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The Milking Characteristics of Identical Twin Cattle

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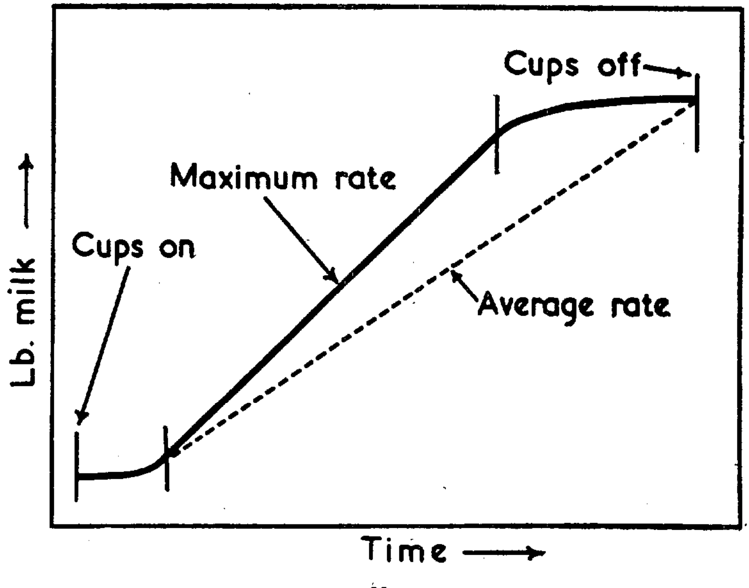
SOME ten years ago Whittlestone first stressed the necessity of obtaining an understanding of the milking characteristics of dairy cattle. To this end he devised an automatic milk flow recorder and thus characterised the milk ejection curve of normal dairy cows[1]. Subsequent work demonstrated that the milking rate of a cow is relatively stable over long periods [2, 3] and difficult to alter save by severe changes in shed management.[4,5,6] In the light of this information, attention was focussed on the genetic control of milking character. Preliminary data on milking times provided by the New Zealand Dairy Board indicated a marked difference between the daughters of different bulls within herds, but considerable variation between herds in the A.B. offspring of the same sire.[7] A relationship between observed milk yield and milking rate has also been reported.[8,9]

With this general background, a series of studies were commenced using the identical twin herd at Ruakura, the primary object being to assess the relative importance of inherited and environmental factors on the milking character of dairy cattle milked under reasonably uniform conditions.

The recording device used in this work was designed by D.S.M. Phillips. It consisted of an evacuated cylinder in which a weighted rod was suspended by a spring. As milk flowed into this cylinder the buoyancy of the rod increased, the subsequent movement being recorded by a trace; a very simple and satisfactory technique.

Fig. 1.



As with most experimental techniques, the repeatability of successive records on the same individual may be used as a criterion of the usefulness of a measurement in subsequently comparing groups of animals. To this end, some 13 sets of identical twins at similar stages of lactation were subjected to uniform milking and feeding techniques and six recordings of average and maximum flow rates made at morning milkings over a two-month period of peak lactation. Figure 1 illustrates a typical milk flow curve together with the measurements termed maximum and average rates, whilst Table 1 lists the percentage of variation attributable to the major sources of variability encountered in this trial. Repeatability (R) is obtained as the ratio of the variance between unrelated individuals and the estimated total variance among random single records. From Table 1 then R = 90.4% for maximum rate of flow and 80.7% for average rate, indicating in both cases satisfactory consistency in successive measurements on the same animal over the period in question.

TABLE 1 — IDENTICAL TWINS.

	Variance Components (%)	
	Maximum Rate	Average Rate
Between Sets	72.4	59.0
Within Sets	18.0	21.7
Between Individuals	90.4	8.07
Residual	9.6	19.3

Twin heritability estimates, derived by comparing the between set variability to total variability are 72.4% for maximum rate and 59.0% for average rate. The between set variance includes, however, not only the variation due to total inheritance, but also that due to other factors affecting both members of sets alike, namely pre-natal environment, contemporary local environment and genotype-environment interactions.

One method of assessing the likely importance of these latter factors is to compare the records of fraternal and identical twins run under uniform environmental conditions. Three estimates of genetic variation may then be derived.[10]

1. From identical twins as already indicated;
2. From fraternal twins and derived in like fashion to the estimates from identical twins, and
3. From using the pooled identical and fraternal twin data, whereby an estimate of genetic variation may be derived unbiased by maternal and contemporary environmental factors affecting twin sets alike.

Fourteen fraternal twins were available for such a comparison, measurements being made in similar fashion to those made on the identical twins. Though it is realised that this data is limited and thus subject to sampling errors, the available information to date is summarised in Table 2.

TABLE 2 — FRATERNAL TWINS.

	Variance Components (%)	
	Maximum Rate	Average Rate
Between Sets	43.1	33.7
Within Sets	51.4	57.7
Between Individuals	94.5	91.4
Residual	5.5	8.6

As with identical twins, the sum of the between-within set components of variance provides an estimate of the expected "between individual" variability in the population. The corresponding estimates of repeatability are 94.5% for maximum rate and 91.4% for average rate whilst the estimates of heritability are 86.2% and 67.4% respectively.

Using the pooled data, estimates of repeatability proved to be of the order of 92% for maximum rate and 85% for average rate whilst heritability estimates were again of high order. In effect, then, the limited information available indicates that on a within herd basis milk flow rates are likely to be strongly inherited, considerable genetic variation existing between cattle in regard to these characteristics. Table 3 illustrates the mean flow rates encountered in this trial with estimates of standard deviations.

TABLE 3 — MEAN RATES OF MILK FLOW.
(Lbs. per minute)

	Identical		Fraternal	
Maximum Rate	4.38		3.95	
S.D.		0.37		0.31
Average Rate	3.16		3.19	
S.D.		0.32		0.28

Some five years ago Baxter demonstrated that the major factor contributing to variations in milking rate between cattle was the size and elasticity of the sphincter muscle of the teat.[11] More recently the comparison at Ruakura of a 16-8 hourly milking with a 12-12 hourly milking interval using twin cattle provided an opportunity of assessing the influence of interval between milking, and thus milk yield, on flow rates. Relevant data for eight sets of twins split between milking at 5 a.m. and 5 p.m. and 8 a.m. and 4 p.m. is summarised in Table 4:

TABLE 4 — MEAN RATES OF MILK FLOW.
(Lbs. per Minute)

	Maximum Rate			Average Rate		
	12-12	16-8	Diff.	12-12	16-8	Diff.
p.m. (12/8)	4.79	4.44	.34	3.21	2.73	0.48
a.m. (12/16)	4.84	4.87	—.03	3.48	3.51	—0.03
Difference	—0.05	—0.43	0.37	—0.27	—0.78	0.51

Thus, the lower milk yields associated with an eight-hour secretion interval has reduced both maximum and average rates compared with the 16 hour interval, whilst with the cattle milking on a 12-12 hourly interval evening milking rates appear to have been slightly less than morning milking rates. Appreciable variation occurred in the response of different animals, an analysis of variance indicating marked first order interactions between treatments (milking intervals) milking times (p.m. v. a.m.) and twin sets. In passing, it is worth recording that in the data available to date no appreciable differences in milk and fat production exist between the twins milked on a 12-12 hourly schedule as compared with their mates milked on the 16-8 hourly schedule.

The apparent relationship between milk yield and flow rate on a within-cow basis is substantiated by a consideration of lactation trends in flow rates. Table 5 summarises the available data for twelve cows observed at five stages in lactation, 5 a.m. observations being made at each stage, while Table 6 records the mean response of 18 cows observed during three periods in the subsequent year. Again, 5 a.m. observations were made at each period for each animal.

What of the relationship of flow rate to milk yield existing between cattle? Does the high yielder have, on average, a faster rate of flow than the low yielder? Evidence already published by the New Zealand Dairy Board[8] and by Dodd and Foot in England[9] indicates that this is actually the case.

TABLE 5 — FLOW RATES DURING LACTATION.

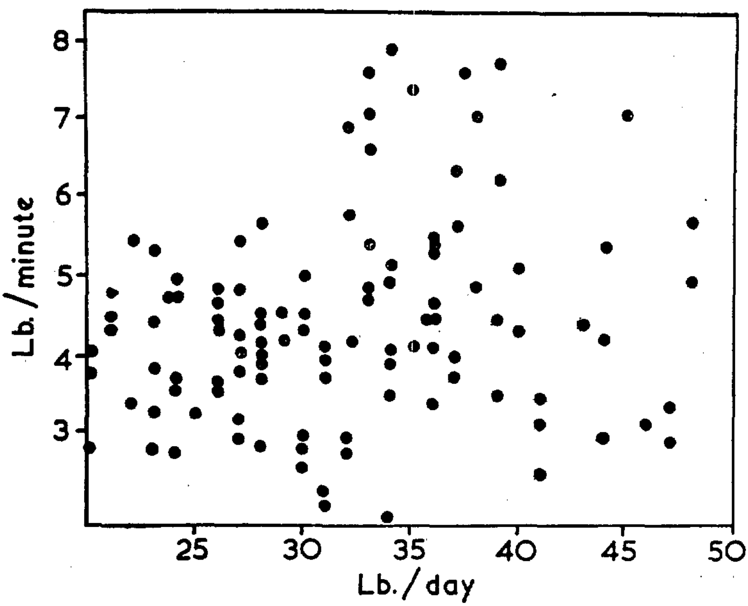
Period:	Aug-Sept	Oct-Nov	Dec-Jan	Feb-March	April-May
Max. Rate	4.01	4.14	4.29	3.73	3.48
Av. Rate	3.15	2.95	3.00	2.65	2.32
Milk in lb per day	24.2	24.8	20.1	15.3	12.1

TABLE 6 — FLOW RATES DURING LACTATION.

Period:	Octo.-Nov.	Dec.-Jan.	Feb.-March
Maximum Rate	4.42	4.31	3.73
Average Rate	2.70	2.56	2.13
Milk in lb per day	30.2	25.8	17.8

The relationship between peak yield and maximum flow rate (mean of five observations) recorded for all available animals milked at No. 4 Dairy, Ruakura, during the last three seasons is depicted in Figure 2. A lack of relationship is apparent between yield and flow rates, the regression between the two variables not differing significantly from zero. A similar picture is obtained when average flow rates are considered or when lactation yield is used as the independent variable.

Fig. 2.



8.

These data thus differ from those of the New Zealand Dairy Board and of the English workers and some explanation of the cause of the difference is called for. One possibility is that the Ruakura data is biassed through sampling variability, an insufficiently large sample yet being recorded; however, as some 110 cows are involved, this seems unlikely. Another possible explanation lies in the milking technique actually employed. Thus, it may be argued that under conditions where milking falls short of ideal the slower milkers are the animals most likely to be the first penalised in production in which case a relationship between flow rate and yield may well exist.

An approach to this problem has been made by subjecting eight sets of twins to a good versus poor milking trial, the decline in yield of the poorly milked twin being compared with that of its well-milked mate and related to the maximum rate of milk flow. Under poor milking the time for which the cow was washed and the time the animal was left before the cups were placed on was varied each day according to a set routine, the treatment embracing 36 days at the peak of lactation.

TABLE 7.

Set	Decline	M. Rate	Av. Rate	Rank Order Ascending		Descending
179	2.49	3.31	2.69	6	8	7
333	2.60	3.53	2.75	7	7	6
501	4.00	3.70	2.41	8	6	8
515	0.46	5.74	3.73	1	1	1
527	1.42	3.87	3.59	3	5	2
539	2.34	4.65	4.65	5	2	3
549	1.15	4.26	3.03	2	3	5
5115	1.76	3.98	3.14	4	4	4
		4.12	3.25			

Production decline has been represented as the relative fall in daily milk production within twin sets. Maximum and average rates of flow for the poorly milked twin member are tabulated alongside this data. The final three columns list this data in ranking order.

Though the evidence is yet limited, it does suggest that slower milking animals have been more adversely affected by poorer milking than free milking cattle. On such grounds it may be possible to explain the relationship reported by the Dairy Board, though it hardly explains the English results where milking conditions are reported to be excellent.[12]

The other major point of interest in this data is the marked variation between twin sets in their response to poor milking.

This last point is of considerable importance in progeny test work and provides a probable explanation for several anomalies in available progeny test data. Thus, the ranking order of bulls tested at progeny test stations in England and Denmark is not in close agreement with the ranking order of those same bulls when surveyed by daughters throughout the industry. Again, in New Zealand, the natural surveys of bulls often differ markedly from subsequent A.B. surveys. Part of the explanation of this problem is probably differential feeding but it also seems likely that part is due to milking method differences. Thus, naturally surveyed bulls leaving free milking stock will be likely to have better A.B. surveys than bulls leaving slower milking daughters. The obvious answer to this type of problem is to survey bulls under the average conditions in which they are to be used. For this reason, then, an A.B. policy of purchasing young bulls and surveying them on the basis of daughters spread throughout the industry is to be encouraged.

The apparent combination of a high heritability of milking character and marked variation in the responses of individuals to milking methods lead to a final point concerning the importance of good versus poor milking in individual herds. Granted these two conditions, a situation exists whereby as the result of a breeding policy the milking characteristics of different herds of cows may vary quite appreciably from year to year. In consequence, the importance of good milking compared with poor milking will vary in like manner from herd to herd and from season to season.

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Discussion

Professor CAMPBELL: In view of the high repeatability values for milk flow rates, how many measurements would be required to grade the milking characteristics of cows for the purpose of rating bulls?

Mr. BRUMBY: This would depend upon the estimate of repeatability appropriate to the actual conditions.

Mr. LAWRY: Concerning the Dairy Board data referred to, the discrepancy between these findings and Mr. Brumby's may be partly explained by the fact that under ordinary farm conditions the cups are not removed at the real end-point of milking.

Mr. BRUMBY: It is difficult to measure milking rate without some special recording device.

Mr. LAMBOURNE: What was the absolute magnitude of decline in production of the ill-treated twin sets? Did this occur immediately after the onset of poor milking or was it progressive over the whole period?

Mr. BRUMBY: It is not possible to give a straight answer because the cows were meal-fed for the first half of the trial and this appeared to minimize the effects of poor milking.