A Model Describing the Relationship Between Electrical Conductivity and Forage Dry Matter Content

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ABSTRACT

The correlation between dry matter (DM) content, electrical conductivity (EC) and ash content was found to be linear in grass and alfalfa during drying. While minerals in grass and alfalfa were very stable components during drying, their concentrations and EC increase accordingly; therefore, the EC value could serve as a measurement to determine DM content. Results indicated that EC measurement in grass and alfalfa during drying was simple, accurate, fast and easily repeatable, and could serve as an alternative method for DM determination.

Key words: Electrical conductivity, dry matter, rye grass, alfalfa

INTRODUCTION

Water is the major component in fresh plants. In forage crops the water content affects the quality and determines the appropriate preservation technology. Grass, alfalfa and their products are very important for feeding ruminants, and preservation is necessary during the year when forage production is below the amount required to feed livestock, and to level off the peak rate of production during the growing season. Silage and hay making are the most common means of grass and alfalfa preservation; both are related to water content, which is roughly 80% in fresh grass and alfalfa. Both hay making and ensiling requires removal of water, a process that is done in practice by field drying, a complex biophysical process (Bosma & Gabries 1992) in which it is hard to predict the drying, rate. Therefore, frequent tests must be performed to determine the DM content during the drying process, since accurate determination of water content in grass and alfalfa is a key factor in deciding when and how to handle the material. Water content is a variable parameter in cut grass and alfalfa, and changes with time. A quick and accurate determination method would be very helpful. Electrical conductivity of forage leachate has been used as an index of the degree of conditioning related to drying rates (Kraus *et al* 1995). The common method of DM determination in grass and alfalfa is oven drying (AOAC, 1984), which takes from 2 to 48 h (depending on temperature) and requires three weighings.

The method of DM determination proposed in this paper is based on the EC of the material, expressed as microsiemens/cm (μS/cm). Parker (1989) explains the terms conductivity and Siemens. Electrical conductivity is proportional to the density of free ions. In grass and alfalfa, the principal factor that affects EC is the concentration of minerals (ash) dissolved in the water. During the field drying period, some organic and biochemical processes continue, but the mineral content does not change.

Consequently, the mineral concentration in the cut forages increases proportionally as they dry, along with the EC value.

The purpose of the present study was to determinate the relationship between DM ash contents, and the EC in grass and alfalfa during the drying period of the same harvested plants.

MATERIALS AND METHODS

Ryegrass (Lolium preen), grown on clay soil was harvested as a 3rd cut in August 1996. Fresh grass contained 20.4% DM and 8.4% ash (dry wt. basis). Alfalfa (Medicago sativa L.) also grown on clay soil was harvested in August 1996 as a 2nd cut 42 days after the first cut. Fresh alfalfa contained 16.1% DM, and 12.1% ash (dry wt. basis). An MX32 Blender (Brown AG, Frankfurt am Main,

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Germany) was used to mix forage uniformly in water during about 2 min for fresh grass and up to 5 min for very dry material. Conductivity was determined with a WTW Konductometer Salinometer, LF191 (Wissenschaftlich-technische Werkstatten GmbH, D-8120 Weilhiem, Germany). Ten grams of grass or 20 g of alfalfa were blended in 600 ml of de-mineralized water. Dry matter was determined by oven drying at 105^0C for 24h. Ash content was determined on dried grass or alfalfa in a muffle furnace, at 600^0C for 2h. The forage-water space blend was filtered through a 500μm sieve (Laboratory Test Sieve, Endecotts Ltd, England) to remove long particles of fresh forage, which disturb EC measurement. Drying (at the first stages) was carried out in a Climate Control Unit (Kasper and Bosma 1996, DLO, IMAG, 6700 AA Wageningen, The Netherlands, personal communication). The unit consisted of 12 cells in which temperature; humidity and airflow could be regulated to ensure uniform drying. A balance was located in the chamber to indicate water losses. Statistical analysis was performed according to the recommendations of the Genstat 5 Committee (1993).

EXPERIMENTS WITH GRASS

Two experiments were carried out:

1. Determination of EC of grass at different DM contents. Fresh grass from a commercial field was brought to the laboratory, and EC and DM were measured immediately. Part of the grass was first partially dried in the Climatic Control Unit and later intensively dried in an oven. Successive samples (30 samples, each with four replicates, ranging from 20.4 to 100% DM) were taken for EC measurement and DM determination. EC measurement was done on the water solution after blending 10 g of grass in 600 ml of de-mineralized water, and filtering through a sieve as described above.
2. Determination of EC of solutions contains various concentrations of ash originating from grass. Dried grass was burnt to ash. Successively increasing amounts of ash (ranging from 8 to145 mg, proportional to its content in grass ranging from fresh to dry) were dissolved in 800 ml of de-mineralized water, and the ECs of the solutions were measured. The use of 600 ml of water in experiment 1 and 800 ml in experiment 2 was determined according to convenience and the dissolving speed of the ash.

EXPERIMENTS WITH ALFALFA

Three experiments were carried out:

1. Determination of EC at different DM contents of alfalfa: fresh alfalfa (at the beginning of flowering) grown under commercial conditions was brought to the laboratory and its EC and DM content were measured immediately. Part of the alfalfa was first partially dried in a drying control chamber and later intensively dried in an oven. Successive samples (30 samples ranging from 16.1 to 100% in DM content) were taken for EC measurement and DM determination.
   Electrical conductivity measurement was carried out on the solution obtaining by blending 20 g of alfalfa in 600 ml of de-mineralized water and filtering through a sieve. Although the alfalfa plant is composed of stem and leaves, a whole plant was sampled to maintain the same proportion between the two parts. We found that 45.5% of the fresh weight consisted of leaves (with 15.9% DM) and 54.5% of stems (with 15.1% DM).
2. Determination of EC in different concentrations of ash: dried alfalfa (whole plant) was reduced to ash, and successively increasing amounts (8-200 mg) of the ash were dissolved in 800 ml of de-mineralized water and the EC of the solution was measured.
3. Separate determination of EC in different concentrations of leaf and stem ash. Separate solutions were prepared with ash originating from leaves or from stems. Their ECs were measured as in experiment 2.

RESULTS AND DISCUSSION

1st. Grass: The regression of EC vs. grass DM content was linear as shown in Fig. 1

Under the test conditions, 10 g of dry grass (100% DM) contained 840 mg of ash and reached a conductivity value of 1600 μS/cm. In other words every 8.4mg of ash originated from 1% of the DM in a 10g grass sample, and corresponded to a conductivity value of 16 μS/cm. From this it follows that 0.25% DM corresponded to a conductivity of 4 µS/cm, a relationship which was easy to use in practice.

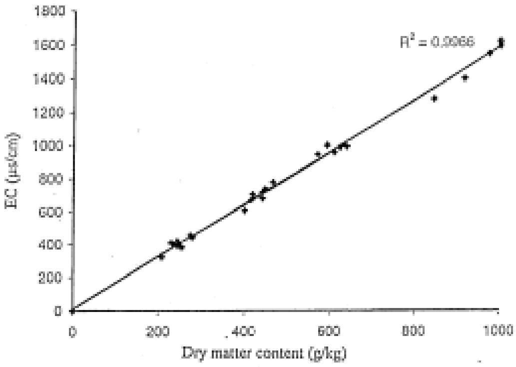

Figure 1. EC as a function of dry matter content. The line represents the least square linear fit to the data.

The regression of EC vs. ash concentration in water solution was also linear (Fig. 2)

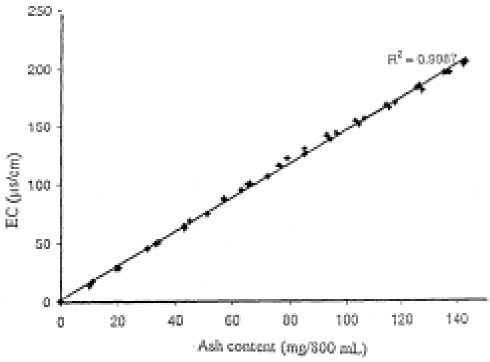

Figure 2. EC as a function of ash content. The line represents the least square linear fit to the data.

The results of experiments 1 and 2 were compared by calculating the regression coefficients vs. EC of added ash and ash contents, respectively, in grass in the same amount of water. When ash was added by increments to water, the linear relationship of EC to ash was maintained. It was important to note that the EC of soil or sand was negligible because the solution of soil contaminants was negligible under these conditions. Therefore, contamination with them had no effect. While minerals were stable components, their concentrations increased linearly during drying, and could serve as a good indicator of DM content. The correlation between DM and ash contents, and EC was very high, and, therefore, the measured EC would indicate the DM content.

2nd. Alfalfa: The regression of EC vs. alfalfa DM content was linear (Fig.3).

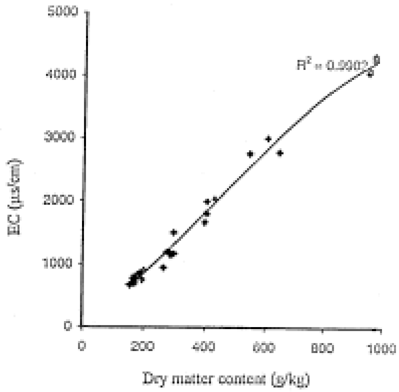

Figure 3. Trend: EC as a function of dry matter content. The line represents the least square polynomical fit to the data.
The equation is: $y = 3.68\ x + 3.3\ E\text{-}3\ x^2 - 3\ E\text{-}6\ x^3$

Under the test conditions, 20g of dry alfalfa (100% DM) contained 2420mg of ash, which indicated a conductivity of 4070 µS/cm. Consequently, every 24.2 mg of ash originated from 1% DM content in the alfalfa and contributed 40.7 µS/cm to the conductivity, or that 0.1% DM corresponded to a conductivity of 4 µS/cm, again, a value that was easy to measure. The regression of EC vs. ash concentration in water (originating from the whole plant) was linear (Fig. 4).

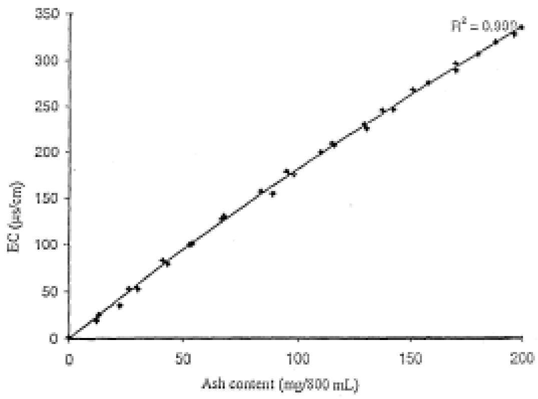

Figure 4. EC as a function of ash content. The line represents the least square polynomical fit to the data.

The lower measured EC of the whole plant ash could be attributed to its lower solubility at high ash concentration. The ECs of ash from the stem and from the leaves were measured separately, and that of the stem ash was about 60% higher than that of the leaf ash, which indicated higher soluble mineral content in the stem. Comparative results of the ECs of the whole plant ash and of those of the stem or leaves are given in Fig. 5. These show that the EC of alfalfa was due to the ash content of the plant. Plant minerals dissolved readily in water and the EC response was very rapid. In contrast, the conductivity of soil was found to be almost zero under the same measurement conditions (in cold water for a few seconds). Thus soil contamination would not significantly affect the results obtained by EC measurement.

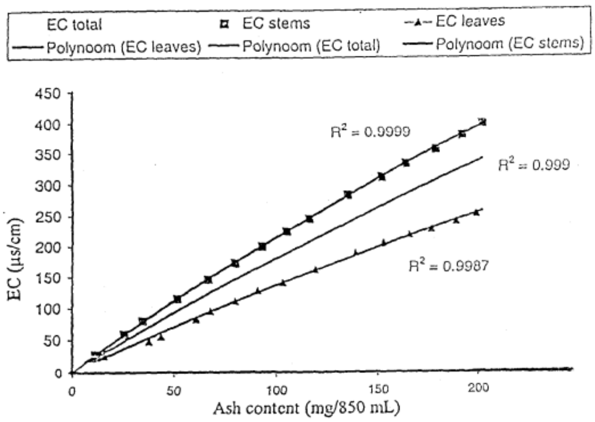

Figure 5. EC as a function of ash content in the stems, the leaves and the total plant. The lines represent the least square polinomical fits to the data.

The equations are:

$y = 1.4648\ x - 0.001\ x^2$, *x = ash content of the leaves*

$y = 1.9311\ x + 0.0012\ x^2$, *x = ash content of the total plant*

$y = 2.3287\ x - 0.0018\ x^2$, *x = ash content of the stems*

CONCLUSION

EC measurement is simple, accurate, fast and easily repeatable, and can serve as an alternative method for DM determination in grass and alfalfa.

RESUMO

A correlação entre o conteúdo da matéria seca (MS), condutividade elétrica (CE) e o conteúdo de cinza revelaram-se lineares na grama e na alfalfa durante a secagem. Os minerais presentes na grama e na alfalfa demonstraram ser componentes muito estáveis durante a secagem. Desta forma as concentrações de minerais e a CE poderiam ser utilizadas como parametros para determinação da MS. Os resultados indicaram que a determinação da CE na grama e na alfalfa durante a secagem era simples, exata, rápida e facilmente repetitível, e poderia ser utilizado como um método alternativo para a determinação de MS.

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