ESTIMATING FORAGE QUALITY LOSSES DURING FIELD DRYING

D.M. Brown[1], A.G. Barr[2] and D.M. Smith[3]
[1]Department of Land Resource Science, University of Guelph. Guelph, Ontario N1G 2W1
[2]National Hydrology Research Centre, 11 Innovation Blvd. Saskatoon, Sask. Canada S7N 3H5
[3]Institute of Hydrology, Maclean Building, Crownmarsh Gifford, Wallingford 0X10 8BB

ABSTRACT
The objective of this study was to determine how well changes in forage quality could be simulated during field drying for hay. Measurements of moisture content and three quality components were made during eight drying periods over three years. Samples were taken from forage swaths at one to four day intervals during drying period. Changes in total dry matter and its constituents were calculated from the measured/simulated changes in quality components. Comparison of simulated and measured changes were made for total losses and cumulative changes during each drying period. The simulated total dry matter losses were within the error limits of measurement for two of three rain-free and four of five prolonged drying periods. It was necessary to assume that loss of crude protein from plant cells was one-half as susceptible as the loss of non-protein cell contents.

KEYWORDS
Alfalfa (lucerne), ADF, NDF, crude protein, swath moisture content

ACRONYMS
ADF and NDF-Acid and Neutral Detergent Fibre; CP-crude protein; SimForQ-Simulation of Forage Quality losses

INTRODUCTION
When forage is to be harvested as dry hay, wet, humid weather causes significant yield loss and quality changes by prolonging the drying period. Quality loss results from plant respiration, leaching, leaf shatter, microbial activity and bleaching by the sun (Carter, 1960 and Smith and Brown,1994). A model (SimForQ) developed to estimate alfalfa yield and quality changes during field drying for hay has been developed (Barr et al. 1995). SimForQ integrates the losses owing to respiration, leaching, leaf shatter and microbial activity. The purpose of this study was to determine how well SimForQ estimated moisture and quality losses during field drying.

METHODS
Forage quality changes during field drying for hay were observed and simulated during eight drying periods at Elora Research Station (43.6°N, 80.4°W)Ontario in 1991, 1992 and 1993. Three of the periods were rain-free and five were prolonged by frequent rainfall. Table 1 summarizes the site, year, growth cycle (cutting), species composition, dates of cutting and final harvest, and rainfall conditions for each drying period.

Forage quality was measured from samples collected at the time of cutting and final harvest and additionally at 1-4 day intervals during drying. Samples were collected by hand from four different windrows within an area of approximately 700 m^2. Each sample contained four subsamples of 0.1-0.15 kg of dry matter. Care was taken to sample uniformly from the top to the bottom of the windrow, and to include the full length of cut stems. The first samples from each windrow were collected immediately after cutting. The four subsamples were combined in a paper bag and then sealed in a plastic bag. They were taken to a field house, removed from the plastic bag, weighed, dried in a forced-air drying oven for 48 h at 65-70°C and then reweighed. The forage moisture content was calculated on both wet- and dry-weight bases. Dried samples were held in paper bags at 20°C, then ground using a Wiley mill to pass a 2mm screen, and separate samples were analysed for ADF and NDF (Goering and Van Soest, 1970) and for CP using the modified Kjeldahl procedures for nitrogen determination.

The total and constituent dry-matter losses caused by respiration and leaching were determined from measured changes in ADF, NDF and CP. ADF (A) was assumed to be resistant to loss. The fractional loss of dry-matter dD'(kg kg^{-1}) was calculated from initial and final values of acid detergent fibre (A) as

$$\delta D' = 1 - A_i/A_f \quad (1)$$

where the subscripts i and f denote initial and final, i.e. at cutting and final harvest (baling), and the prime (') denotes calculated. Eq. (1) assumes no tedding leaf losses, as the samples analysed in this study were not tedded.

The calculated fractional dry-matter loss dD' was partitioned into fractional constituent losses for non-protein cell contents (dc', kg kg^{-1}), crude protein (dp',kg kg^{-1}) and hemicellulose (dh', kg kg^{-1}) as

$$\delta D' = \delta c' + \delta p' + \delta h' \quad (2)$$

The fractional change in hemicellulose (dh', kg kg^{-1}) was calculated from initial and final values of acid detergent fibre (A) and neutral detergent fibre (N) as

$$\delta h' = N_f(A_i/A_f) - N_i \quad (3)$$

The fractional change in crude protein (dp', kg kg^{-1}) was calculated from initial and final values of CP (P) as

$$\delta p' = P_f(1 - \delta D') - P_i \quad (4)$$

The fractional change in non-protein cell contents (dc', kg kg^{-1}) was calculated from Eq.(2). It should be noted that, because dD', dh', dp' and dc' are defined as losses, relative to the initial total dry matter, their signs are positive when a loss occurs.

Initial and final ADF, NDF and CP were calculated as the mean of four samples on the days of cutting and final harvest. When a second set of four samples was available within 36 h of cutting or final harvest, it was used also to estimate the mean. This helped to overcome the problem of high sample-to-sample variability (Fig. 1). The uncertainty in dD' was estimated using a probable error analysis (Fritschen and Gay, 1979) based on the uncertainties in the measured values of A_i and A_f. The uncertainties in A_i and A_f were based on 95% confidence intervals estimated using the same samples as were used to calculate the means of A_i and A_f.

RESULTS AND DISCUSSION
Quality changes. The measured (†) and simulated progression of ADF, NDF and CP during the drying period after cutting 3 in 1992 are shown in Fig. 1. The measured initial average quality was used for the simulation with SimForQ. The progression of change in quality is shown for the model without (—) and with (—) the component for microbial activity to show the importance of this component for estimation of the rate of change in alfalfa quality during a long drying period. The increase in NDF was simulated more accurately than ADF (Fig. 1). For some reason, there was a large decrease in measured CP content at final harvest that was not accounted for by SimForQ.

Dry matter losses. The simulated fractional losses in alfalfa dry matter during the 11-day drying period in 1992 separated by mode of loss, was 178 g kg^{-1} due to plant respiration, 5 g kg^{-1} due to leaching, and 69 g kg^{-1} due to microbial activity. Leaching losses increase in proportion to rainfall amount and respiration losses increase with temperature and length of drying period.

Moisture losses. The subroutine that estimates change in moisture content of the forage swath is a very important component of SimForQ. The ability to estimate change in moisture is illustrated in Fig. 1d. For some reason the decrease in moisture content was overestimated on 05 September, otherwise the drying subroutine provided the progression of moisture change very accurately.

The SimForQ model provides a logical framework for estimation of forage quality changes and dry matter losses during field drying for hay. However, further research is required in - (1) the microbial respiration component, (2) simulation of the swath microclimate, and (3) assessment of losses caused by tedding, as described by Barr et al. 1995.

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Table 1
Details on forage swaths that were sampled for moisture content and quality during field drying at Elora Research Station. (1992, Cut 3 was used as an example for this paper).

Year	Cut.	Approx. dry matter (t ha^{-1})	Alfalfa/ timothy ratio	Date Cutting	Final Harvest	Hours of rain	Rain (mm)
1991	1	5.6	60/40	4 June	8 June	0	0.0
1991	2	3.8	90/10	15 July	18 July	0	0.0
1991	3	2.8	90/10	12 Aug.	21 Aug.	17	61.0
1992	1a	5.2	80/20	12 June	16 June	0	0.0
1992	1b	5.6	88/12	16 June	28 June	26	41.6
1992	2	3.8	96/4	28 July	6 Aug.	27	29.0
1992	3	2.8	100/0	31 Aug.	11 Sept.	26	33.2
1993	1	5.6	50/50	16 June	25 June	36	85.6

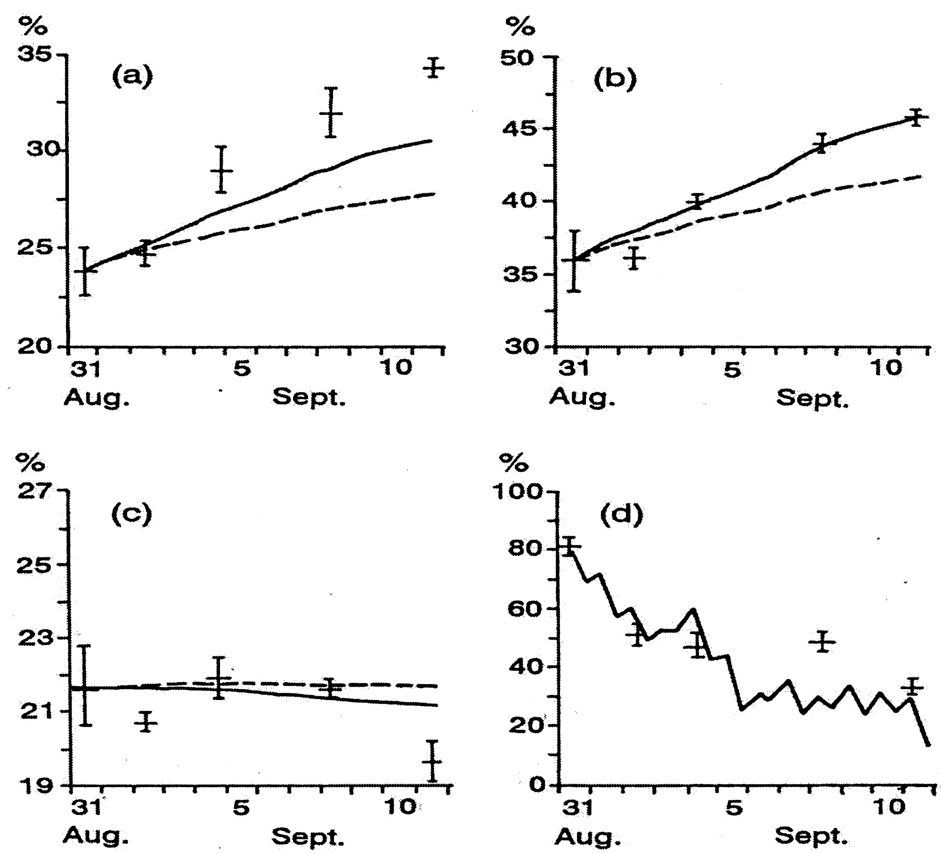

Figure 1
Measured (†) amd simulated change in quality for ADF (a), NDF (b) and CP (c), expressed as percent of dry matter, during the drying period for cutting 3 in 1992 and change in forage moisture content (d), expressed as percent on wet weight basis. (The progress of changes in quality determined by SimForQ are shown with (——) and without (-------) the microbial activity subroutine).