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ECONOMIC EVALUATION OF REPLACEMENT RATES IN DAIRY HERDS
II. SELECTION OF COWS DURING THE FIRST LACTATION

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ABSTRACT

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The economic optimal rate of culling for milk production during the first lactation was studied with an extended version of a model presented by Renkema and Stelwagen (1979).

Four culling policies were compared. The usual moderate culling procedure was the most profitable, the policy with no culling for milk yield being a close second. Heavy culling policies did not appear to be attractive.

For a situation without genetic progress in milk production, production levels were calculated , below which, cows in first lactation with average performance in other traits should be removed from the herd. For this purpose future milk yields were estimated. These were based upon the actual milk yield of the cow, and included the probability of disposal due to ill-health at different ages, as well as correlations between partial and total milk yield of first lactation and correlations between milk yield in the completed first lactation and successive lactations. The results showed that the strongest selection should be made 2 or 3 months after calving. At that time cows producing less than about 88% of the herd level at the same age can be culled. At the end of the lactation this so-called critical milk yield decreased to about 86%. The results implied that about 20% of cows in first lactation could be culled for production. Seasonal effects may influence the critical milk yield considerably.

The article was restricted to short-term aspects and did not consider any effects of the culling policy on the genetic capacity of future generations of cows. Additional calculations showed that the rate of genetic progress in a herd is affected very little by the intensity of culling for milk production.

INTRODUCTION

The average herd life of dairy cows is mainly shortened because of disease and insufficient productive capacity. The economic importance of improved health, permitting a longer herd life has been described by Renkema and Stelwagen (1979). The present study concerns the economic optimal rate of culling for milk production within the herd during the first lactation. We shall restrict ourselves to the short term, disregarding any effects of the culling policy on the genetic productive capacity of the next generation of cows. In this article we shall distinguish between the herd as a whole and individual cows.

The herd as a whole

The economic effects of the disposal of cows because of (presumed) insufficient productive capacity, are calculated for different culling policies.

Individual cows

From the economic point of view, it is important to know the critical production level below which a cow with average performance in other traits, compared with her herdmates, should be removed from the herd during the first lactation. Productive capacity can be estimated from the actual milk yield corrected for season, year and stage of lactation. On the one hand, a cow in first lactation with inferior milk yield would probably have more profitable successive lactations, whereas the replacement young cow has still to begin with the first and generally least profitable lactation. On the other hand, the present cow has produced less milk than her herdmates of the same age and she will probably continue to do so in successive lactations. These and other relevant aspects are economically evaluated with an extended version of the model of Renkema and Stelwagen (1979).

METHODS AND DATA

Methods

The herd as a whole

Four policies are distinguished (see Table I):

I. The present policy in practice, in which mostly ill-health or sometimes insufficient productive capacity are reasons for disposal of cows (compare q_i for Policies I and II). Here, about 58% of the female calves are necessary for the next generation of dairy cows.

II. Culling is not based on production. The cows are only removed from the herd because of ill-health. Here about 51% of the female calves are used for the replacement of the dairy herd.

III. Poorly producing cows are removed during the first lactation at the highest possible rate. All cows may supply the next generation.

IV. As III, but no calves are raised from cows that leave the herd because of insufficient production.

The four policies are compared on the basis of average earned income per cow per annum over the average productive lifetime. This income is calculated with a model that is described in the next section, 'Individual cows'.

Throughout this study, it is assumed that the size of the herd, as well as the age distribution for a given policy, remain constant from year to year. It is assumed that from a herd averaging 100 cows, 40 female calves can reach first calving each year. The culling policies have the same marginal probabilities of disposal due to disease (q_i, Table I). These probabilities, based on the estimation by Dijkhuizen (1977), differ slightly from those used by Renkema and Stelwagen (1979) because more recent data have been included (Stellingwerf, 1977). The age distribution of the herd is presented for each policy in Table I.

TABLE I

The age distribution of the herd per policy

Policy:	I		II		III		IV	
Lactation	q_i	f_i	q_i	f_i	q_i	f_i	q_i	f_i
1	0.210	0.233	0.140	0.205	0.670	0.400	0.570	0.339
2	0.200	0.183	0.150	0.176	0.150	0.132	0.150	0.146
3	0.210	0.147	0.180	0.149	0.180	0.112	0.180	0.124
4	0.220	0.117	0.200	0.122	0.200	0.092	0.200	0.101
5	0.230	0.091	0.230	0.098	0.230	0.074	0.230	0.081
6	0.250	0.070	0.250	0.075	0.250	0.057	0.250	0.062
7	0.270	0.052	0.270	0.056	0.270	0.043	0.270	0.047
8	0.290	0.038	0.290	0.041	0.290	0.031	0.290	0.034
9	0.320	0.027	0.320	0.029	0.320	0.022	0.320	0.024
10	0.350	0.018	0.350	0.020	0.350	0.015	0.350	0.016
11	0.380	0.012	0.380	0.013	0.380	0.011	0.380	0.011
12	0.410	0.007	0.410	0.008	0.410	0.006	0.410	0.007
13	0.440	0.004	0.440	0.005	0.440	0.004	0.440	0.005
14	0.470	0.002	0.470	0.003	0.470	0.002	0.470	0.003
Average productive herd life (lact.)	4.29		4.90		2.50		2.93	

f_i = Fraction of the cows in the ith lactation.
q_i = The number of cows that are removed during or at the end of the ith lactation as a fraction of the number of cows in the ith lactation (marginal probability of disposal).

The removal rate of poor producers has an effect on the expected milk yield of the herd in subsequent lactations. The average yield in the remainder of the first lactation (after culling) and in subsequent lactations may be estimated by the following formula:

$$\bar{x}_s = \bar{x} + i_s \, r \, \sigma_p$$

$\bar{x}$: the average of all first lactations in absence of culling;
i_s : the intensity of selection when a fraction s is selected (s = 1−culling fraction);
r : the correlation between the culling criterion and the completed first lactation yield or the yield of succeeding lactations;
σ_p: the phenotypic standard deviation of the first lactation yield.

Individual cows

In the extended version of an economic model, presented in its simpler form by Renkema and Stelwagen (1979), a cow can be replaced every month during the first lactation (the lactation has been divided into periods of 30.4 days). In subsequent lactations, a present cow just like replacement cows in all lactations, may be removed at the end of the eighth period (245 days in lactation). This corresponds with the average lactation length of the last lactation before disposal (Stellingwerf, 1977). A calving interval of 12 months and an age at first calving of 24 months is assumed.

The replacement criterion in a herd with constant size is: a cow should be replaced if the sum of the expected differences in profits (SED formula) between the present cow and the replacement cow is negative, taking into account the probability of disposal.

$$\mathrm{SED}_i = (\mathrm{me}_{i+1}-\mathrm{ae})+(1-\mathrm{q}_{i+1})\,[(\mathrm{me}_{i+2}-\mathrm{ae})+(1-\mathrm{q}_{i+2})\,[(\mathrm{me}_{i+3}-\mathrm{ae})\ldots\ldots\ldots\ldots(1-\mathrm{q}_{n-1})\,[\mathrm{me}_n-\mathrm{ae}]\,]\,]$$

i = moment of decision;

$\mathrm{me}_{i+1,\ldots,n}$ = marginal earned income of a present cow per period or per lactation taking into account the probability of disposal because of disease;

ae = average earned income of a replacement young cow, taking into account the probability of disposal because of disease and poor production;

n = moment at which the difference between marginal and average earned income is zero ($\mathrm{me}_n = \mathrm{ae}$)

$q_{i+1,\ldots,n-1}$ = marginal probability of disposal of a present cow due to disease.

The SED formula is illustrated in Fig.1.

For the replacement cow, all probabilities of disposal were used which Dijkhuizen (1977) estimated from literature (see also Table I, Policy I). For the present cow we only used the probability of disposal due to ill health, as we wanted to determine the optimal culling policy for cows with insufficient production. The cow can be removed during the first lactation at the end of a monthly period. Therefore, the probability of disposal due to disease has been assigned to each successive period of the first lactation. The frequency of several diseases, and the risk of disposal due to them, is highest in the early stages of lactation (Stellingwerf, 1977).

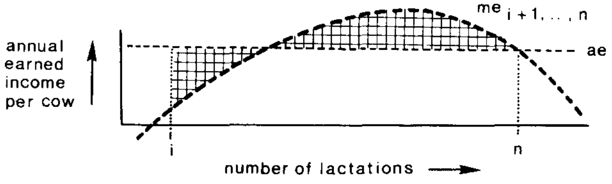

Fig.1. Comparison of the annual earned income of a present cow and its replacement.

The decision to replace a cow should be taken preferably before she is inseminated again. So, the decision has to be based on the milk yield of 2, or at most 3 months after calving. At that time, there is much uncertainty about the future milk yield. In order to estimate future milk yields, we used correlations between partial and total first lactation milk yield ($r_{p,t}$), and correlations between the milk yield in the completed first lactation and successive lactations ($r_{1,n}$), assuming that the phenotypic standard deviation of the daily production (corrected for age, season, herd level and stage of lactation) is independent of lactation number and stage of lactation.

From Dommerholt (1976), the following correlations ($r_{p,t}$) between partial and total first lactation are adopted in our calculations:

Months in lactation	2	3	4	5	6	7	8	9	10
$r_{p,t}$	0.915	0.944	0.963	0.975	0.983	0.990	0.997	0.999	1.000

The correlation between the first and second lactation ($r_{1,2}$) is based on the results of Politiek and Vos (1976), who found this value within a herd in which no selection had taken place. The values of $r_{1,3}$ up to $r_{1,14}$ are assumed to decrease at a degressive rate (e.g. Förster, 1971). The following coefficients are used:

Lactation	2	3	4	5	6	7	8	9	10
$r_{1,n}$	0.700	0.670	0.642	0.616	0.592	0.570	0.550	0.532	0.516
Lactation	11	12	13	14					
$r_{1,n}$	0.502	0.490	0.480	0.472					

Data

In the model, a dairy farm is assumed to buy pregnant heifers through the market or from its own rearing section. The area of grassland per cow is taken to be such that the cows can eat grass or preserved grassland products ad libitum in summer as well as in winter.

As in the model of Renkema and Stelwagen (1979), the following costs and returns are included in the model: milk production returns, slaughter value of the cows, value of the calves, the cost of a 2-year-old heifer just before calving, feed cost and sundries. Most of them are related to age, month of calving and season. The prices have been based on the year 1975. Because of incidental price fluctuations, the costs and returns have been normalized. For a detailed description, see the full report of this study (Korver, 1977).

RESULTS

Herd as a whole

Table II shows Policy I (common practice at present) to be the most profitable, with Policy II (culling not based on production) a close second. This result does not imply that Policy I is optimal as we only compared some extreme

TABLE II

Relative milk yield (corrected for age, stage of lactation and season; corrected milk yield in absence of culling for production = 100), and average earned income per cow per annum, per culling policy

Policy:	I	II	III	IV
Beginning 1st lactation	100.0	100.0	100.0	100.0
End 1st lactation	102.1	100.0	111.6	110.9
5th lactation	103.3	100.0	107.2	106.7
14th lactation	102.6	100.0	105.5	105.2
Average annual earned income (Dfl)	1363	1351	1246	1315

cases. However, the economic results of Policy I were rather stable when the culling rate was increased or decreased by a few percent. Anyhow, a heavy culling policy (III and IV) is not attractive: the higher milk yield in the older age classes with heavy culling does not outweigh the unfavourable age distribution and the higher cost of rearing young stock. From the study of Pearson and Freeman (1973), in which other methods of calculations have been used and other circumstances have been concerned, the same conclusion can be drawn at medium and high cow depreciation costs.

Individual cows

We calculated the production levels (the milk yield of cows in first lactation as a percentage of the herd average after correction for age and stage of lactation) below which first lactation cows with average performance in other traits should be removed from the herd ($SED_i \leqslant 0$). The resulting critical milk yields, according to the moment of decision, are presented in Table III. These results imply that the strongest selection could be made shortly after calving, although the increasing degree of certainty would lead to a higher critical production level towards the end of the first lactation. However, by that time most of the first lactation, generally the least profitable, has passed and the expectation about future profits is more favourable. This results in a lower critical production level towards the end of the first lactation. Obviously, the latter effect predominates.

According to Table III, the results are slightly affected by the average milk yield of the herd; but when expressed in absolute terms the critical levels are practically independent of the herd level.

Until now, the moment of decision and the moment of disposal were supposed to be the same. Additional calculations showed that in almost every case there is no advantage in keeping the first lactation cow any longer when the decision of replacement has been taken.

So far, we have assumed that the present cow is only replaced by a young cow with the same month of calving. When seasonal effects are taken into ac-

TABLE III

Critical production levels (as a percentage of the herd level at the same age) below which a first lactation cow should be removed, according to herd level and moment of decision

Months after calving : Herd level (%)	2	3	4	5	6	7	8	9	10
110	89.1	89.0	88.9	88.6	88.4	88.1	87.8	87.2	86.8
100	88.2	88.1	88.0	87.7	87.5	87.2	86.9	86.5	86.0
90	87.1	87.1	86.9	86.7	86.6	86.2	85.9	85.4	85.0

count, the results presented in Table III sometimes change because the cows calving in autumn are more profitable than cows calving in spring.

DISCUSSION

This article was restricted to short-term aspects and disregards any effects of the culling policy on the genetic capacity of future generations of cows. For different culling intensities, Syrstad (1972) estimated the genetic progress for the path from dams to daughters, and Korver (1977) calculated the economic value of genetic improvement in a dairy cattle population with the method of Brascamp (1973). From these calculations, it may be concluded that the rate of genetic progress in a herd is hardly affected by the intensity of culling for production. Pearson and Freeman (1973) found the same under a moderate rate of genetic improvement in the sire population.

If we suppose a normally divided production and a phenotypic intra-herd standard deviation of the milk yield of 15%, the results in Table III imply that about 20% of the first lactation cows could be culled for production capacity.

The replacement young cow was thought to have an average genetic capacity for milk yield. If a replacement young cow with above average productive capacity was available, the critical milk yields would be increased. Within a herd all heifers could be ranked according to their estimated breeding value. The critical milk yields will be decreased by higher rearing cost. Higher slaughter values of the cows will give the opposite.

By analogy with the method reported, the sums of expected differences (SED, see p. 32) can also be calculated for the cows during the second and subsequent lactations. In all cases, SED concerns the whole remaining life expectancy. SED per remaining time-unit of life can be considered as an important criterion for determining the order within a herd concerning the expected net profits per cow per time-unit, as has been pointed out by Renkema and Stelwagen (1979). Palmer (1975) also developed an economic ranking method for culling. His ranking criterion however, was based only on the remainder of the current lactation and the first part of the next lactation. Stewart et al. (1977) studied the culling decision in dairy herds using dynamic programming. How far the method presented in this article and those of other studies could be used as a regular aid for decisions about replacement in individual herds should be investigated.

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RESUME

Korver, S. et Renkema, J.A., 1979. Evaluation économique du taux de réforme dans les troupeaux laitiers. II. Sélection des vaches au cours de la première lactation. *Livest. Prod. Sci.*, 6: 29—37 (en anglais).

On a étudié le taux optimum de réforme pour production insuffisante en première lactation, à l'aide d'un élargissement d'une modèle présenté par Renkema et Stelwagen (1979).

On a comparé quatre politiques de réforme. La méthode habituelle de réforme modérée est la plus profitable, suivie de près par l'absence de réforme pour la production laitière. Les politiques de réforme sévères n'apparaissent pas intéressantes.

Dans la situation de l'absence de progrès génétique de la production laitière, on a calculé le niveau de production laitière au dessous duquel on devrait réformer les vaches en première lactation qui sont par ailleurs dans la moyenne pour les autres caractères. Pour cela on a calculé les productions laitières futures à partir des productions observées et en incluant la probabilité d'élimination pour cause de maladie à différents âges, ainsi que les corrélations entre d'une part la production laitière partielle et la production totale à la première lactation, et d'autre part, la production laitière totale à la première lactation et celle aux lactations ultérieures.

Les résultats montrent que la sélection la plus sévère doit être effectuée 2 à 3 mois après le vêlage. Les vaches produisant alors moins de 88% de la moyenne du troupeau au même âge peuvent être éliminées. Ce niveau, dit critique, n'est plus que d'environ 86% à la fin de la lactation. Ces résultats supposent un taux de réforme d'environ 20% pour production insuffisante à la première lactation. Les influences saisonnières peuvent modifier considérablement la production laitière critique.

Ce travail est limité aux aspects à court terme. Il ne prend en considération aucune des influences de la politique de réforme sur la capacité génétique des générations futures. Des calculs annexes montrent que la vitesse du progrès génétique dans un troupeau est très peu modifiée par l'intensité de la réforme pour production laitière insuffisante.

KURZFASSUNG

Korver, S. und Renkema, J.A., 1979. Ökonomische Bewertung der Remontierungsraten in Milchrinderherden. II. Selektion der Kühe während der ersten Laktation. *Livest. Prod. Sci.*, 6: 29—37 (in Englisch).

Die ökonomisch optimale Merzquote für die Milchleistung während der ersten Laktation wurde an Hand einer erweiterten Version eines von Renkema und Stelwagen (1979) vorgelegten Modells untersucht. Es wurden vier verschiedene Merzquoten miteinander verglichen. Die normale, mittlere Merzquote brachte den höchsten Ertrag. Wurde keine Merzung auf der Basis der Milchleistung vorgenommen, so folgte diese Massnahme dicht auf dem zweiten Platz. Eine besonders hohe Merzquote war offenbar nicht sinnvoll.

Für eine Situation ohne genetischen Fortschritt in der Milchleistung wurden Leistungsgrenzen errechnet, unterhalb der erstlaktierende Kühe mit Durchschnittsleistungen in anderen Merkmalen aus der Herde entfernt werden sollten. Zu diesem Zweck wurden zukünftige Milchleistungen geschätzt. Diese basierten auf der aktuellen Milchleistung der Kuh und schlossen die Wahrscheinlichkeit des Verkaufs auf Grund schlechter Gesundheit bei verschiedenem Alter ein. Ausserdem waren Korrelationen zwischen partieller und gesamter Milchleistung in der ersten Laktation sowie Korrelationen zwischen Milchleistung in der abgeschlossenen ersten Laktation und den folgenden Laktationen enthalten. Die Ergebnisse zeigen, dass die schärfste Selektion 2 oder 3 Monate nach dem Abkalben erfolgen sollte. Dann können Kühe, die weniger als ca. 88% des Herdenniveaus bei gleichem Alter erreichen, gemerzt werden. Am Ende der Laktation nimmt diese sogenannte kritische Milchleistung auf ca. 86% ab. Die Ergebnisse zeigen, dass etwa 20% der Kühe in der ersten Laktation auf Grund ihrer Leistung gemerzt werden könnten. Jahreszeitliche Einflüsse können die kritische Milchleistung erheblich beeinflussen.

Die Arbeiten waren auf kurzfristige Aspekte beschränkt und berücksichtigten keine Einflüsse der Merzquote auf die genetische Kapazität zukünftiger Generationen von Kühen. Zusätzliche Berechnungen ergaben, dass der genetische Fortschritt in einer Herde sehr wenig von der Intensität der Merzung auf Grund der Milchleistung beeinflusst wird.