

Clinical effects of feeding low dietary phosphorus levels to high yielding dairy cows

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IN most intensive dairy systems, the input of phosphorus exceeds the output which may lead to phosphorus accumulation and cause environmental problems (Van der Meer and Van der Putten 1995). The input of phosphorus can be reduced by decreasing the amount of phosphorus fertiliser used and purchasing feeds with low phosphorus contents. As a result, however, diets for dairy cows may contain less phosphorus than required for optimal production. Little is known about the effects of low dietary phosphorus supply on feed intake, milk yield, reproduction and health. Therefore, a two-year experiment was carried out to evaluate the effects of feeding low amounts of phosphorus to high yielding dairy cows.

Twenty-four high yielding dairy cows, about 90 days after parturition and housed in tied stalls, were allocated to two groups of nine and one group of six cows on the basis of calving date, milk yield and milk composition. One group of nine cows was fed at 67 per cent (P_{67}) of the phosphorus requirement recommended by the Dutch Committee on Mineral Nutrition (NCMN 1973). The other group of nine cows was fed at 80 per cent (P_{80}) of the recommended phosphorus requirement and the group of six cows was fed at 100 per cent (P_{100})

of the recommended phosphorus requirement. The recommendation system used the following equation to estimate the phosphorus requirement of dairy cows:

$$\text{Total phosphorus (g/day)} = 0.042 \times \text{LW} + 1.5 \times \text{FCM}$$

where LW is liveweight (kg) and FCM is 4 per cent fat-corrected milk (kg/day).

During the lactation period, the actual phosphorus content in the diets was 2.3, 2.6 and 3.3 g/kg dry matter for P_{67} , P_{80} and P_{100} respectively. All cows received a mixed basal diet containing grass silage (or dried grass), maize silage, pressed beet pulp and a low phosphorus concentrate mixture. In addition to the basal diet, cows received 500 g concentrate mixture with a variable phosphorus content according to the experimental group, per kg milk above the amount of milk they could produce from the basal diet. Different phosphorus levels in the concentrate mixtures were realised using feed grade monosodium phosphate. The amount of concentrate mixture was adjusted weekly on the basis of actual milk yield and milk composition. The experiment started in the fifth week of 1996 and lasted for 21 months. Other results will be published elsewhere.

Dry matter intake and milk yield were measured daily and the milk composition (fat, protein and lactose) was measured once a week. Blood and milk samples were taken incidentally and analysed for inorganic phosphorus (P_i) content (Quinlan and Desesa 1955). Feed intake and milk performance parameters were analysed as a block design with block and dietary phosphorus levels as treatments.

Nearly five months after the start of the experiment, the milk yield and milk lactose content of four of the nine cows in group P_{67} decreased abruptly from 17.3 kg milk and 4.33 per cent lactose in week 23 to 6.7 kg milk and 3.77 per cent lactose in week 28 (Fig 1c). As a result of this observation, the average milk yield of all cows in that group was found to be lower com-

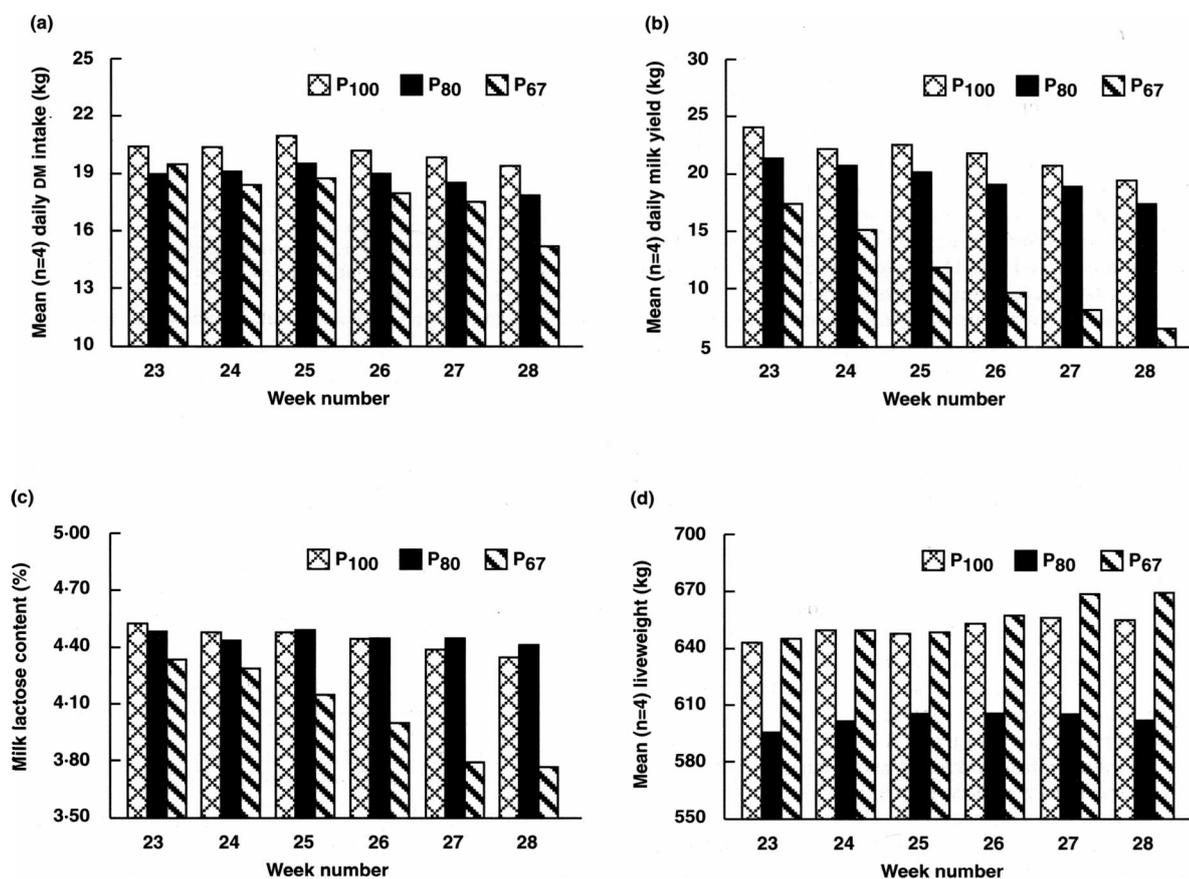


FIG 1: Mean daily (a) dry matter (DM) intake (kg), (b) milk yield (kg), (c) milk lactose content (%) and (d) liveweight (kg) of four comparable cows in each treatment group during the five weeks before drying off

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pared with the yields in the two other groups (Table 1). Although the differences were substantial (22.1 and 21.9 versus 18.8 kg milk/day), they were not significant due to the relatively high standard error of the mean. However, when the four affected cows in P_{67} were compared with four cows in the same stage of lactation in the other treatments, the differences became highly significant ($P < 0.01$). Fig 1 shows the mean results of these four comparable cows per treatment from week 23 to week 28. Except in week 28, where forage allowance was reduced for the four cows on P_{67} , dry matter intake hardly differed between the treatments. However, milk yield and milk lactose content decreased for cows on P_{67} , while the liveweight of the four affected cows on that treatment increased more than for the other treatments. The four affected cows were dried off after week 28, which was six to 22 weeks before the intended drying off date.

The P_i concentration in blood plasma of the four cows on P_{67} as measured in week 26, was 1.8 mmol/litre, indicating no sign of phosphorus depletion (Rodehutsord and others 1994). This relatively high blood plasma P_i concentration probably resulted from improved phosphorus status caused by the fall in milk yield without a concomitant decrease in dry matter and phosphorus intake. This may immediately have increased blood plasma P_i (Rodehutsord and others 1994). In contrast to phosphorus in the blood plasma, phosphorus in the milk of the four cows on P_{67} varied between 0.55 and 0.89 g/litre which was much lower than observed in the other groups (0.9 to 1.0 g/litre).

Since lactose and sodium ions (Na^+) are the most important osmotic components in milk and, thus, in regulating milk volume (Mephram 1988), low milk lactose contents are inversely associated with high Na^+ contents in milk. In this study, the Na^+ content in milk increased to 1.6 g/litre, compared with normal levels of about 0.4 g Na^+ /litre (NCMN 1973). It could not be concluded which of the two processes, lactose or Na^+ secretion in milk, was first influenced by 'phosphorus deficiency'. It is unknown whether the decrease in lactose synthesis in the intercellular fluid of mammary cells is a result of reduced activities of enzymes involved in the lactose synthetase-catalysed reaction between glucose and uridine-diphosphate-galactose (Mephram 1988). Otherwise, the entry of glucose into the cells is probably inhibited by a reduced number of active glucose transporters causing a reduction in milk yield after fasting and refeeding (Mephram 1988). This mechanism of reducing milk yield after fasting and refeeding could be involved in the present study where irreversible reactions on milk yield and milk lactose production were observed (Fig 1). However, the role of phosphorus in activating glucose transporters is unclear.

After nearly two years on diet P_{80} postparturient haemoglobinaemia and haemoglobinuria was observed in one high yielding dairy cow, 14 days after calving. Four other cows on the same phosphorus treatment and at the same lactation stage did not show any signs of haemoglobinuria. The P_i concentration in the blood plasma of the affected animal, sampled two days after the first signs of haemoglobinuria, was 1.3 mmol/litre, which was low compared with the range of P_i levels of 1.3 to 2.5 mmol/litre described by Rowlands and others (1977). The Dutch Committee on Mineral Nutrition (1973) stated that a level of blood P_i of 1.1 mmol/litre can be measured without any signs of hypophosphataemia. Thus, although a low level of P_i of 1.3 mmol/litre was measured in this study, it was not a clear indication of hypophosphataemia based on the range of normal observed levels. However, the P_i in the blood plasma may have increased during the two days between the first signs of milk reduction and blood sampling. A blood transfusion increased the dry matter intake and health status (that is, activity) of the cow, within two days. However, the cow lost all its body condition and was dried off within a week.

Phosphorus deficiency can reduce the adenosine triphosphate (ATP) content in red blood cells, influencing the structure

TABLE 1: Dietary phosphorus content and the effects on the mean dry matter intake, milk yield and milk composition of feeding 100 per cent (P_{100}), 80 per cent (P_{80}) and 67 per cent (P_{67}) of the recommended phosphorus requirement (NCMN 1973) during the five weeks before drying off

Treatment	P_{100}	P_{80}	P_{67}	Standard error	Significance difference
Dietary phosphorus (g/kg dm)	3.3	2.6	2.3	—	
DM (kg)	19.4	19.1	18.8	1.1	NS
Net-energy (kVEM)	17.4	17.1	16.8	1.2	NS
Protein (DVE)	1580	1538	1512	167	NS
Yield (kg/day)					
Milk	22.1	21.9	18.8	3.1	NS
FPCM	23.6	23.1	20.4	3.2	NS
Milk composition (g/kg)					
Fat	44.9	43.6	45.7	2.7	NS
Protein	36.4	35.6	36.8	1.7	NS
Lactose	44.6	44.9	43.4	0.1	NS

kVEM 6.9 MJ net-energy-lactation according to van Es (1978), DVE true protein digested in the small intestine (Tamminga and others 1994), NS Not significant, FPCM Fat protein corrected milk, DM Dry matter

and function of the cell, increasing fragility and haemolysis, which may lead to haemoglobinuria (Wang and others 1985). Jubb and others (1990) observed a haemoglobinuria in dairy cows without dietary phosphorus deficiency. They hypothesised that hypophosphataemia occurs in the early postparturient period after recovery from preparturient ketoacidosis caused by underfeeding in late pregnancy. In the repletion period, circulating oxidants may cause erythrocyte damage which may predispose to hypophosphataemia. In this study, during the non-lactating period, the cow was fed slightly more than the energy and protein requirements and at 80 per cent of the phosphorus requirement (NCMN 1973) recommended for that period. On the basis of the actual dry matter intake and liveweight growth measurements during the preparturient period, the relevant cow was not underfed. It is likely that this occurrence of haemoglobinuria was caused by the process described by Wang and others (1985).

In conclusion, rations for high yielding dairy cows should not contain phosphorus contents lower than 3.0 g/kg dry matter.

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