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# Environmental impact of heifer management decisions on Dutch dairy farms

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## Abstract

Dairy farming contributes substantially to Dutch environmental problems. A dynamic heifer rearing model was used to determine the extent to which the rearing activity influences nutrient flows on a dairy farm. Based on current rearing conditions, the economic optimal rearing policy resulted in an average accounting nutrient surplus of 51.4 kg of nitrogen and 17.0 kg of phosphate per heifer per year.

To study the sensitivity of the optimal rearing policy to environmental measures as the Dutch mineral accounting system (MINAS), the model was extended with the mineral accounting relationships and a 'least mineral' ration formulator. Optimal rearing policy, in terms of growth rate and breeding decisions, was only slightly influenced by these measures. The effects on ration composition and nutrient surpluses were considerable.

*Keywords:* dairy heifer, MINAS, nutrient surpluses, modelling, rearing policy

## Introduction

Increasing environmental problems in agriculture urge policy makers to develop instruments to reduce and control the pollution caused by current intensive farming practices. In an attempt to decrease the environmental effects from nutrient surpluses, the Dutch government has developed a so-called manure policy. The aim of regulating manure is to decrease the nutrient surpluses to the extent that the limits of the carrying capacity of the environment are no longer exceeded (Dietz, 1992).

As part of the manure policy, a mineral accounting system (MINAS) became compulsory for Dutch livestock farms in 1998. This nutrient accounting system determines the nutrient surpluses by recording the nitrogen and phosphate contents of farm inputs (i.e., feed, fertiliser) and outputs (i.e. milk, meat). The difference between input and output, minus a levy-free threshold level for acceptable surpluses per hectare, constitutes the mineral surpluses per farm that will be taxed (Anonymous, 1997b).

Nutrient losses in Dutch dairy farming are considerable. Research of Aarts *et al.* (1988) indicated that 85% of the nitrogen input and 67% of the phosphate input are lost to the environment. Data of 350 representative dairy farms indicated average losses per hectare in 1993 of 388 kg nitrogen and 57 kg phosphate (Mandersloot *et al.*, 1995).

Most dairy farmers try to minimise the negative economic consequences resulting from the MINAS legislation by adapting their management strategy. The most important decision variables affecting nutrient use and nutrient losses on a dairy farm are animal density, feed ration of the animals and fertilising levels of grassland and arable land (Berentsen & Giesen, 1994; Van Keulen *et al.*, 1996). To reduce nutrient surpluses, dairy farmers are especially advised to reduce their number of young stock (Teenstra, 1997). Generally, farmers raise more replacement heifers than actually required for maintenance of the dairy herd size, to enable selection for better replacements.

To maximize farm income, dairy farmers are faced with the complex dilemma of minimizing rearing costs, while ensuring or enhancing future cow performance. Heifer management decisions interact with biological aspects of growth, thus influencing future profitability of the heifer (Hoffman & Funk, 1992; Mourits *et al.*, 1997). With the introduction of MINAS the complexity of heifer management increased even more.

In this study the heifer rearing optimisation model of Mourits *et al.* (1999b) was used to determine the extent to which the rearing activity influences the nutrient flows on a dairy farm and to examine the impact of MINAS on the optimal rearing strategy.

## Material and Method

First the mineral accounting system, MINAS is explained in general terms. Also a concise description of the heifer optimization model is given. For a detailed definition of the basic model, reference is made to Mourits *et al.* (1999a, 1999b).

### *MINeral Accounting System, MINAS*

Over the past 40 years Dutch livestock production has increased tremendously. As a consequence, manure production increased, resulting in serious environmental problems like acidification, eutrophication, and pollution of surface and ground water. To face these environmental problems, the Dutch government has formulated new legislation since the 1980s (Dietz, 1992).

With the MINAS regulation, farms with more than 2.5 Livestock Units (LU) per hectare are obliged to keep a nutrient account for inputs and outputs of nitrogen and phosphate at farm level. 2.5 LU is assumed equivalent to a production of 102.5 kg of phosphate through manure each year, produced by 2.5 mature dairy cattle, 13.9 pork pigs or 427 broilers. In the Netherlands about 50.000 farms exceed the animal density of 2.5 LU per hectare. However, after the year 2000 all farms with livestock will have to participate in the mineral accounting system (Anonymous, 1997b).

MINAS comprises two accounting systems viz., the specific account and the estimated account. The specific nutrient account is an accurate recording of all nitrogen and phosphate inputs and outputs on the farm. Wherever possible, farmers need to account for the exact quantity of nutrients. Consequently, all information on the quantities of minerals delivered to the farm in the form of livestock, feed, manure and fertiliser and removed from the farm in the form of products and manure has to be recorded. Part of this information is often directly provided by the suppliers and buyers. For determination of the nutrient content of manure, authorised personnel must take samples of farm manure on location and the amount of manure, leaving the farm must be monitored.

Within the estimated account system nutrient accounting is limited to the nutrient flows on the field. Quantification of nutrient inputs and outputs is based on official fixed rates. These rates are used to calculate the quantities of nitrogen and phosphate in manure and other fertilisers. Also official fixed rates are used to determine the output of nutrients by crops (e.g., grass, maize, hay, etc.). The estimated account is easier and cheaper to perform, but also less accurate. The official input rates have deliberately been set above actual averages to encourage farmers to select in favour of specific accounting (Anonymous, 1997b; Teenstra, 1997).

Nutrient balances refer to a period of one calendar year. The difference between inputs and outputs, minus a levy-free threshold level, constitutes the nutrient surpluses per farm that will be levied. The levy-free surpluses will be reduced over time (Table 1). In addition to levy-free surpluses per ha, there is also an annual correction for nitrogen losses per animal through ammonia volatilisation from manure. For dairy cattle this correction corresponds with 9.7 kg per heifer < 1 year, 20.5 kg per heifer ≥ 1 year and 30.0 kg per mature cow, above a threshold level of 60 kg per hectare (Anonymous, 1997b).

Surpluses per ha exceeding the acceptable levels are levied at Dfl 2.50 per kg for the first 10 kg phosphate per ha and Dfl 10 for each additional kg. The levy for surplus nitrogen is Dfl 1.50 per kg per ha (Anonymous, 1997b). For a typical grassland dairy farm with a cultivated area of 30 ha, an animal density of 3 LU and a nutrient surplus per ha of 390 kg nitrogen and 55 kg phosphate, the levied surpluses in 1998 would be 60 kg nitrogen per ha and 15 kg phosphate per ha, resulting in a nutrient levy of Dfl 4950. Related to the economic results of 1996–1997, this amount would correspond to 15% of the entrepreneurial income on an average Dutch dairy farm (Van Dijk *et al.*, 1997).

### *Basic heifer rearing model*

In the stochastic dynamic optimisation model of Mourits *et al.* (1999b), heifer rearing is modelled as a separate farming activity. Optimisation starts with new-born

Table 1. Levy-free surpluses per calendar year (Anonymous, 1997b).

| | 1998 | 2000 | 2002 | 2005 |
|---|---|---|---|---|
| Phosphate, kg/ha | 40 | 35 | 30 | 25 |
| Nitrogen, kg/ha grassland | 300 | 275 | 250 | 180 |
| Nitrogen, kg/ha arable land | 175 | 150 | 125 | 100 |

calves and ends with full-grown heifers to be sold at market prices. The rearing activity is structured by time steps or stages of one month. Decisions are, therefore, taken on a monthly basis. At each stage, the state of a heifer is described by the following state variables (number of classes in brackets); Age (29), Season (12), Body Weight (173), Reproductive state (32) and Maximum prepubertal growth rate (3). The maximum duration of the rearing period is set to 30 months. Season is considered due to its effects on prices of feed, milk, meat and calves and on expected milk production, which can substantially influence economic results. Body Weight (BW) is the main variable, as it determines the onset of puberty, and influences feed costs, slaughter value, expected milk production and market price. Reproductive state describes the various prepubertal, cyclic and pregnancy states, while maximum prepubertal growth rate is included to estimate the influence of prepubertal average daily gain (ADG) on future milk production ability (Mourits *et al.*, 1999b). A prepubertal growth rate exceeding 0.9 kg per day is assumed to have a negative influence on the future production ability of the heifer (Mourits *et al.*, 1999a).

In the model, the weaning period is fixed at 2 months, resulting in weaned calves at a BW of 75 kg, after which optimization of the rearing decisions starts. The objective function in the model is defined as maximization of total present value of expected net returns per heifer place. For each possible combination of the state variables, the model determines the optimal decision with respect to growth rate, moment of insemination and replacement. Growth is classified in five levels of weight gain viz., 0.3, 0.5, 0.7, 0.9 and 1.1 kg/day. However, ADG was limited after 3 reproductive cyclic months to a maximum of 0.7 kg/day (Mourits *et al.*, 1999a).

Three sets of transition probabilities are used to represent uncertainty in the processes of puberty, conception and involuntary disposal. The probability of puberty is normally distributed over the BW classes with an average BW at puberty of 276 kg and a variation coefficient of 10%. The marginal probabilities of conception are determined as the product of percentage of oestrus detected, conception rate per service and number of oestrus per month. The probabilities of involuntary disposal during each month decrease with age from 0.6 to 0.15%.

Costs within the model include the costs of heifer calves, breeding, veterinary treatment and feed, the latter being the largest component. For each combination of state variables and weight gain strategy, a least cost ration is determined by means of a separate linear programming model (Mourits *et al.*, 1997). The objective of this feed model is to minimise the cost of a feed ration while providing adequate levels of energy, protein and phosphorus, within the limits of the animal's dry matter intake. In this study, the estimates of net energy, protein and phosphorus requirements, maximum dry matter intake capacity, and substitution rate of roughage by concentrates were derived from to the Dutch feeding recommendations of 1997 (Anonymous, 1997a; Van Vliet, 1997). The feedstuffs used in the ration formulations are typically for current practice, with in summer (May through October) grass and concentrates and in winter (November through April) silage and concentrates (Table 2). The costs of housing and labour supplied by the farmer are considered fixed costs and are therefore not included in the calculation of the rearing costs.

Gross returns of heifer rearing consist of the value of full-grown heifers and the

Table 2. Feed characteristics per kg DM (Anonymous, 1998).

| | Base price (Dfl) | Price + levy[a] (Dfl) | Energy (VEM[b]) | Protein (DVE[c]) | Nitrogen (g) | Phosphate (g) |
|---|---|---|---|---|---|---|
| Grass | | | | | | |
| before Jul 1 | 0.18 | 0.25 | 985 | 98 | 33.4 | 9.3 |
| from Jul 1 to Sep 1 | 0.18 | 0.25 | 960 | 102 | 34.4 | 9.3 |
| after Sep 1 | 0.18 | 0.25 | 955 | 104 | 32.3 | 9.3 |
| Grass silage | 0.25 | 0.32 | 825 | 70 | 32.3 | 9.1 |
| Maize silage | 0.29 | 0.32 | 909 | 47 | 13.3 | 4.3 |
| Hay | 0.31 | 0.36 | 789 | 78 | 23.2 | 6.8 |
| Straw | | | | | | |
| wheat | 0.21 | 0.22 | 432 | 3 | 6.9 | 1.8 |
| barley | 0.22 | 0.24 | 516 | 13 | 6.6 | 2.5 |
| Concentrates | 0.34 | 0.40 | 1036 | 100 | 25.0 | 10.2 |

[a] Levy system of Dfl 1.5 per kg nitrogen and Dfl 2.5 per kg phosphate.
[b] Dutch Feed Unit: 1000 VEM = 6.9 MJ of $Ne_l$.
[c] True protein digested in small intestine.

slaughter value of disposed young stock. The market value of full grown heifers is estimated relative to a predefined standard heifer (Mourits *et al.*, 1999b). The value depends on BW at calving due to its relation with milk yield and its effect on the occurrence of dystocia (i.e., complications around parturition) (Hoffman & Funk, 1992), on prepubertal ADG for its expected impact on future production (Foldager & Sejrsen, 1991) and on calving season because of the seasonal differences in production and prices.

Heifers that fail to conceive after 6 cyclic months are sold at slaughter prices. No returns are obtained for heifers, that are prematurely culled (Mourits *et al.*, 1999b).

### *Incorporation of MINAS in the heifer rearing model*

The production process on most Dutch dairy farms consists of 3 interdependent activities: grassland exploitation, rearing young stock and managing dairy cows. In the heifer model, the rearing activity is modelled as a separate farming activity (Mourits *et al.*, 1999b). Required new-born calves and feed to raise dairy replacements are, therefore, 'purchased' from the dairy and roughage production components, while the full grown replacements are 'sold' to the dairy component.

Although MINAS refers to the mineral balance of the complete dairy system, this study only considers the nutrient flows within the rearing component of the farm. Moreover, the nitrogen and phosphate surpluses are determined using an accounting relationship rather than a 'true' production function, since the accounting relationship is used by the government as a base for levying Dutch dairy farms.

In this study, recording of nutrient flows is based on the specific nutrient account system. For the determination of the nutrient balance within the rearing activity, the following nutrient flows are considered;

- purchase of heifer calf
- purchase of feed
- sale or involuntary disposal of (full grown) heifer
- annual nitrogen correction per heifer

The nutrient input with the purchase of a new-born calf is based on the official fixed rate. The quantities of discharged nutrients through sale or disposal of a heifer are also based on these official deduction rates (Table 3).

The amounts of nitrogen and phosphate within the formulated rations, are derived from the nutrient contents of the feeds in the heifer feed model (Table 2). During the weaning period calves are fed according to a standardised feeding pattern. Cumulated over the two weaning months, the standardised ration consisted of 35 kg of milk replacer, 15 kg of DM concentrates and 6 kg of DM hay, representing a total nutrient input of 1.9 kg of nitrogen and 0.8 kg of phosphate.

The annual corrections for nitrogen losses per animal through ammonia volatilisation are included as a reduction of the nitrogen surplus. As the heifer model only considers the rearing activity of the dairy farm, the levy free surpluses per hectare of farming land could not be taken into account (Table 1). The estimated nutrient surpluses will therefore have a larger impact on the final mineral levies of intensive farms (= high animal density) than on those of extensive farms (= low animal density).

Nutrient surpluses are levied based on the system of Dfl 1.50 per kg nitrogen and Dfl 2.50 per kg phosphate. Incorporation of the various MINAS elements did not alter the objective function of the heifer model, which is maximization of the total present value of expected net returns per heifer place by optimization of the rearing decisions.

*Organisation of calculations*

In this study the MINAS incorporated rearing model as well as the original basic heifer rearing model (Mourits *et al.*, 1999a) are used. Both models consist of an optimization unit and an evaluation unit. In the evaluation unit the economic results under a given policy are calculated. For instance, the MINAS incorporated model can be used to evaluate the influence of MINAS for a situation where the rearing policy is determined without the consideration of the MINAS regulation.

The following three rearing alternatives have been evaluated:

Table 3. Official fixed rates to determine the inputs and outputs of nutrients through dairy cattle (kg/animal) (Anonymous, 1997b).

| | Nitrogen | Phosphate |
|---|---|---|
| Heifer calf | 1.3 | 0.8 |
| Heifer < 1 year | 7.9 | 5.2 |
| Heifer ≥ 1 and < 2 year | 12.3 | 8.1 |
| Heifer ≥ 2 year | 13.3 | 8.8 |
| Dairy cow | 15.2 | 10.1 |

1) Optimal economic rearing policy and resulting nutrient surpluses without MINAS (base scenario). In this scenario, optimum rearing policy is determined without considering the MINAS legislation. This means that the original version of the heifer rearing model is used for the optimization of the rearing decisions. Technical and economic results are calculated based on the optimum situation. Furthermore, the economic consequences of the application of this basic optimum policy in a situation with MINAS are evaluated, by calculating the nitrogen and phosphate surpluses and corresponding mineral levies.
2) Influence of MINAS on the economic optimal rearing policy and resulting nutrient surpluses (MINAS scenario). Optimal rearing policy is determined by the MINAS incorporated rearing model. Feed prices are increased according to the levy system of MINAS to reflect the influence of mineral supply by feed (Table 2). The least cost rations are formulated on the basis of these levy included feed prices, while actual feed costs are determined by the original feed prices (= levy-free). Technical and economic results are determined for the MINAS situation, while the economic results of the optimized policy are also calculated for a situation without the MINAS regulation.
3) Influence of least mineral ration formulation on the economic optimal rearing policy and resulting nutrient surpluses (least mineral scenario). In this scenario heifers are reared on 'least mineral' rations. The objective of the ration formulation model is modified from minimization of costs to minimization of nutrient content. The impact factors within the objective function correspond with the weight of the mineral levies (i.e., MIN{1.5 nitrogen + 2.5 phosphate}). The rearing pattern was optimised without consideration of the MINAS regulation, using the original rearing model. Technical results are calculated for the optimized situation (i.e. MINAS excluded), while the economic results are determined for a situation with and without MINAS.

## Results

### *Optimal rearing policy and nutrient surpluses without MINAS regulation (base scenario)*

Based on the critical prepubertal growth rate of 0.9 kg/d and a maximum ADG after 3 cyclic months of 0.7 kg/d, the optimal policy resulted in an average optimum calving age of 21.0 months at an average calving BW (excl. foetal tissue) of 536 kg (Table 4). Most of the heifers (57.2%) calved between 20 and 22 months of age. Only 3.2% had a calving age of 24 months or more (Table 4). Prepubertal heifers reached puberty at an average age of 9.8 months and a BW of 288 kg. Breeding commenced 1.6 months later at a BW of 339 kg.

The optimum rearing pattern of dairy replacements resulted in an average purchase per heifer per year of 287 kg DM of concentrates and 1950 kg DM of roughage (Table 4). Cumulative DM intake of 3820 kg per full grown heifer consisted of 45.8% grass, 41.3% grass silage and 12.8% concentrates (Figure 1).

Table 4. Technical and economic results per full grown heifer based on the optimal rearing strategy within alternative situations[a].

| | Base scenario | MINAS | 'Least mineral' |
|---|---|---|---|
| *Technical results* | | | |
| Calving age (months) | 21.0 | 21.1 | 20.7 |
| Calving age < 20 months (%) | 9.9 | 12.1 | 13.5 |
| Calving age ≥ 20 and < 22 months (%) | 57.2 | 51.4 | 63.7 |
| Calving age ≥ 22 and < 24 months (%) | 29.7 | 32.2 | 20.5 |
| Calving age ≥ 24 months (%) | 3.2 | 4.3 | 2.3 |
| Calving BW (kg) | 536 | 530 | 530 |
| Feed intake per heifer | | | |
| Concentrates (kg DM/year) | 287 | 228 | 1133 |
| Roughage (kg DM/year) | 1949 | 1961 | 1021 |
| Nitrogen (kg/year) | 72.0 | 63.7 | 46.6 |
| Phosphate (kg/year) | 21.2 | 18.9 | 17.3 |
| Nutrient surplus per heifer | | | |
| Nitrogen (kg/year) | 51.4 | 43.1 | 26.0 |
| Phosphate (kg/year) | 17.0 | 14.7 | 13.1 |
| *Economic results* | | | |
| Feed costs[b] (Dfl/year) | 497 | 491 | 647 |
| Net returns, levy excluded (Dfl/year) | 299 | 292 | 154 |
| Net returns, levy included[c] (Dfl/year) | 180 | 190 | 84 |

[a] In all alternatives the critical prepubertal ADG equalled 0.9 kg/d, while maximum ADG after 3 cyclic months corresponded with 0.7 kg/d.
[b] Feed costs weaning period excluded.
[c] Levy system of Dfl 1.5 per kg nitrogen and Dfl 2.5 per kg phosphate.

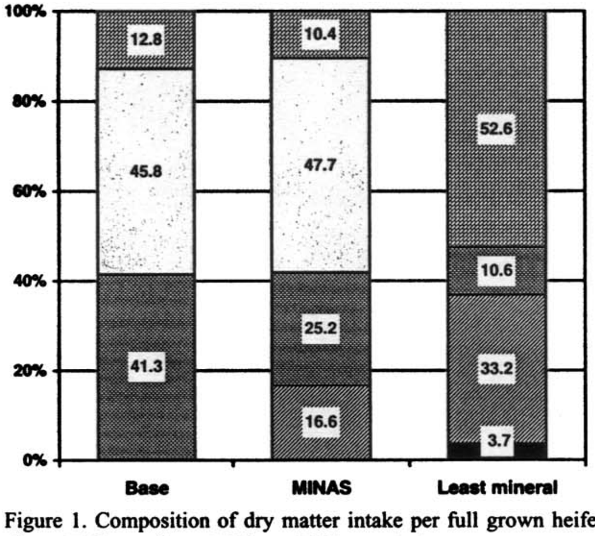


Figure 1. Composition of dry matter intake per full grown heifer. Symbols: ■ Hay and Straw, ▨ Maize silage, ⊟ Grass silage, ▩ Grass, ⊠ Concentrates.

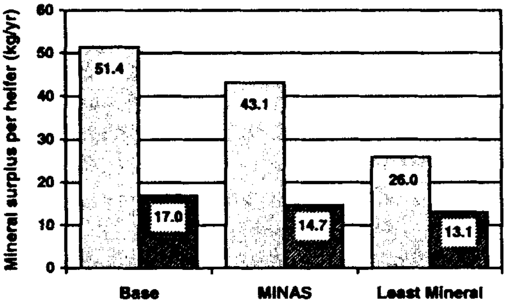


Figure 2. Nitrogen and phosphate surpluses per heifer per year according to the optimized rearing patterns within the described alternatives. Symbols: ☐ Nitrogen, ▨ Phosphate.

Average discounted rearing cost were Dfl 817 of which 60.8% (Dfl 497) was caused by average feed costs for heifers older than 2 months. Expected net returns (gross returns minus costs) per heifer per year, calculated as an annuity, equalled Dfl 299 (Table 4).

The complete ration resulted in a nutrient input of 126.0 kg nitrogen and 37.1 kg phosphate per full grown heifer or 72.0 kg nitrogen and 21.2 kg phosphate per heifer per year (Table 4). Balancing the nutrient supplies (purchase calf and feed) with the nutrient discharges (sale heifer and nitrogen correction) resulted in a surplus of 51.4 kg/year for nitrogen and 17.0 kg/year for phosphate (Table 4, Figure 2). Total mineral levy would be Dfl 209 per full grown heifer or Dfl 120 per heifer per year. Application of the optimized rearing pattern in a situation with MINAS would therefore result in a decrease of discounted net returns to an amount of Dfl 180 per heifer per year (Table 4).

*Influence of MINAS on optimum rearing policy and nutrient surpluses (MINAS scenario)*

In the MINAS scenario, optimum rearing policy eventuated in an average calving age of 21.1 months at an average BW of 530 kg (Table 4). Average age and BW at puberty coincided with 10.0 months and 288 kg, respectively. Breeding commenced at an average age of 11.4 months and an average BW of 333 kg.

Under the optimum rearing policy heifers were fed on average 228 kg DM of concentrates and 1961 kg DM of roughage annually. Ration composition differed from the one within the base scenario (Figure 1). Part of the grass silage was substituted by maize silage to correct for the excessive amount of protein in the winter ration. The ratio between the costs per unit of energy and the mineral levies is for maize silage more profitable than for grass silage (Table 2). However, the degree of substitution is limited by the low content of phosphorus in maize silage.

The optimum feeding pattern resulted in a nutrient intake of 63.7 kg nitrogen and 18.9 kg phosphate per heifer per year (Table 4). Balancing these supplies with the nutrient discharges resulted in an accounting surplus of 43.1 kg nitrogen and 14.7 kg phosphate per heifer per year (Figure 2).

Average feed costs of heifers older than 2 months were Dfl 491 per year (Table 4), with net returns per heifer per year of Dfl 190. Application of the optimized pattern in a situation without MINAS would lead to average net returns of Dfl 292 per heifer per year (Table 4).

*Influence of 'least mineral' ration formulation on rearing policy and nutrient surpluses (least mineral scenario)*

The optimal strategy to raise young stock based on the least mineral scenario resulted in an average calving age of 20.7 months at a BW of 530 kg. Puberty was reached at an average age of 9.8 months. First insemination occurred at an average age and BW of 11.0 months and 330 kg, respectively.

Raising a full grown heifer required on average 1133 kg DM/year of concentrates and 1021 kg DM/year of roughage (Table 4). Under minimization of mineral contents, ration composition was completely different from the composition in the base scenario. Heifers were no longer pastured during summer. A ration of hay and straw (4%), grass silage (11%), maize silage (33%), and concentrates (53%) (Figure 1) was selected on the basis of its more favourable ratio of energy and mineral contents. In the ration formulation energy requirements were, generally, more restricting than protein requirements. The relation between protein and mineral contents within the ration was therefore of minor importance.

The ration provided the required amounts of energy, protein and phosphorus, while minimizing mineral intake. The mineral content per unit of energy was lowest for maize silage. The phosphorus supply of maize silage was, however, insufficient to meet the animal requirements. Consequently, concentrates are required to provide energy and phosphorus at the lowest level of nitrogen. Grass silage, straw and hay were included to provide the minimum required amount of structure within the ration.

Relaxation of the phosphorus constraint would reduce the contribution of concentrates in the ration to a minimum of 14%, and increase that of maize silage to a maximum of 63%.

Feed intake eventuated in a nutrient input of 46.6 kg nitrogen and 17.3 kg phosphate per heifer per year (Table 4). Balancing the nutrient flows resulted in a surplus of 26.0 kg/year for nitrogen and 13.1 kg/year for phosphate (Table 4, Figure 2).

Annual feed costs per heifer increased from Dfl 497 in the base scenario to Dfl 647. Due to the use of more expensive feeds net returns decreased to Dfl 154 per heifer per year. In a situation with MINAS, net returns after mineral levies would reduce to Dfl 84 per heifer per year (Table 4).

## Discussion

Efficient nutrient utilisation becomes increasingly important within the dairy farm management system. Due to interactions of technical and economic aspects, the complexity of farm management increases. Farmers need insight in the relations between the various management units to determine their most optimum farming strategy.

The objectives of this study were to determine the effect of the heifer rearing unit on the nutrient flow of a dairy farm and to study the sensitivity of the optimal rearing strategy for environmental measures as MINAS and the use of least mineral rations.

The optimal rearing policy in the base scenario resulted in an accounting nutrient surplus per heifer per year of 51.4 kg nitrogen and 17.0 kg phosphate. For a typical Dutch dairy farm with an average area of 24 ha grassland and 6 ha arable land (Van Dijk *et al.*, 1997), these nutrient losses corresponds to 1.7 kg/ha for nitrogen and 0.6 kg/ha for phosphate. Based on the average recorded surpluses in 1993 (viz. 388 kg nitrogen/ha and 57 kg phosphate/ha (Mandersloot *et al.*, 1995)) and an animal density of 2.5 LU, the levied farm surplus would approximately be equal to 98 kg nitrogen/ha and 17 kg phosphate/ha. A reduction in the number of heifers by one would then result in a decrease in the farm nitrogen and phosphate surpluses by less than 2% and 4%, respectively.

However, interpretation of these results needs further consideration. As mentioned earlier a dairy farm consists of the 3 interdependent activities: roughage production, heifer rearing, and dairy cow management. In the rearing models, interactions with the other 2 activities are not included. Nevertheless, the interaction between the rearing unit and the roughage production unit plays an important role in extrapolating nutrient surpluses per heifer to farm level. The calculated surpluses per heifer reflect the situation in which all roughage is purchased. In practice, heifers are fed with roughage that is produced at the same farm, which requires a larger mineral input than is actually assimilated by its products (e.g. grass, grass silage). Heifer rearing, as an interdependent component of the dairy farm, will therefore be associated with higher mineral surpluses per heifer than calculated in the model.

On the other hand, the calculated surpluses per heifer are somewhat overestimated as part of the mineral surpluses (in the form of manure) can be used as fertiliser, thus reducing purchase of chemical fertilisers.

The influence of these two aspects on the mineral surplus per heifer decreases with increasing intensity of the farms. Due to a higher animal density, intensive farms realise a higher animal production per ha than extensive farms at the expense of more purchased feed. Moreover, the mineral surpluses in manure are higher, resulting in higher mineral losses per ha. For instance, Aarts *et al.* (1988) calculated total nitrogen input on intensive farms at 250–285 kg/ha higher than on extensive farms, while output was only 40–60 kg/ha higher. In the present study all nutrients in feed are considered as input, while all nutrients in manure are considered as surplus. The modelled rearing system can therefore be regarded as a representation of the rearing situation on current intensive farms.

The results of this study suggest that a decrease in the number of young stock will only result in a substantial reduction in the nutrient surpluses on a dairy farm if it involves a large number of heifers. However, under current management reducing young stock is limited to the number of replacement heifers required to maintain the milking herd size. Off-farm rearing could be an alternative to reduce young stock and, therefore, the nutrient surpluses on a farm. However, this option need some careful consideration, because of the increased risk for introduction of infectious diseases (Van Schaik, 2000).

For an effective reduction of farm nutrient losses in an economic way, improved resource management in all 3 parts of the dairy system is a necessity. Research results of a prototype farming system indicate that on average intensive dairy farms can halve nutrient inputs through fertilisers and feeds, without the need to reduce milk production per hectare (Aarts *et al.*, 1999).

Optimum rearing strategy, in terms of growth rate and breeding decisions, was only slightly influenced by measures aiming at reduced nutrient surpluses (Table 4), but the effect on ration composition was considerable (Figure 1).

In the MINAS scenario, feed price, energy content, mineral levy and mineral content were decisive for the least cost ration formulation. Generally, energy requirements were more restricting than protein requirements. Per unit of energy, the levy included price of grass silage was no longer lower than the levy included price of maize silage. As a consequence, 39% grass silage was replaced by maize silage. Further substitution was prevented by the low phosphorus content of maize silage. Grass remained the least expensive provider of energy even after inclusion of the mineral levies.

Compared with the base results, the optimum policy and ration in the MINAS scenario had only a slight impact on the levy free economic results. Net returns for a production system without MINAS were Dfl 7 lower (–2%) (Table 4). On the other hand the calculated nutrient surpluses of nitrogen and phosphate were, respectively, 16% and 14% lower (Figure 2). Hence, in a production system with MINAS the optimal policy of the MINAS alternative resulted in 6% higher net returns (Table 4).

In the mineral minimization scenario, ration composition depended on the relation between energy and mineral content. Mineral content per unit of required energy and phosphorus was lowest for a ration consisting mainly of concentrates and maize silage, explaining the increase in intake of these more expensive feeds (feed costs + 30%). Surpluses of nitrogen and phosphate were considerable reduced by 49% and 23%, respectively (Table 4). Once again, these reductions in nutrient surpluses underline the significant impact of ration compositions on the mineral balance. Inclusion of other (mineral-low) feeds, in addition to those in Table 2, could reduce the increase in feed costs associated with these reductions. However, it should be noticed that most Dutch farmers produce their own roughage (grass, grass silage and maize silage). Purchase of other feeds will therefore need to match with this production.

In the MINAS scenario, payment of some levies was economically more efficient than a profound reduction of nutrient input by an alteration of the ration composition as in the least mineral scenario. However, within the following years, MINAS regulation will become more stringent, represented by an increase in levies, a reduction in the levy-free surpluses and a limitation in the application of animal manure (Anonymous, 1999). Due to the increase in levies, composition of the least cost ration in the MINAS scenario will become more and more comparable to the composition of the least mineral scenario. Nevertheless, despite the more stringent regulation, optimum calving age and weight will remain within the range as described in Table 4.

## Conclusion

The optimal rearing strategy was not sensitive for measures as the MINAS regulation or the use of least mineral rations.

Based on the results, a reduction of farm mineral surpluses by a decrease in number of heifers is limited due to its relative small impact on mineral losses per hectare. For a more effective reduction of farm mineral losses, other options such as adaptation of the feed ration and reduction in nitrogen fertilisation on grassland (Teenstra, 1997, Aarts *et al.*, 1999) should be considered. At farm scale a combination of all measures will be necessary to meet the targets for the nutrient losses set by the Dutch government.

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