4.30	0.6020	16.5	5.55	0.9158	16.5	5.90	0.9735	14.1	6.10	0.8601	16.9	5.50	0.9295	14.4	5.20	0.7488	15.7	5.65	0.8871	16.2	5.10	0.8262
16	15.6	5.55	0.8658	15.0	5.00	0.7500	15.5	5.20	0.8060	14.1	5.40	0.7614	15.4	5.25	0.8085	13.9	4.40	0.6116	16.2	6.05	0.9801	14.6	5.15	0.7519
17	16.2	6.20	1.0044	15.5	4.70	0.7285	16.6	5.75	0.9545	14.4	4.65	0.6696	16.4	5.00	0.8200	16.1	5.35	0.8614	15.6	5.85	0.9126	15.6	4.65	0.7254
18	14.1	5.70	0.8037	14.1	5.75	0.8108	12.6	6.20	0.7812	12.5	5.25	0.6563	12.3	5.60	0.6888	13.0	5.55	0.7215	12.1	5.90	0.7139	13.1	5.40	0.7074
19	13.2	4.35	0.5742	13.4	4.90	0.6566	13.0	5.15	0.6695	12.4	4.75	0.5890	13.2	4.80	0.6336	12.3	4.40	0.5412	12.8	5.25	0.6720	13.1	4.60	0.6026
20	13.6	4.15	0.5644	14.1	4.75	0.6698	14.2	5.75	0.8165	12.6	4.20	0.5292	13.6	5.10	0.6936	12.8	4.30	0.5504	12.5	4.75	0.5938	13.2	4.70	0.6204
21	16.2	5.65	0.9153	16.5	5.95	0.9818	17.0	5.75	0.9775	16.9	5.55	0.9380	17.1	5.10	0.8721	15.9	4.80	0.7632	15.3	5.10	0.7803	18.8	5.15	0.9682
22	19.7	5.15	1.0146	17.9	4.40	0.7876	19.3	5.25	1.0133	16.5	4.30	0.7095	18.4	5.15	0.9476	17.6	4.40	0.7744	18.8	5.35	1.0058	16.5	3.85	0.6353
23	13.2	5.60	0.7392	12.9	5.10	0.6579	12.5	5.20	0.6500	11.0	4.25	0.4675	13.9	5.80	0.8062	12.1	5.00	0.6050	13.3	5.75	0.7648	12.5	4.55	0.5688
24	11.7	7.55	0.8834	11.8	4.45	0.5251	13.4	6.60	0.8844	12.3	6.65	0.8180	12.3	6.20	0.7626	10.8	5.65	0.6102	12.7	6.60	0.8382	11.7	6.45	0.7547
25	11.8	4.70	0.5546	15.0	5.60	0.8400	13.0	6.35	0.8255	12.6	4.75	0.5985	13.0	5.60	0.7280	11.5	5.20	0.5980	12.8	5.75	0.7360	13.0	5.60	0.7280
26	9.7	5.15	0.4996	10.8	5.00	0.5400	12.7	8.20	1.0414	9.7	6.95	0.6742	10.4	6.30	0.6552	11.5	6.85	0.7878	11.5	8.20	0.9430	9.9	5.05	0.5000
27	14.5	6.20	0.8990	14.8	5.95	0.8806	14.5	6.30	0.9135	14.5	5.85	0.8483	15.5	6.35	0.9843	12.3	4.60	0.5658	14.7	6.55	0.9629	13.6	5.55	0.7548
28	13.6	6.05	0.8228	12.5	4.85	0.6063	13.3	56 0	0.7448	12.4	4.85	0.6014	13.5	5.55	0.7493	11.6	4.25	0.4930	13.8	6.20	0.8556	12.9	4.85	0.6257
29	9.9	5.85	0.5792	10.1	4.75	0.4798	10.4	5.70	0.5928	8.3	5.15	0.4275	10.6	520	0.5512	9.3	5.85	0.5441	9.8	5.70	0.5586	9.4	5.80	0.5452
30	15.0	5.25	0.7875	10.4	4.15	0.4316	14.0	6.00	0.8400	11.5	5.35	0.6153	12.4	5.20	0.6448	10.4	3.90	0.4056	13.7	6.10	0.8357	5.4	3.30	0.1782

APPENDIX 2

Primary yield and residual milk
at equal (12 hour) milking intervals

	Primary Yield			Residual Milk		
	Milk (lb)	Fat (%)	Fat (lb)	Milk (lb)	Fat (%)	Fat (lb)
Cow 1						
a.m.	13.1	8.00	1.048	2.6	15.75	0.410
	9.7	6.00	0.582	4.2	14.50	0.609
	11.1	7.40	0.821	1.7	15.10	0.257
	7.2	5.45	0.392	7.2	14.40	1.037
	4.7	6.20	0.291	4.2	15.20	0.638
p.m.	6.9	4.40	0.304	5.9	14.75	0.870
	10.5	4.30	0.452	6.5	15.00	0.975
	11.3	6.45	0.729	1.9	13.50	0.257
	9.4	5.80	0.545	3.6	14.70	0.529
	10.0	5.50	0.550	4.1	16.60	0.681
Cow 2						
a.m.	15.0	5.00	0.750	2.0	13.12	0.262
	13.0	3.35	0.436	4.9	10.05	0.492
	16.0	5.10	0.816	2.0	14.20	0.284
	12.1	2.80	0.339	6.7	12.50	0.838
	16.3	5.35	0.872	5.2	14.50	0.754
p.m.	14.3	5.05	0.722	2.3	12.3	0.283
	16.4	8.05	1.320	2.0	16.9	0.338
	16.8	6.65	1.117	1.8	14.0	0.252
	13.8	6.80	0.938	2.8	14.0	0.392
	6.6	4.00	0.264	4.8	13.1	0.629
Cow 3						
a.m.	10.9	6.00	0.654	0.6	10.25	0.062
	10.3	5.65	0.582	2.0	10.40	0.208
	10.7	6.55	0.701	2.1	14.40	0.302
	10.0	5.75	0.575	2.0	12.30	0.246
	9.6	5.65	0.542	2.6	14.00	0.364
p.m.	10.4	6.60	0.686	0.8	11.50	0.092
	11.1	6.00	0.666	1.9	11.25	0.214
	12.2	6.00	0.732	1.4	12.00	0.168
	11.8	6.80	0.802	1.5	13.60	0.204
	10.5	5.90	0.620	1.5	13.80	0.207

	Primary Yield			Residual Milk		
	Milk (lb)	Fat (%)	Fat (lb)	Milk (lb)	Fat (%)	Fat (lb)
Cow 4						
a.m.	9.8	6.10	0.598	2.0	19.70	0.394
	9.7	5.75	0.558	1.3	16.60	0.216
	9.8	5.05	0.495	1.0	14.70	0.147
	10.2	6.45	0.658	1.4	19.50	0.273
	9.7	4.95	0.480	1.2	14.10	0.169
p.m.	10.2	4.75	0.490	1.6	15.00	0.240
	11.3	5.25	0.593	1.8	15.90	0.286
	3.9	1.60	0.062	8.3	10.80	0.896
	9.3	5.60	0.521	1.2	15.90	0.191
	9.6	7.10	0.682	1.1	18.20	0.200
Cow 5						
a.m.	9.9	6.60	0.653	1.5	16.50	0.248
	9.4	6.80	0.639	1.2	15.60	0.187
	9.0	7.30	0.657	1.5	16.30	0.245
	9.2	7.20	0.662	1.2	15.50	0.186
	9.3	7.60	0.707	1.1	15.60	0.172
p.m.	10.2	7.55	0.770	0.8	17.50	0.140
	10.9	7.70	0.839	1.1	16.10	0.177
	9.5	7.45	0.708	1.1	17.60	0.194
	9.1	6.70	0.610	1.3	17.70	0.230
	8.7	6.60	0.574	1.1	14.40	0.158
Cow 6						
a.m.	11.2	5.65	0.633	2.5	16.00	0.400
	7.7	3.95	0.304	6.5	12.20	0.793
	11.4	4.95	0.564	3.6	17.00	0.612
	9.1	3.70	0.337	6.4	12.80	0.819
	10.7	7.15	0.765	1.4	15.40	0.216
p.m.	13.0	4.60	0.598	2.2	14.75	0.325
	13.8	5.20	0.718	3.0	18.70	0.561
	7.4	6.15	0.455	3.0	14.90	0.447
	7.7	4.85	0.373	3.7	11.90	0.440
	9.3	7.40	0.688	1.5	17.10	0.257

APPENDIX 3.

MORNING AND EVENING MILK PRODUCTION OF 51 JERSEY COWS - from 11/2/54 to 17/2/54.

MILKING		COW NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
11/2	P.M.	9.3x	9.1	6.7	8.0	5.2	7.5	6.6	8.1	8.1	5.2	7.4	8.6	6.8	5.1	9.3x	7.0	12.6	6.9	4.2	7.3	6.3
	A.M.	13.4	12.3	7.2	14.3	11.2	10.7	8.9	12.3	13.3	10.0	12.2	13.5	9.8	7.4	14.2	11.6	15.4	9.9	8.4	10.8	6.2
	RATIO	0.694	0.740	0.930	0.559	0.464	0.701	0.742	0.659	0.609	0.520	0.607	0.637	0.694	0.689	0.655	0.603	0.818	0.697	0.500	0.676	1.016
12/2	P.M.	9.0	8.4	7.0	7.3	6.0	7.4	6.9	10.3	7.7	5.6	5.8	8.1	6.5	5.3	6.6	7.6	11.5	6.5	5.7	5.6	5.2
	A.M.	13.0	13.7	6.6	13.4	9.1	10.8	8.8	10.1	12.6	9.0	9.4	12.8	10.0	7.1	14.0	13.4	16.7	9.7	8.9	10.9	5.5
	RATIO	0.692	0.613	1.061	0.545	0.659	0.685	0.784	1.020	0.611	0.622	0.617	0.633	0.650	0.746	0.471	0.557	0.689	0.670	0.640	0.514	0.945
13/2	P.M.	9.8	10.0	6.5	7.8	6.8	6.6	6.0	7.8	8.2	5.9	6.9	8.8	7.6	4.7	10.9	8.5	12.0	8.0	4.3	7.8	5.8
	A.M.	13.3	7.5	7.2	14.3	12.0	12.2	9.2	13.6	13.1	9.9x	11.3	13.0	10.3	8.1	15.4	12.3	15.0	8.9	7.5	21.8	7.8
	RATIO	0.737	1.333	0.903	0.545	0.567	0.541	0.652	0.574	0.626	0.596	0.611	0.677	0.738	0.580	0.708	0.691	0.800	0.899	0.573	0.358	0.744
14/2	P.M.	9.8	9.0	5.7	7.8	6.4	7.6	6.6	4.1	8.6	6.2	7.6	8.2	7.4	5.1	9.1	7.4	11.1	7.9	5.3	8.7	3.8
	A.M.	12.7	17.5	7.8	13.8	11.0	12.0	10.0	12.3	12.3	9.4	10.2	12.5	11.0	7.5	12.4	11.8	18.3	8.4	8.6	9.6	8.0
	RATIO	0.772	0.514	0.731	0.565	0.582	0.633	0.660	0.333	0.699	0.660	0.745	0.656	0.673	0.680	0.734	0.627	0.607	0.940	0.616	0.906	0.475
15/2	P.M.	9.3	10.0	6.2	8.4	6.8	7.9	7.2	5.8	6.0	6.2	7.7x	6.3	7.4	5.0	10.0	8.2	11.8	8.3	5.2	8.8	5.7
	A.M.	13.1	12.5	8.2	12.1	11.3	11.7	9.1	10.7	12.3	9.1	11.0	13.0	10.5	7.9	12.9	11.9	15.6	7.2	6.7	9.3	7.4
	RATIO	0.710	0.800	0.756	0.694	0.602	0.675	0.791	0.542	0.488	0.681	0.700	0.485	0.705	0.633	0.775	0.689	0.756	1.153	0.776	0.946	0.770
16/2	P.M.	9.0	8.4	4.7	8.5	6.1x	7.1	7.0	7.0	7.6	6.2	8.8	7.6	7.8	5.0	9.4	7.0	13.1	7.1	4.8	10.6	5.5
	A.M.	12.1	13.4	8.1	12.5	10.1	11.3	7.8	11.0	13.2	8.8	6.7	12.2	9.4	7.3	13.8	11.4	15.8	8.2	8.1	4.8	6.2
	RATIO	0.744	0.627	0.580	0.680	0.604	0.628	0.897	0.636	0.576	0.705	1.313	0.623	0.830	0.685	0.681	0.614	0.829	0.866	0.593	2.208	0.887
17/2	P.M.	9.0	8.8	5.9	8.4	6.5	7.6	6.6	7.2	6.9	6.3	6.8	7.1	7.5	5.0	9.9	8.3	11.6	6.4	4.5x	7.2	3.7
	A.M.	10.5	13.0	7.5	11.2	8.8	10.4	7.9	10.7	10.7	8.4	9.1	12.1	10.0	6.2	11.7	10.4	14.4	8.2	7.4	7.5	6.5
	RATIO	0.857	0.677	0.787	0.750	0.739	0.731	0.835	0.673	0.645	0.750	0.747	0.587	0.750	0.806	0.846	0.798	0.806	0.780	0.608	0.960	0.569

MILKING		COW NUMBER 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
11/2	P.M.	6.0	8.0	13.9	7.3	8.3	7.1	16.1	6.5	10.6	7.2	8.6	7.5	10.8	10.2	8.0	5.0	8.0	9.3	7.7	11.1	12.3
	A.M.	11.3	11.6	21.6	12.5	15.3	10.5	19.6	11.0	14.9	10.7	12.6	12.0	15.2	16.2	12.2	7.3	11.5	14.7	11.9	17.3	18.4
	RATIO	0.531	0.690	0.644	0.584	0.542	0.676	0.821	0.591	0.711	0.673	0.683	0.625	0.711	0.630	0.656	0.685	0.696	0.633	0.647	0.642	0.668
12/2	P.M.	8.0	16.0	14.1	6.5	8.3	6.8	14.6	6.4	9.1	6.4	8.0	7.2	10.7	9.5	7.5	4.3	6.2	9.4	7.0	10.2	11.3
	A.M.	15.3	13.1	20.0	12.3	13.5	10.5	22.5	11.7	15.8	8.5	13.6	12.3	11.3	16.2	13.0	7.0	11.3	15.0	12.0	17.6	18.7
	RATIO	0.523	1.221	0.705	0.528	0.615	0.648	0.649	0.547	0.576	0.753	0.588	0.585	0.947	0.586	0.577	0.614	0.549	0.627	0.583	0.580	0.604
13/2	P.M.	8.3	7.8	15.0	6.8x	8.1	6.6	17.4	7.5	9.9	7.0	8.9	7.6	9.1	10.3	8.3	5.0	8.0	10.1	7.5	11.0	13.0
	A.M.	12.2	13.2	19.9	11.6	15.4	10.5	18.9	11.2	16.5	9.1	13.4	12.5	15.9	17.1	12.8	6.2	12.4	16.2	12.6	17.7	19.3
	RATIO	0.680	0.591	0.754	0.586	0.526	0.629	0.921	0.670	0.600	0.769	0.664	0.608	0.572	0.602	0.648	0.806	0.645	0.623	0.595	0.621	0.674
14/2	P.M.	8.2	8.7	14.5	7.6	9.4	6.5	16.0	7.5	9.6	7.5	7.9	6.7	11.2	10.7	8.0	4.9	7.5	10.1	8.1	11.5	10.5
	A.M.	12.6	12.9	20.9	12.1	14.0	11.0	21.3	10.8	14.9	8.9	13.4	12.4	13.3	15.4	13.1	7.6	11.1	14.7	12.2	17.5	18.9
	RATIO	0.651	0.674	0.694	0.628	0.671	0.591	0.751	0.694	0.644	0.843	0.590	0.540	0.842	0.695	0.611	0.645	0.676	0.687	0.664	0.657	0.556
15/2	P.M.	9.5	8.3	15.7	6.2	10.0	7.8	16.2	7.5	10.6	7.5	8.6	8.2	10.1	10.0	8.7	5.0	7.6	10.5	7.6	11.7	13.5
	A.M.	11.6	11.8	19.7	11.1	13.7	11.1	19.3	9.6	13.9	8.9	12.9	12.0	13.1	16.1	12.2	6.8	10.7	14.5	11.6	16.7	7.4
	RATIO	0.819	0.703	0.797	0.559	0.730	0.703	0.839	0.781	0.763	0.843	0.667	0.683	0.771	0.621	0.713	0.735	0.710	0.724	0.655	0.701	1.824
16/2	P.M.	8.8	7.3	14.8	5.1	8.5	6.8x	15.3	7.3	10.0	6.7	8.3	7.0	6.8	9.8	7.6	5.8	7.1x	10.3	7.0	10.8	12.0
	A.M.	10.0	12.6	19.5	12.5	13.7	9.0	18.7	10.0	13.8	7.4	11.9	11.3	13.0	15.4	10.1	5.5	11.5	14.5	11.8	17.1	18.8
	RATIO	0.880	0.579	0.759	0.408	0.620	0.756	0.818	0.730	0.725	0.905	0.697	0.619	0.523	0.636	0.752	1.055	0.617	0.710	0.593	0.632	0.638
17/2	P.M.	7.7	7.4	13.2	6.6	8.9	6.8	14.7	6.8	10.6	6.4	8.4	8.0	9.7	9.9	7.2	4.9	6.3	9.0	7.2	11.2	12.5
	A.M.	11.4	11.0	17.6	9.9	11.4	8.8	17.8	9.1	12.0	7.9	12.0	10.7	15.2	14.1	10.1	5.4	14.8	13.2	10.8	15.8	15.6
	RATIO	0.675	0.673	0.750	0.667	0.781	0.773	0.826	0.747	0.883	0.810	0.700	0.748	0.638	0.702	0.713	0.907	0.426	0.682	0.667	0.709	0.801

x. Value estimated by "Missing Plot" technique.

APPENDIX 3. (Continued)

MILKING	COW NUMBER 43	44	45	46	47	48	49	50	51
11/2 P.M.	3.6	5.3	12.2	10.8	8.4	7.3	6.8	8.4	15.6
A.M.	5.9	7.6	19.2	15.8	13.2	12.5	10.7	11.0	17.7
RATIO	0.610	0.697	0.635	0.684	0.636	0.584	0.636	0.764	0.881
12/2 P.M.	4.4	5.5	11.7	17 .2	8.2	7.6	6.5	7.1	14.2
A.M.	13.4	6.5	17.8	8.3	13.1	11.2	10.6	11.8	19.0
RATIO	0.328	0.846	0.657	2.072	0.626	0.679	0.613	0.602	0.747
13/2 P.M.	3.4	6.1	12.7	9 .5	7.6	6.0	6.7	8.8	16.0
A.M.	5.9	6.5	18.0	15.8	13.8	13.0	11.5	10.8	20.8
RATIO	0.576	0.938	0.706	0.601	0.551	0462	0.583	0.815	0.769
14/2 P.M.	3.6	5.4	12.6	8.9	8.1	7.9	6.8	8.2	14.5
A.M.	6.0	7.4	18.4	16.2	13.8	13.0	11.0	11.5	19.0
RATIO	0.600	0.730	0.685	0.549	0.587	0.608	0.618	0.713	0.763
15/2 P.M.	5.6	4.7	14.0	9.8	9.1	7.6	7.1	7.3	16.9
A.M.	4.9	7.8	16.8	16.7	13.1	11.0	10.2	11.4	20.1
RATIO	1.143	0.603	0.833	0.587	0.695	0.691	0.696	0.640	0.841
16/2 P.M.	3.0	5.2	12.5	10.9	8.5	7.2	6.5	7.7	15.6
A.M.	5.4	6.5	16.5	14.3	11.1	11.4	9.8	11.4	18.0
RATIO	0.556	0.800	0.758	0.762	0.766	0.632	0.663	0.675	0.867
17/2 P.M.	4.3	4.6	11.5	9.8	7.8	7.6	6.7	7.9	14.5
A.M.	6.1	6.7	17.0	14.2	10.5	10.5	9.5	10.6	18.5
RATIO	0.705	0.687	0.676	0.690	0.743	0.724	0.705	0.745	0.784

APPENDIX 4.

Residual Milk and Primary Yield for 44 Jersey Cows 1953/54

	Primary Yield			Residual Milk			Total Milk (lb) (Residual & Primary)
Cow No.	Milk (lb)	Fat (%)	Fat (lb)	Milk (lb)	Fat (%)	Fat (lb)	
1	10.3	6.70	0.690	1.3	14.75	0.192	11.6
2	10.5	6.75	0.709	1.3	16.20	0.211	11.8
3	7.6	5.05	0.384	2.0	10.75	0.215	9.6
4	8.9	5.65	0.503	1.5	11.75	0.176	10.4
5	8.9	5.55	0.494	0.9	10.00	0.090	9.8
6	8.0	5.75	0.460	1.6	11.50	0.184	9.6
7	13.3	5.00	0.665	2.2	18.50	0.407	15.5
8	8.1	5.25	0.425	0.4	10.25	0.410	8.5
9*	12.0	4.40	0.528	3.8	13.25	0.504	15.8
10*	12.5	6.40	0.800	1.4	15.00	0.210	13.9
11	17.2	5.55	0.955	2.1	16.00	0.336	19.3
12	9.4	5.45	0.512	1.5	12.75	0.191	10.9
13	15.8	4.50	0.711	5.0	22.75	1.138	20.8
14	10.0	5.40	0.540	1.6	16.00	0.256	11.6
15	8.8	5.30	0.466	2.0	21.50	0.430	10.8
16	8.5	4.80	0.408	3.9	15.50	0.605	12.4
17	14.8	4.90	0.725	2.6	18.00	0.468	17.4
18	13.1	8.00	1.048	2.6	15.75	0.410	15.7
19*	14.0	5.45	0.763	3.0	15.50	0.465	17.0
20	18.5	4.45	0.823	4.3	19.50	0.839	22.8
21	14.5	4.80	0.696	1.3	15.00	0.195	15.8
22	12.9	5.20	0.671	2.2	18.25	0.402	15.1
23	26.6	4.15	1.104	7.0	23.50	1.645	33.6
24	7.8	6.20	0.484	0.7	13.30	0.093	8.5
25	18.6	5.00	0.930	1.7	14.75	0.251	20.3
26	12.3	4.40	0.541	3.0	16.00	0.480	15.3
27	13.9	5.10	0.709	1.0	14.50	0.145	14.9
28	9.5	6.30	0.599	1.5	12.25	0.184	11.0
29*	19.1	4.55	0.869	3.5	15.25	0.534	22.6
30	18.5	5.30	0.981	3.4	17.50	0.595	21.9
31	15.5	4.80	0.744	1.8	14.80	0.266	17.3
32	13.7	5.30	0.726	1.5	18.80	0.282	15.2
33	7.5	7.40	0.555	1.0	16.00	0.160	8.5
34	12.8	5.05	0.646	1.6	14.25	0.228	14.4
35	10.9	6.00	0.654	0.6	10.25	0.062	11.5
36	15.8	6.85	1.082	1.1	14.30	0.157	16.9
37	10.2	4.75	0.490	1.6	15.00	0.240	11.8
38*	18.5	4.45	0.823	4.4	17.75	0.781	22.9
39	10.5	4.25	0.446	2.1	12.00	0.252	12.6
40	17.5	9.20	1.610	1.8	20.25	0.365	19.3
41	11.5	6.15	0.707	1.5	15.25	0.229	13.0
42	10.0	7.00	0.700	0.4	11.88	0.048	10.4
43	11.2	5.65	0.633	2.5	16.00	0.400	13.7
44	13.1	5.55	0.727	2.0	19.25	0.385	15.1

* 12 hour milking intervals

APPENDIX 5

Primary yield and residual milk at morning and evening milking at $14\frac{1}{4}$ and $9\frac{3}{4}$ hr. intervals.

Cow No.	A.M. P.Y. lbs.	A.M. R.M. lbs.	P.M. P.Y. lbs.	P.M. R.M. lbs.
1	11.8	3.6	8.7	3.1
	14.1	3.2	9.5	3.4
2	13.6	1.2	10.0	1.2
	14.9	1.2	11.0	1.5
3	10.3	7.1 *	13.6	2.0
	14.5	2.4	12.1	2.2
4	2.4	11.5 *	9.4	1.5
	13.5	1.2	9.7	1.1
5	12.1	4.1	11.5	1.5
	LOST		9.6	1.2
6	15.2	3.1	12.5	1.4
	13.2	5.0	12.1	2.0
7	16.9	2.4	9.4	1.8
	13.1	6.9	14.1	1.3
8	16.4	1.9	12.1	0.6
	14.2	3.9	11.6	1.2

* Cow on heat

Checked

APPENDIX 6.

TOTAL MILK AND FAT PRODUCTION, INCLUDING RESIDUAL MILK REMOVED BY "PITOCIN".

DATE	A.M. MILK YIELD (lb.)	A.M. TIME INTERVAL HOURS.	A.M. FAT (%)	A.M. FAT (lb.)	P.M. milk YIELD (lb.)	P.M. TIME INTERVAL HOURS	P.M. FAT (%)	P.M. FAT (lb.)
COW 1.								
28/2/54	8.6	12.033	6.60	0.568	8.4	11.950	6.20	0.521
1/3	8.9	12.250	5.75	0.512	9.3	11.817	6.00	0.558*
2/3	10.0	12.100	6.30	0.630	8.7	11.967	5.85	0.509
3/3	9.8	11.950	5.50	0.539	9.8	11.883	6.20	0.608
4/3.	10.5	12.117	5.90	0.620	9.2	11.900	5.95	0.547
5/3	10.5	12.150	6.00	0.630	9.7	12.167	6.60	0.640
COW 2.								
28/2	8.8	12.033	5.95	0.524	10.2	11.833	5.70	0.581
1/3	10.9	12.300	6.10	0.665	10.4	11.733	5.65	0.588
2/3	11.0	12.133	5.70	0.627	11.5	11.967	5.90	0.679
3/3	11.2	11.933	5.80	0.650	11.2	11.900	5.80	0.650
4/3	11.5	12.117	5.40	0.621	11.8	11.900	5.60	0.661
5/3	11.4	12.400	5.80	0.661	11.6	11.917	5.95	0.690
COW 3.								
28/2	8.4	11.833	6.10	0.512	8.7	11.917	5.15	0.448
1/3	9.4	12.250	6.00	0.564	9.3	11.783	5.35	0.498
2/ 3	10.5	12.017	5.55	0.583	10.3	12.000	5.70	0.587
3/3	10.2	12.000	5.60	0.571	10.9	11.900	5.75	0.627
4/3	10.3	12.067	5.55	0.572	9.6	11.933	5.30	0.509
5/3	10.8	12.433	5.64	0.609*	10.2	11.800	5.75	0.587
COW 4.								
28/2	5.6	12.000	3.35	0.188	10.9	11.917	5.05	0.550
1/3	9.8	12.250	5.70	0.559	9.7	11.850	5.20	0.504
2/3	9.0	11.950	5.30	0.477	9.2	11.917	5.25	0.483
3/3	11.0	12.033	5.30	0.583	9.9	11.800	5.40	0.535
4/3	9.7	12.083	5.35	0.519	10.7	11.750	5.20	0.556
5/3	10.1	12.617	5.80	0.586	10.2	11.783	5.15	0.525
COW 5.								
28/2	10.2	11.917	6.80	0.694	10.4	11.833	6.00	0.624
1/3	11.3	12.333	6.55	0.740	11.7	11.750	5.80	0.679
2/3	11.6	12.017	6.05	0.702	12.8	11.983	5 .95	0.762
3/3	12.3	12.017	6.60	0.812	12.3	11.933	5.80	0.713
4/3	12.2	12.017	6.05	0.738	12.7	12.117	5.25	0.667
5/3	12.1	12.250	6.00	0.726	11.8	11.883	5.45	0.643

* Value estimated by missing plot technique.

DATE	A.M. MILK YIELD (lb.)	A.M. TIME INTERVAL HOURS	A.M. FAT (%)	A.M. FAT (Lbs.)	P.M. MILK YIELD (Lbs.)	P.M. TIME INTERVAL HOURS	P.M. FAT (%)	P.M. FAT (Lbs.)
COW 6.								
28/2/54	14.5	12.083	4.70	0.682	16.3	11.867	4.55	0.742
1/3	15.0	12.183	4.50	0.675	17.2	11.867	4.20	0.722
2/3	17.2	12.167	4.40	0.757	16.7	11.783	4.25	0.710
3/3	16.6	12.083	4.50	0.747	18.9	11.867	4.45	0.841
4/3	16.7	12.017	4.55	0.760	17.8	12.017	3.80	0.676
5/3 .	17.6	12.483	4.55	0.801	16.9	11.617	4.40	0.744
COW 7.								
28/2	8.6	12.300	6.65	0.572	8.6	11.750	6.15	0.529
1/3	10.4	12.183	6.15	0.640	10.5	11.817	6.45	0.677
2/3	9.1	12.083	6.00	0.546	9.7	12.000	6.50	0.631
3/3	9.9	11.983	6.70	0.663	9.9	11.933	[illegible].70	0.663
4/3	10.4	12.033	6.05	0.629	10.2	12.033	6.20	0.632
5/3	9.3	12.267	6.45	0.600	10.9	11.683	6.45	0.703
COW 8.								
28/2	11.1	11.917	6.35	0.705	10.0	11.833	5.30	0.530
1/3	10.4	12.167	5.60	0.582	11.0	11.917	5.75	0.633
2/3	11.6	12.117	5.20	0.603	11.5	11.900	5.85	0.673
3/3	12.1	11.983	5.15	0.623	11.4	11.883	5.60	0.638
4/3	12.5	12.067	5.15	0.644	12.4	11.900	5.25	0.651
5/3	12.3	12.400	5.20	0.640	11.3	11.867	5.60	0.633
COW 9.								
28/2	11.3	12.133	5.50	0.622	12.2	12.033	4.85	0.592
1/3	12.6	12.067	5.40	0.680	14.5	11.983	5.05	0.732
2/3	12.7	11.983	5.40	0.686	13.7	12.433	5.05	0.692
3/3	13.5	11.633	5.15	0.695	13.1	11.783	5.20	0.681
4/3	14.0	12.250	5.00	0.700	14.5	11.767	5.10	0.740
5/3	14.1	12.483	5.40	0.761	12.9	11.700	4.80	0.619
COW 10.								
28/2	9.6	11.917	6.30	0.605	9.2	11.917	5.75	0.529
1/3	8.7	12.250	6.25	0.544	10.5	11.750	5.60	0.588
2/3	10.3	12.083	6.00	0.618	10.4	11.800	5.50	0.572
3/3	11.3	11.950	5.80	0.655	11.6	12.117	5.90	0.684
4/3	10.5	11.867	5.70	0.599	11.7	12.117	5.65	0.661
5/3	10.8	12.233	6.20	0.670	10.6	11.700	5.65	0.599