An Approach to Nutrient Management on Dairy Farms

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ABSTRACT

In the European Union, groundwater should contain less than 50 mg of nitrate/L. Individual countries have developed alternative strategies for phosphorus (P). In The Netherlands, regulations based on P limited the amount of manure applied per hectare. A more balanced P supply to the land has been achieved by transport of manure from surplus to deficit regions. Costs of processing of manure to pellets appeared to be (too) high. In animal production experiments, lowering the P content of concentrates and mineral supplements reduced P losses without an adverse effect on production. In addition to the European guideline for nitrate, ammonia volatilization should be reduced by 50 to 70%. Management practices for reducing nitrogen (N) losses were studied with a farm model, developed at PR. A combination of a more efficient use of fertilizer N, restricted grazing, and a more balanced diet, and, to a lesser extent, higher milk production per cow resulted in considerable reductions in nitrate leaching. The application of slurry by injection diminishes the ammonia volatilization at farm level by almost 50%. This technique has become obligatory, and is only allowed during the growing season. Other techniques, like low emission housing and covering of slurry storage have relatively high costs. Starting in 1998, farmers have to keep a record of nutrients on a balance sheet. A tax will be imposed on surpluses of N and P. This new instrument replaces the regulations based on P. To further improve efficiency of use of N and P, farmers have the nutrient balance sheet available as an integrated management tool. Urea content in bulk milk has been introduced as a new indicator for the utilization of N in the diet. Also, fertilizer applications are improved. Furthermore, an experimental farm was set up to integrate all available expertise and analyze the resulting nutrient flows and farm performance.

(**Key words**: nutrient, management, dairy farming)

Abbreviation key: **MUN** = milk urea N.

INTRODUCTION

In the European Union, reduction of nutrient losses in animal husbandry is of major concern. Therefore, goals for limiting losses of minerals to the ground and surface water have been imposed, and measurements to reach these goals have been suggested. However, individual countries have developed alternative routes and take additional measures to deal adequately with nutrient losses.

Dairy farming in The Netherlands is intensive. Nitrogen and P are considered the most important nutrients to be controlled. The European guideline for N (less than 50 mg of nitrate/L in the groundwater) is in use. In addition, ammonia volatilization (emission) in agriculture should be reduced by 50 to 70% by the year 2000 compared to the calculated level of volatilization in 1980. For P, the balance between supply and utilization by plants should be restored (14).

From 1984 to 1995 the main emphasis was on generic measures to reduce nutrient losses. From 1995 on, environmental policies are based on stimulating the individual farmer to increase the efficiency of nutrient use, as described by the Ministry of Agriculture, Nature Management and Fisheries (14). The plan is to introduce or upgrade 'good farming practices.' As a main management tool, a nutrient balance sheet has been developed.

This article focuses on the methodology of nutrient management in The Netherlands. Ways of reducing N and P surpluses and increasing the efficiency of use of N and P are outlined. In this context, the recent introduction of a measure for urea in bulk milk [milk urea nitrogen (**MUN**)] as an indicator for the utilization of N in the diet will be discussed.

All available techniques and knowledge have been integrated in a new farm setup. The performance of this experimental farm is described.

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NATIONAL MANURE REGULATIONS

The amount of manure produced from cattle, poultry, and pigs in The Netherlands is about 80 million tons/yr. In the 1980s environmental policy discussions resulted in the establishment of organizational structures and the introduction of several generic measures to reduce nutrient losses. Regulations limit the amount of manure produced (14). A cow, calf, and heifer are assumed to produce phosphate (P_2O_5) on average per year at 41, 9, and 18 kg, respectively. A pig was assumed to produce 7.4 kg of P_2O_5/yr. In addition, a manure production quota has been assigned to each farm (e.g., for a grassland farm, quota = number of ha × 125 kg of P_2O_5). If a farmer exceeds this quota, he has to pay a levy over the produced surplus on a yearly basis. In addition, the amount of manure (produced, bought, or both) to be applied on the land has been restricted. On grassland, until 1998, at most 150 kg of P_2O_5/ha from manure was allowed to be applied; on maize land and on arable land 110 kg of P_2O_5 was allowed.

Since 1995, the Dutch policy on manure and ammonia moves from a generic towards a farm-oriented approach. The nutrient balance sheet is to become the cornerstone of mineral management in agriculture in The Netherlands. On this sheet, the imports, exports, and surpluses of minerals, such as N and P, are recorded at the farm level (as an example, see Table 1). For all farms, the balance sheet is meant as a management tool. But for intensive dairy farms, this balance sheet is also a tool to declare surpluses. Starting in 1998, dairymen are required to achieve an acceptable nutrient balance for their farm operations. Surpluses above an allowable standard will be taxed. The previously mentioned levy on manure production above the assigned P_2O_5 quota will no longer be in use.

MANAGEMENT OF NITROGEN

Various groups of farmers have already collected data on N and P surpluses for several years. It appeared that large variations existed between dairy farms (21). Results show that the largest import of N on the farm comes from concentrates and fertilizers. However, N losses at the farm level can be reduced by modifications in the management of the dairy operation (3). Management practices that influence the N losses on a dairy farm were studied (8, 22). These management factors were studied with the PR farm model (20) to assess their contribution to the reduction of mineral losses at the farm level. Computations were performed with a set of simulated farms. A combination of a decreased use of fertilizer N, restricted grazing, and a low N diet, and, to a lesser extent, a lower stocking rate due to higher milk yields, resulted in considerable reductions of nitrate leaching to groundwater. Slurry application by injection diminished ammonia volatilization at the farm level by almost 50% (10). Higher milk yields and a lower N application reduced ammonia volatilization somewhat further. Low emission techniques in housing and covering of slurry storages were less effective and cost efficient. For example, the yearly cost of reducing the N surplus by 1 kg on the farm by means of slurry injection is \$0.5 to \$5, but by means of covering the slurry storage with a roof \$10 to \$20 (stores are only filled during some months of the year). The use of a straw crust as cover is economically more attractive but is not allowed. Modifications of the housing system require even larger investments than covering the slurry storage with a roof (22). The effectiveness of various practices is depicted in Figure 1. The variation shown for each management practice is mainly caused by differences in the farm situation.

Because slurry application by injection is of major importance in reducing the ammonia volatilization, slurry injection has become obligatory on all soils in The Netherlands (14). Various machines have been developed to inject slurry into the soil or deposit the slurry on top of the soil between the grass. Also, application of manure to the land is only allowed during certain periods of the year (in the growing season). Covering of slurry storage built after 1987 is required as well.

IMPROVING EFFICIENCY OF NITROGEN USE

Feeding

Sophisticated protein evaluation systems may provide a basis for the farmer to optimize protein intake and to reduce avoidable losses of nitrogen. Within the system in use in The Netherlands—the so-called DVE-OEB system (18)—the requirements and the supply of protein are expressed as DVE: the true protein digested in the small intestine. In addition, the OEB value (the ruminally degraded protein, RDP, balance) indicates the losses of N in the rumen. An OEB value above zero indicates a surplus of RDP relative to energy, which means that there is a potential loss of N. If the OEB value is below zero, there is a shortage of RDP relative to energy, which means that microbial protein synthesis is possibly impaired. In dairy cows, 70 to 80% of the N excreted in the

TABLE 1. Import of N and P_2O_5 to, export from, and the remaining surplus on a dairy farm: an example for a farm with 25 ha of grassland, 5 ha of maize, 55 dairy cows, and 7.500 kg of milk per cow

	N (kg/ha)			P_2O_5 (kg/ha)		
	Import	Export	Surplus	Import	Export	Surplus
Concentrates	90	...		43	...	
Fertilizer	230	...		17	...	
Manure	...	...		...	...	
Roughages	34	...		12	...	
Cattle	...	13		...	9	
Milk	...	76		...	28	
Other	1	...		...	...	
Total	355	89	266	72	37	35

urine is in the form of urea (2). The concentration of urea in blood, milk, and urine is closely related (6, 15). Hof et al. (5) and Schepers and Meijer (17) studied the value of MUN as a tool to monitor the utilization of total dietary N. These studies showed that MUN was inaccurate for evaluating the utilization of dietary protein. However, these studies also revealed a high correlation between OEB and MUN in bulk milk samples. From these studies, it is concluded that determination of the MUN in bulk milk on a regular basis can be used to monitor the OEB value of the diet in order to minimize the losses of N that occur in the rumen.

Meijer et al. (12) observed a large variation in the intake of OEB between individual cows within a herd, mainly because of variation in roughage intake. To ensure that the intake of OEB of each cow within the herd is at least larger than zero, the diet of group fed cows must contain approximately 300 OEB, which corresponds with a MUN of 90 to 135 mg/kg. This recommendation compares reasonably well with figures obtained from other European countries.

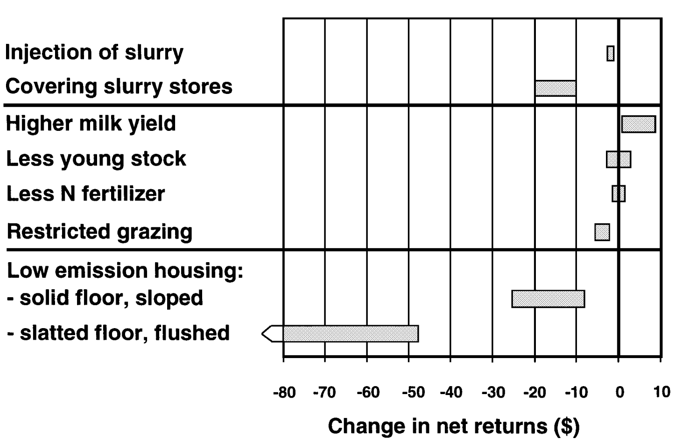

Figure 1. Effect of various management practices on net returns when the N surplus is reduced by 1 kg.

Recently, the dairy industry has started to determine the MUN of the bulk milk in each batch of milk collected at the farm as a service for the farmer. The farmers are informed weekly about the MUN in the bulk milk of the five most recent batches, providing an opportunity to monitor the OEB of the diet. High (more than 135 mg/kg) or low concentrations of MUN (less than 90 mg/kg) during 3 or more consecutive batches indicate an excess or shortage of OEB, respectively. This problem can be corrected by adjusting the OEB in the diet. However, when cows are kept in different feeding groups, one figure for MUN obtained from bulk milk samples only will not be sufficient to make proper adjustments of OEB in the diets. Monitoring the MUN in samples of individual cows has also limited value (see Figure 2), due to the large variation among and within cows (5, 17). Schepers and Meijer (17) showed that evaluation of OEB was accurate when the mean MUN of individual samples was based on feeding groups that consisted of at least 10 cows. Currently, our research station is making an effort to examine the feasibility of a monitoring system based on the mean MUN of individual samples from cows of different feeding groups.

Fertilizing

Efficiency of N use is also increased by the introduction of an improved N fertilizer application (23). Included in the advice on grassland are the soil N supply, the target yield per cut, and the actual weather conditions. Reduced N inputs result in a slightly less yield and in a reduced protein content in the grass.

MANAGEMENT OF PHOSPHORUS

In some regions of the country, the restriction on the amount of P_2O_5 from manure to be used per

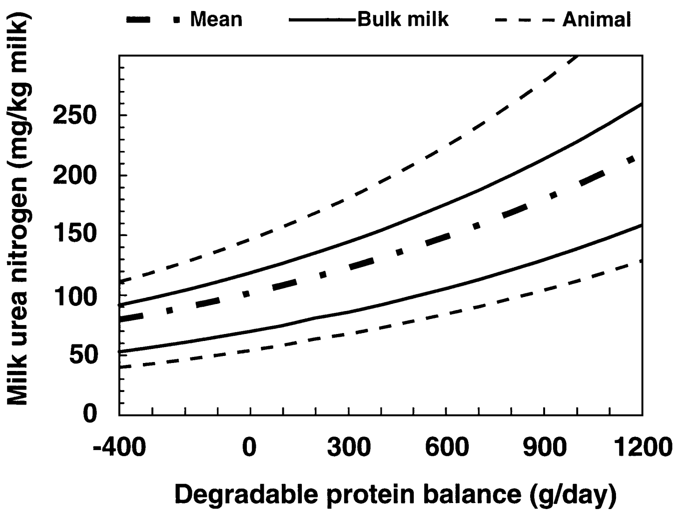

Figure 2. Relation between milk urea nitrogen and the degradable protein balance in the diet.

hectare caused a large surplus of manure, especially in those regions where pig and poultry farming are concentrated. Farmers need to dispose of the surplus manure by sale contracts. Manure cooperatives transport this manure from surplus to deficit areas. Manure processing plants have been built to transform surplus manure into marketable products. The produced manure pellets may be used for nonagricultural purposes and in other countries. Of the total amount of manure produced in the country of 80 million tons in 1996, about 15 million tons were distributed to arable land, 0.8 million tons were processed, and 0.8 million tons were exported. The plan was to multiply the manure-processing capacity. However, the costs of processing manure to pellets appeared to be (too) high (19).

IMPROVING EFFICIENCY OF PHOSPHORUS USE

Feeding

Feeding excess P is a major source of the surplus P on the nutrient balance. Therefore, more accurate feeding of P to dairy cows is required to reduce this surplus. A 5-yr farm system development research program on the nutrition and management of a high-yielding dairy herd (11) indicates that major progress can be made in the reduction of excess P in the diets of dairy cows. Measures such as eliminating additional P in compound concentrates and mineral preparations, increased milk production, replacing compound concentrates by low P feeds (e.g., ground maize ear silage), and lower concentrations of P in forages resulted in a considerable reduction of excess P in diets of dairy cows and in P intake close to the current requirements. A daily excess P intake of 16 g/cow during 1993 to 1994 was reduced to virtually zero by 1996 to 1997 (Figure 3) without affecting milk yield per cow. This accounts for a lower yearly intake of almost 6 kg of P/cow.

Recently, studies have been undertaken in the United States (25) to evaluate the current NRC recommendation for daily P intake in dairy cows. Also, the results of this study indicate that the practice of feeding phosphorus in excess of the recommendation is unnecessary. Preliminary results in The Netherlands even show that feeding 20% below the current Dutch requirements does not compromise animal performance (H. Valk, 1998, personal communication).

Fertilizing

A precise application of P fertilizer and manure to the field also increases the efficiency of the use of P. The fertilizer P recommendations on grassland are improved by considering the P status of the soil, a correct spreading of manure, and a better estimate of the yield (24).

NEW FARM SYSTEM

The focus of manure and nutrient management must be to optimize nutrient flow and utilization at every point within the total dairy farm system. This system was recently described by Grusenmeyer and Cramer (4). With this goal in mind, in 1990, a research farm named De Marke was built for 80 dairy cows. The farm is located on sandy soil and is completely devoted to the analyses and integration of nutrient flows (1). Average N losses on this farm were planned to be reduced by 70%, and the P surplus should be zero. At this farm, besides the environmental regulations, all management practices are directed towards reducing nutrient losses. In Figures 4 and 5 the effect of strict nutrient management on P in the soil and nitrate in the groundwater is illustrated subsequent to 1990. The cost of the environmental management practices is calculated to be approximately \$2.50/100 kg of milk, and milk returns are \$37.50/100 kg (9).

DISCUSSION AND CONCLUSIONS

To reduce nutrient losses, several approaches are possible. Activities and policies can be focused at a

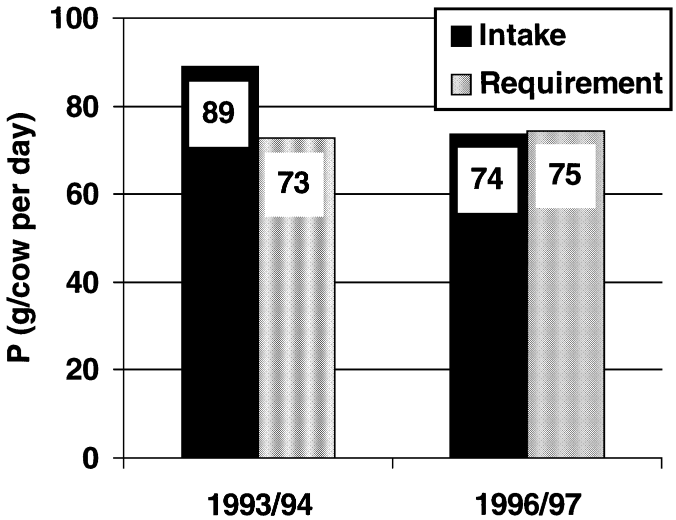

Figure 3. Phosphorus intake and P requirement of dairy cattle.

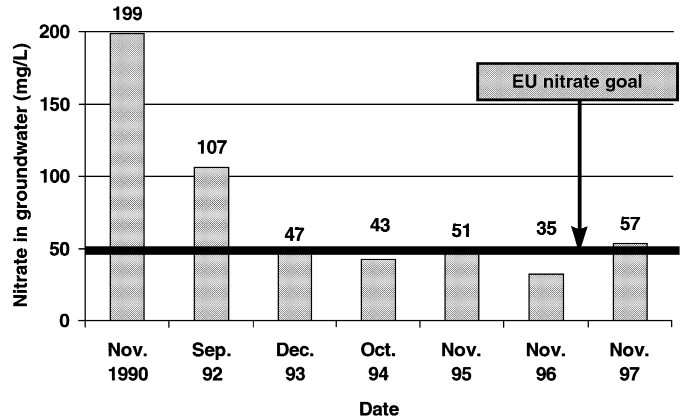

Figure 5. Average nitrate content in groundwater on research farm De Marke in different years.

national scale as well as at the farm level. In The Netherlands both approaches are combined to achieve a maximum result. At a national scale, transport of manure from surplus to deficit regions and manure processing plants have been stimulated. Also, general regulations are introduced that apply to all dairy farms. Examples are the covering of slurry storage, the injection of slurry into the soil and a maximum allowed amount of manure (P) per hectare.

Odor control as described by Miner (13) has not been a main issue concerning the dairy industry in The Netherlands. Nevertheless, slurry injection has considerably reduced the odor from manure to the environment and has been a positive and pleasant side effect of this low emission technique. Also the possibility of spreading pathogens by transporting manure (16) has not been a leading component in the discussions. The reduction of nutrient losses was the principal goal in all schemes. But disease control is surely becoming a very important factor in dairy husbandry these days.

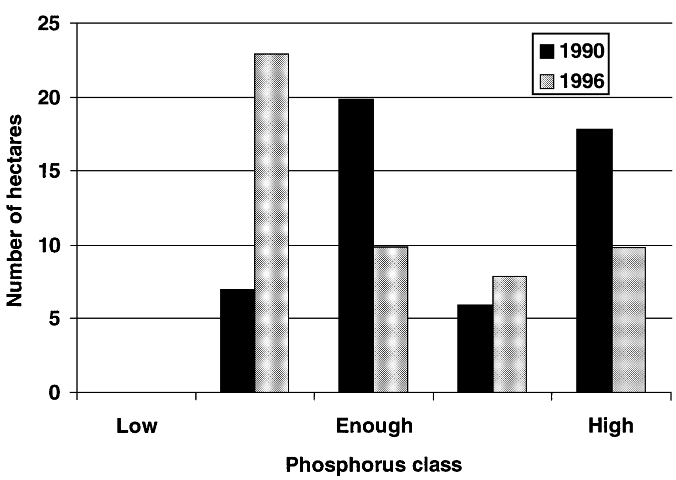

Figure 4. Classification of the soil of research farm De Marke based on the amount of P in the soil.

Another approach is at the farm level. Large variations exist in the fertility of soils and in the intensity of grassland and crop farming. Also, various management practices and programs are available to reduce nutrient losses (3, 7). These practices can be applied to specific farm situations. Therefore, environmental goals are set at the farm level and the farmer is given the responsibility to reach these goals. With this approach the farmer can choose a set of management practices that fit the particular farm business. The nutrient balance sheet is developed as a system to make this approach possible. Emphasis is gradually shifting from general regulations towards the use of the nutrient balance as a central tool in nutrient management. To meet future environmental goals, research efforts are still needed. In this context, whole farm systems are studied as prototype farms, like the experimental farm De Marke.

IMPLICATIONS

A reduction in nutrient losses has been achieved by the introduction of policies at a national level, such as the transport of manure from surplus to deficit regions and the required injection of slurry into the soil. However, to further reduce the loss of nutrients, adjustments in daily management by farmers are essential. Various management practices are available to increase the efficiency of the use of N and P at the farm level. Especially, fertilizing and feeding practices need to be optimized. A nutrient balance sheet, the urea content in bulk milk, and improved fertilizer applications are tools to assist dairy producers in obtaining an acceptable nutrient balance. Applying the national regulations and good farming practices at an experimental farm showed that leaching of nitrate to the groundwater and accumulation of phosphorus in the soil were considerably reduced.

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