

## DIETARY CATION-ANION DIFFERENCE (DCAD) OF FORAGE SPECIES IN NORWAY

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**Abstract.** *The difference between cation and anion concentrations (DCAD) is an important property when assessing feed for dry cows in order to avoid hypocalcaemia following calving. Low values of DCAD may reduce the risk of milk fever. DCAD is often calculated as the difference between the cations  $\text{Na}^+$  and  $\text{K}^+$  and the anions  $\text{Cl}^-$  and  $\text{S}^{2-}$ . Research, particularly in Canada, has shown that chlorine fertilization may reduce DCAD, even to negative values, and that there might be differences in DCAD between commonly used grass species. In a research project in Central Norway the effect on DCAD of different rates of chlorine fertilizer application were investigated. Fertilization with 70, 140 or 210 kg  $\text{Cl}^-$  per hectare in calcium chloride did significantly reduce DCAD in forage from leys dominated by timothy and meadow fescue. Pure stands of seven grass species were fertilized with either 0 or 140 kg  $\text{Cl}^-$  per hectare in spring. The highest values of DCAD were found in perennial ryegrass and festulolium. Forage with low DCAD was given to dairy cows, and the pH in urine was measured to assess the risk of milk fever.*

**Keywords:** anions, cations, DCAD, mineral difference, urine pH.

### INTRODUCTION

Milk fever is the second most common production disease in Norwegian dairy production. About 7% of the calvings in Norway lead to milk fever, which cost more than 50 million NOK. In the sixties Norwegian scientists showed that anions in the feed could reduce the risk of milk fever [1]. Rations with low values of DCAD acidify urine, this acidification hinders calcium reabsorption. Calcium losses through urine activate the homeostatic regulation of calcium by increasing bone mobilization and intestinal absorption [2]. But anionic salts are not very tasty, it may thus be difficult to get the cows to eat the products. The most common formula of DCAD is:  $([\text{Na}^+]+[\text{K}^+]) - ([\text{Cl}^-]+[\text{S}^{2-}])$  in  $\text{mEq kg}^{-1}$  DM. The contents of K and Cl are easier to manipulate than the contents of Na and S. To prevent hypocalcaemia, the DCAD in rations fed to non-lactating dairy cows 1-2 weeks before calving should be around  $-50 \text{ mEq kg}^{-1}$  [3]. Research has shown that chlorine fertilization may reduce DCAD, even to negative values, and that there might be differences in DCAD between commonly used grass species [3]. The results indicated an economically optimal rate in the spring between 78 to 123 kg  $\text{Cl ha}^{-1}$ . The DCAD decreased with advancing stages of development of the grasses. In a research project in Central Norway the effects of chlorine fertiliser application on DCAD in different types of grassland were investigated. Forage from chlorine fertilised meadows were fed to cows the last two weeks before calving, and the urine pH was measured.

### MATERIALS AND METHODS

A fertiliser experiment was established in young leys dominated by timothy and meadow fescue at three sites in Central Norway in 2012, with three replicates. The experimental plots (2 m x 7 m) were fertilised with either a 'normal' amount of potassium (according to soil analyses) or half the level of 'normal'. The application of nitrogen and phosphorus in spring was 120 kg and 17 kg per hectare, respectively. At each level of potassium application, the following amounts of chlorine were given as calcium chloride in spring, in three replicates: 0, 70, 140 and 210 kg  $\text{ha}^{-1}$ . The experiments were harvested in 2012 and 2013. The first cut was taken about two weeks after start of heading of timothy.

A similar field experiment (small plots, three replicates) was established in Central Norway in 2013. Instead of four levels of chlorine fertilization, the treatments were: 0 kg  $\text{Cl}$ , 140 kg  $\text{Cl ha}^{-1}$  in either calcium chloride or magnesium chloride and 280 kg in calcium chloride. The levels of potassium were either 'normal' (according to soil analyses) or 2/3 of 'normal' amount of potassium. This experiment was harvested in two years.

On two experiments established on two year old leys, dominated by timothy and meadow fescue, 14 kg Cl ha<sup>-1</sup> in calcium chloride was applied either at normal time in spring, or one or two weeks after normal time (small plots, three replicates). The experiments were harvested only one year.

In another type of experiment pure stands of seven grass species were established at three sites in 2012, and fertilised and harvested in 2013 and 2014. The species were: Timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* L.), cocksfoot (*Dactylis glomerata* L.), smooth brome grass (*Bromus inermis* Leyss.), reed canary grass (*Phalaris arundinacea* L.), perennial ryegrass (*Lolium perenne* L.) and festulolium (*Festulolium*). The plots were fertilised with either zero or 140 kg Cl in calcium chloride in spring on main plots. The grasses were seeded on small plots, with two replicated. The first cut was harvested about two weeks after start of heading of timothy for all species, except smooth brome grass and reed canary grass, which were cut one week later.

Grass samples from all experiments were analysed for content of minerals. Dietary cation-anion difference (DCAD), as mEq kg<sup>-1</sup> DM, was calculated according to the following equation: ((Na/22.9+K/39.1) – (Cl/35.5+S x 2/32.07))\*1000. The contents of Na, K, Cl and S are given in g kg<sup>-1</sup> DM. Feed quality was estimated by NIRS in one replicate in 2012 and 2013.

In 2012 and 2013 mini silage bales were produced at the first cut from four different meadows, three of them were 1-2 years old dominated by timothy and meadow fescue. And one meadow was older, with also other grasses. The meadows were fertilised in spring with about 140 kg ha<sup>-1</sup> Cl in chloride. The silage was fed to the cows, and urine pH was measured. Cows that did not get urine pH below 7 were given concentrate rich in anions.

Data from the fertiliser experiments (means for three replicates within year and site) were analysed according to an ANOVA with a split-plot design. The fixed factor potassium fertilization rate was on main plots and the fixed factor chlorine application rate on sub-plots. Year (1 and 2) and site (1, 2 and 3) were included as random factors in the model. For the trials comparing different species, means for two replicates within each of three sites in one experimental year were subjected to ANOVA. These data were also analysed as a split-plot, with chlorine application rate on main plots and grass species on sub plots. Site was included in the model as a random effect.

Table 1

**Dietary cation-anion difference (DCAD), content of minerals and dry matter yield at first cut.**  
**Effects of chlorine and potassium fertilisation on leys dominated by timothy and meadow fescue.**  
**Average of three field trials in two years.**

| K fert.                   | Cl fertilisation           | DM yield t ha <sup>-1</sup> | DCAD mEq kg <sup>-1</sup> DM | K g kg <sup>-1</sup> DM | Na g kg <sup>-1</sup> DM | Cl g kg <sup>-1</sup> DM | S g kg <sup>-1</sup> DM |
|---------------------------|----------------------------|-----------------------------|------------------------------|-------------------------|--------------------------|--------------------------|-------------------------|
| Low                       | 0                          | 7.3                         | 151                          | 16.7                    | 0.51                     | 7.5                      | 1.4                     |
|                           | 70 kg Cl ha <sup>-1</sup>  | 7.3                         | 83                           | 18.2                    | 0.74                     | 11.6                     | 1.4                     |
|                           | 140 kg Cl ha <sup>-1</sup> | 7.1                         | 52                           | 18.9                    | 0.72                     | 13.4                     | 1.3                     |
|                           | 210 kg Cl ha <sup>-1</sup> | 7.2                         | 43                           | 18.4                    | 0.78                     | 13.3                     | 1.4                     |
| Normal                    | 0                          | 7.2                         | 134                          | 19.3                    | 0.48                     | 10.5                     | 1.4                     |
|                           | 70 kg Cl ha <sup>-1</sup>  | 7.1                         | 110                          | 21.6                    | 0.64                     | 13.5                     | 1.4                     |
|                           | 140 kg Cl ha <sup>-1</sup> | 7.3                         | 81                           | 21.2                    | 0.46                     | 14.1                     | 1.4                     |
|                           | 210 kg Cl ha <sup>-1</sup> | 6.9                         | 64                           | 21.7                    | 0.48                     | 15.0                     | 1.4                     |
| P potassium fertilisation |                            | ns                          | ns                           | ns                      | ns                       | 0.01                     | ns                      |
| P chlorine fertilisation  |                            | ns                          | 0.00                         | 0.05                    | ns                       | 0.00                     | ns                      |
| P Cl fert. * K fert.      |                            | ns                          | ns                           | ns                      | ns                       | ns                       | ns                      |

## RESULTS AND DISCUSSION

Application of potassium and calcium chloride did not affect the dry matter yield in the fertilisation experiments (Table 1). The DCAD and the contents of K, Na and S were not significantly influenced by the level of potassium fertilisation. Application of chlorine did lower the DCAD, and increased the

content of K and Cl. The difference in DCAD between an application of 140 and 210 kg Cl ha<sup>-1</sup> was not significant. It was expected that a higher application rate of potassium should increase the content of potassium in the plants, but even if the average K content at the low level was 3 g kg ha<sup>-1</sup> lower than at the normal level, the difference was not significant. Why the chlorine fertilisation affected the content of potassium and why the content of chlorine was influenced by the level of potassium fertilisation is not easy to explain.

There were no significant effects of potassium and chlorine fertilisation on the content of crude protein, water soluble carbohydrates (WSC) and indigestible fibre (iNDF) and feed unit concentration (Table 2). For all treatments the quality parameters were quite low. The differences in fibres (NDF) and organic matter digestibility (OMD) were quite ambiguous, and not easy to explain.

Table 2

**Contents of crude protein, fibre (NDF and iNDF) and water soluble carbohydrates (WSC), digestibility of organic matter (OMD) and feed units per kg DM (FU/kg DM) in the first cut. Effects of chlorine and potassium fertilisation on leys dominated by timothy and meadow fescue. Average of three field trials in two years.**

| K fert.                   | Cl fertilisation           | Crude prot. g/kg DM | NDF g/kg DM | iNDF g/kg NDF | WSC g/kg DM | OMD % | FU/kg DM |
|---------------------------|----------------------------|---------------------|-------------|---------------|-------------|-------|----------|
| Low                       | 0                          | 113                 | 609         | 209           | 111         | 64    | 0.78     |
|                           | 70 kg Cl ha <sup>-1</sup>  | 124                 | 607         | 199           | 101         | 65    | 0.75     |
|                           | 140 kg Cl ha <sup>-1</sup> | 100                 | 638         | 204           | 112         | 61    | 0.70     |
|                           | 210 kg Cl ha <sup>-1</sup> | 105                 | 619         | 196           | 107         | 63    | 0.77     |
| Normal                    | 0                          | 111                 | 602         | 202           | 114         | 64    | 0.74     |
|                           | 70 kg Cl ha <sup>-1</sup>  | 116                 | 615         | 218           | 105         | 63    | 0.73     |
|                           | 140 kg Cl ha <sup>-1</sup> | 105                 | 617         | 218           | 111         | 62    | 0.72     |
|                           | 210 kg Cl ha <sup>-1</sup> | 111                 | 619         | 212           | 99          | 63    | 0.72     |
| P potassium fertilisation |                            | ns                  | 0.04        | ns            | ns          | ns    | ns       |
| P chlorine fertilisation  |                            | ns                  | 0.05        | ns            | ns          | 0.05  | ns       |
| P Cl fert. * K fert.      |                            | ns                  | ns          | ns            | ns          | ns    | ns       |

Table 3

**Dietary cation-anion difference (DCAD), content of minerals and dry matter yield at first cut. Effects of calcium chloride, magnesium chloride and potassium fertilisation on leys dominated by timothy and meadow fescue. Average of one field trial in two years.**

| K fert.                   | Cl fertilisation                        | DM yield t ha <sup>-1</sup> | DCAD mEq kg <sup>-1</sup> DM | K g kg <sup>-1</sup> DM | Na g kg <sup>-1</sup> DM | Cl g kg <sup>-1</sup> DM | S g kg <sup>-1</sup> DM |
|---------------------------|-----------------------------------------|-----------------------------|------------------------------|-------------------------|--------------------------|--------------------------|-------------------------|
| Low                       | 0                                       | 6.2                         | 93                           | 7.9                     | 3.5                      | 6.9                      | 1.1                     |
|                           | <sup>1</sup> 140 kg Cl ha <sup>-1</sup> | 5.9                         | -14                          | 7.6                     | 3.2                      | 10.1                     | 1.0                     |
|                           | <sup>2</sup> 140 kg Cl ha <sup>-1</sup> | 6.1                         | 24                           | 8.1                     | 3.9                      | 10.0                     | 1.1                     |
|                           | <sup>1</sup> 280 kg Cl ha <sup>-1</sup> | 5.5                         | 6                            | 8.0                     | 4.8                      | 11.8                     | 1.2                     |
| Normal                    | 0                                       | 7.1                         | 90                           | 11.3                    | 3.0                      | 9.2                      | 1.1                     |
|                           | <sup>1</sup> 140 kg Cl ha <sup>-1</sup> | 6.7                         | 39                           | 12.0                    | 3.4                      | 12.3                     | 1.1                     |
|                           | <sup>2</sup> 140 kg Cl ha <sup>-1</sup> | 6.6                         | 33                           | 11.8                    | 3.2                      | 12.2                     | 1.0                     |
|                           | <sup>1</sup> 280 kg Cl ha <sup>-1</sup> | 6.3                         | 6                            | 11.0                    | 3.1                      | 12.4                     | 1.0                     |
| P potassium fertilisation |                                         | 0.00                        | 0.00                         | 0.00                    | 0.00                     | 0.00                     | ns                      |
| P chlorine fertilisation  |                                         | ns                          | 0.00                         | ns                      | 0.06                     | 0.00                     | ns                      |
| P Cl fert. * K fert.      |                                         | ns                          | ns                           | ns                      | 0.03                     | ns                       | ns                      |

<sup>1</sup>calcium chloride <sup>2</sup>magnesium chloride

Yield, DCAD and content of minerals for the field trial with another experimental plan than the trials presented in Table 1 are shown in Table 3. The DM yield was significantly larger at plots with a normal level of K application compared to a low level of K. But the DM yield was not influenced by either the amount or the type of chloride fertiliser. At the low level of potassium fertilisation low and even negative values of DCAD were obtained. The content of potassium was low, and was significantly higher at the normal level than at the low level of potassium fertilisation. The content of sodium was much higher than in the other experiments. There was no effect of chloride type on DCAD. Fertilisation with 280 kg Cl ha<sup>-1</sup> did not decrease DCAD compared to 140 kg Cl.

On two experiments the application of 14 kg Cl ha<sup>-1</sup> in calcium chloride was delayed one or two weeks after normal time. The postponed fertilisation did not significantly affect either the DCAD or the content of minerals.

There were significant differences in DCAD between the species, but there were no effects of chlorine fertilisation on DCAD in the different species on average of three field trials in the first year (Table 4). Without chlorine application the DCAD varied from 180 in reed canary grass to 347 in cocksfoot. When chlorine was applied the DCAD was about 150 in meadow fescue, cocksfoot and smooth brome grass. The lowest values were found in perennial ryegrass (69) and reed canary grass (36). In the second year the contents of minerals were analysed only for the treatment with 140 kg Cl ha<sup>-1</sup>. The differences in DCAD between the species were about similar to the first year. The grasses timothy, meadow fescue, cocksfoot and smooth brome grass had a DCAD of about 115. The values of perennial ryegrass, festulolium and reed canary grass were 83, 74 and 48, respectively. The differences in DCAD between species may partly be explained by differences in DM yield and time of heading in the first cut.

Table 4

**Dietary cation-anion difference (DCAD), content of minerals and dry matter yield at first cut.  
Effects of chlorine fertilisation on different species. Average of three field trials in one year.**

| Cl fert.                      |                | DM yield<br>t ha <sup>-1</sup> | DCAD<br>mEq kg <sup>-1</sup> DM | K<br>g kg <sup>-1</sup> DM | Na<br>g kg <sup>-1</sup> DM | Cl<br>g kg <sup>-1</sup> DM | S<br>g kg <sup>-1</sup> DM |
|-------------------------------|----------------|--------------------------------|---------------------------------|----------------------------|-----------------------------|-----------------------------|----------------------------|
| No<br>Cl fert.                | Timothy        | 7.2                            | 235                             | 19.3                       | 0.15                        | 6.8                         | 1.2                        |
|                               | Mead. fescue   | 6.5                            | 229                             | 23.1                       | 0.27                        | 9.9                         | 1.6                        |
|                               | Cocksfoot      | 5.9                            | 347                             | 23.9                       | 0.88                        | 7.8                         | 1.5                        |
|                               | S. brome grass | 7.4                            | 213                             | 16.8                       | 0.27                        | 5.8                         | 1.1                        |
|                               | Reed c. grass  | 6.4                            | 180                             | 19.4                       | 0.20                        | 8.1                         | 1.4                        |
|                               | P. ryegrass    | 6.2                            | 268                             | 21.1                       | 1.58                        | 8.9                         | 1.6                        |
|                               | Festulolium    | 6.4                            | 312                             | 25.2                       | 1.10                        | 9.1                         | 1.7                        |
| 140 kg<br>Cl ha <sup>-1</sup> | Timothy        | 7.0                            | 110                             | 19.9                       | 0.17                        | 12.3                        | 1.1                        |
|                               | Mead. fescue   | 6.7                            | 154                             | 24.6                       | 0.22                        | 14.4                        | 1.6                        |
|                               | Cocksfoot      | 5.4                            | 156                             | 28.0                       | 1.15                        | 18.3                        | 1.5                        |
|                               | S. brome grass | 7.0                            | 154                             | 18.7                       | 0.20                        | 10.1                        | 1.1                        |
|                               | Reed c. grass  | 6.9                            | 36                              | 20.4                       | 0.28                        | 13.9                        | 1.5                        |
|                               | P. ryegrass    | 6.5                            | 69                              | 23.6                       | 2.25                        | 19.6                        | 1.6                        |
|                               | Festulolium    | 6.6                            | 119                             | 27.2                       | 0.95                        | 17.7                        | 1.6                        |
| P chlorine fertilisation      |                | ns                             | ns                              | ns                         | ns                          | ns                          | ns                         |
| P species                     |                | ns                             | 0.00                            | 0.00                       | 0.00                        | 0.00                        | 0.00                       |
| P chlorine fert. * species    |                | ns                             | ns                              | ns                         | ns                          | 0.00                        | ns                         |

The forage quality presented in Table 5 relates to the second half of Table 4 (140 kg Cl ha<sup>-1</sup>). Because of a rather late first cut the quality of most species were quite low. An optimal feed unit concentration for non-lactating cows some weeks prior to calving is probably 0.75-0.80. In reed canary grass, which had the lowest DCAD (Table 4) the feed unit concentration was as low as 0.66 at the actual stage of development. And that is too low for dairy cow forage. Perennial ryegrass had a DCAD of 69 and feed unit concentration of 0.80.

Table 5

**Contents of crude protein, fibre (NDF and iNDF) and water soluble carbohydrates (WSC), digestibility of organic matter (OMD) and feed units per kg DM (FU/kg DM) in the first cut for seven grass species. Average of three field trials in the first year.**

| Cl fert.                      |               | Crude prot.<br>g/kg DM | NDF<br>g/kg DM | iNDF<br>g/kg NDF | WSC<br>g/kg DM | OMD<br>% | FU/<br>kg DM |
|-------------------------------|---------------|------------------------|----------------|------------------|----------------|----------|--------------|
| 140 kg<br>Cl ha <sup>-1</sup> | Timothy       | 85                     | 590            | 227              | 110            | 62       | 0.71         |
|                               | Mead. fescue  | 118                    | 583            | 184              | 116            | 67       | 0.78         |
|                               | Cocksfoot     | 102                    | 625            | 224              | 91             | 62       | 0.70         |
|                               | S. bromegrass | 84                     | 564            | 242              | 192            | 63       | 0.72         |
|                               | Reed c. grass | 91                     | 623            | 287              | 106            | 59       | 0.66         |
|                               | P. ryegrass   | 97                     | 548            | 175              | 153            | 70       | 0.80         |
|                               | Festulolium   | 110                    | 598            | 173              | 107            | 65       | 0.74         |
| P species                     |               | 0.03                   | 0.00           | 0.00             | 0.00           | 0.00     | 0.00         |

As shown in Table 6 the DCAD in the mini bales was higher in 2012 (157) than in 2013 (17-57), probably because the meadow sampled in 2012 was a first year ley and fertilized with cow manure rich in potassium. With the 2013-harvested roughage 15 out of 21 cows had successfully urine pH below 7, no anion-supplement was necessary. The remaining 6 cows also got urine pH below 7 with supplementation with an anion-rich concentrate. Roughage with low DCAD, not necessarily negative, did successfully lower urine pH to milk fever preventive values.

Table 6

**Effect of forage with different dietary cation-anion difference (DCAD) on urine pH of 33 cows in two years. Number of cows with milk fever preventive urine pH-values (6-7) and unsuccessful urine pH-values (>7); without or with anion-rich concentrate.**

| Year                                        | 2012 | 2013 |    |    |
|---------------------------------------------|------|------|----|----|
| DCAD (mEq./kg DM)                           | 157  | 17   | 22 | 57 |
| <b>No. of cows</b>                          |      |      |    |    |
| Cows with urine pH 6-7, without anion conc. | 0    | 7    | 5  | 3  |
| Cows with urine pH 6-7, with anion conc.    | 8    | 2    | 0  | 4  |
| Cows with urine pH > 7 with anion conc.     | 4    | 0    | 0  | 0  |

## CONCLUSIONS

Chlorine fertilisation with approximately 140 kg ha<sup>-1</sup> Cl decreased DCAD in forage significantly to a level suitable for feeding dry cows prior to calving. Although there were differences in DCAD between species, it may be difficult to achieve a sufficient low DCAD by only selecting species with a low DCAD. By analysing pH in urine from cows fed with forage with a low DCAD it was indicated that the risk of milk fever was reduced.

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