# Drying large round bales of alfalfa treated with a chemical drying agent

J. A. BARCLAY and G. C. MISENER

*Research Station, Agriculture Canada, Fredericton, NB, Canada E3B 4Z7.* *Received 4 April 1989, accepted 19 October 1989.*

Barclay, J. A. and Misener, G. C. 1990. **Drying large round bales of alfalfa treated with a chemical drying agent.** Can Agric: Eng. **32**: 99–103. The overall drying time of alfalfa treated with a chemical drying agent and then harvested into large round bales was compared to that of large round bales of untreated alfalfa. The effect of the drying agent on the nutritional quality of the alfalfa was also assessed. The overall drying time was measured from when the alfalfa was cut to when it reached approximately 18% moisture, wet basis. In two trials using second- and third-cut alfalfa, respectively, desiccant-treated hay baled at approximately 35% moisture dried significantly faster ($P<0.05$) than untreated hay baled at the same time. The average reduction in drying time was 23.1% with the treated hay compared to the untreated hay. However, untreated alfalfa field dried to below 35% moisture, dried significantly faster ($P<0.05$) than the desiccant treated hay baled at 35% moisture. Desiccant application increased the acid detergent fiber (ADF) content and decreased the total nitrogen (TN) content during the trial using second-cut alfalfa but had no adverse effects during the trial using third-cut alfalfa. Field-drying the hay to below 35% moisture had the same adverse effect on the ADF and TN of the second-cut alfalfa.

## INTRODUCTION

Typical Eastern Canadian climatic conditions are rarely conducive to long periods of field drying. Rainfall is frequent and hay left in the field to dry is often damaged by adverse weather before it is ready for storage. Alternatively, hay which is baled prematurely at too high a moisture level is subject to spoilage due to heat production and mould growth.

Large round balers have become popular over the past several years. They provide the farming community with an economically attractive, totally mechanized forage system with low labor requirements (Macdonald and Clark 1987). Because of their greater mass, large round bales dry more slowly than rectangular bales. Thus, the chance of spoilage in large round bales is greater. It is largely recognized that hay should be field-dried to a least 18% moisture content before storage (Macdonald and Clark 1987). However, baling at higher moisture contents, followed by artificial drying to 18%, offers certain advantages such as reduced field curing time and thus, reduces risk of exposure to rain (Collins et al. 1987).

Artificial drying systems have been used successfully to accelerate the drying of large round bales in storage. A series of artificial drying experiments using large round bales was conducted at the University of Tennessee (Bledsoe et al. 1985). They measured the effect of dry matter density of the bales and its distribution within the bales on the drying rates. Morrison and Shove (1980) conducted drying studies using a two-bale solar-heated drier. The authors found that bales dried with solar-heated air dried to a lower final moisture content than non-heated bales. A 36-bale farm-scale solar drier was investigated by Baker and Shove (1978). Bales with an initial moisture content of 45% were dried to 20% in 2 days under good operating conditions. An additional day was required when conditions were poor.

Several studies have been conducted to increase the drying rate of hay in the field. Chemical conditioners, such as potassium carbonate ($K_2CO_3$), alter the cuticle of the plant thereby decreasing the resistance to moisture loss. Their effect is more pronounced in the stems of the plants than in the leaves. The stem-drying rate is increased relative to that of the leaves and this results in more uniform drying. By accelerating the drying process, the chemicals also reduce respiratory and weather losses (Macdonald and Clark 1987).

Chemical conditioners have been proven effective in increasing the drying rate of pure alfalfa (Rotz et al. 1987; Beauregard et al. 1988; Butler et al. 1988; Hong et al. 1988; Nocek et al. 1988) and to a lesser degree, of alfalfa-grass mixtures (Beauregard et al. 1988; Butler et al. 1988) but not of pure grass (Beauregard et al. 1988). Beauregard et al. (1988) found that chemical conditioners had little effect under humid conditions which was contrary to Butler et al. (1988) who found that chemical conditioners improved the rate of drying even under humid conditions. In general, chemical conditioning had no effect on hay nutritional quality (Rotz et al. 1987; Hong et al. 1988; Nocek et al. 1988).

To date, very little information has been published describing the combined effect of chemical conditioning and artificial drying on the overall drying time of large round hay bales. The objective of this study was to investigate this combined effect using large round bales of alfalfa and to determine the overall drying time in the field and in an experimental drier. The effect of accelerated drying on the nutritional quality of the hay was also assessed.

## MATERIALS AND METHODS

A drying experiment was carried out during the months of August and September of 1988 at the Agriculture Canada Research Station in Fredericton, New Brunswick. The experiment consisted of two trials using second- and third-cut alfalfa.

Weather information was collected from a weather station located at the Research Station which included hourly temperature, relative humidity and rainfall. This was used to assess drying conditions throughout each trial.

Three treatments, with three bales per treatment, were applied to the alfalfa during each trial: (1) desiccant-treated alfalfa, baled at approximately 35% moisture, wet basis; (2) untreated alfalfa, baled concurrently with the treated alfalfa regardless of moisture content; and (3) untreated alfalfa, baled below 35% moisture.

Treatments 1 and 2 were included to represent desiccant-treated and untreated alfalfa field dried under typical Eastern Canadian climatic conditions. Treatments 1 and 2 were harvested as soon as the desiccant-treated hay reached a moisture content of approximately 35%. Treatment 3 was included to represent untreated alfalfa field dried under ideal field drying conditions assuming no possibility of rainfall. It was left in the field as long as required to allow its moisture content to fall well below 35%.

A mower/conditioner, equipped with a spray boom, was used to mow the alfalfa. The outside edges of the experimental plots were mowed before the start of both trials. A solution was prepared consisting of 12.5 kg of $K_2CO_3$, 16 L of a 90% mixture of methyl esters of fatty acids and 680 L of water (Emerdri Hay drying system). The solution was applied to the swaths at a rate of 350 L/ha while moving at a forward speed of 8 km/h. Swaths were mowed to produce three large round bales of hay per treatment. A buffer swath was left between treatments.

Samples of hay were collected to determine moisture loss in the field. Trays, made out of 0.64-cm mesh wire and measuring 0.81 m by 0.81 m, were used to collect the samples. Four trays were used per treatment. The trays were inserted under a portion of randomly selected swaths and were weighed every two hours until dew fell each evening. A subsample was taken from each tray during baling and dried in a conventional oven at 50°C for 48 h to determine its moisture content. The final tray moisture content was then used to calculate the moisture content at each tray weighing.

An expandable chamber baler was used to form uniform density bales approximately 1.2 m long and 1.5 m in diameter. Baling began when the desiccant-treated swaths reached a moisture level of approximately 35%. Desiccant-treated swaths (Treatment 1) and one set of untreated swaths (Treatment 2) were baled and placed in the experimental drier. The second set of untreated swaths (Treatment 3) was baled and placed in the drier later, when the hay had reached a moisture level of less than 35%.

A pilot-scale experimental drying unit was used to dry the bales (Fig. 1). The unit was designed to dry up to nine large round bales. It was housed in an open structure with a roof for protection from the rain. The drier contained three separate plenums built into a concrete floor. The plenums were equipped with separate fans and heaters which could be individually adjusted to provide various air temperatures. Each fan was powered by a 3.73 kW motor and could deliver up to 40 $m^3$/min of air at 1100 Pa.

The bales were placed on circular wooden platforms and connected to the plenums with flexible vinyl tubes. Steel rings, 0.15 m high, were attached to the platforms. The rings pierced the bales and formed a seal to prevent air leaks from the bale/base interface. Wooden covers measuring 1.2 m in diameter were placed on top of the bales to force the air out towards the top outside section of the bales. The bales were suspended from load cells attached to the ceiling of the support structure. Sensors were connected to a Fluke 2280 Series electronic data logger which recorded bale weight on an hourly basis.

Three bales from each treatment were placed in the drier such that each treatment occupied a separate plenum. The bales were weighed and sampled for moisture content before turning on the drier. The initial bale moisture content was then used to calculate the moisture content at each bale weighing. Core samples from four locations within each bale were taken daily to determine the moisture content of the bottom center, bottom outside, top center and top outside of the bales.

The drier was set to a temperature of approximately 30°C and the bales were dried until they reached an average final moisture content of 18%.

Samples were taken at the beginning and end of each trial for nutritional analysis. Initial values were determined from composite grab samples taken from the field as the treatments were applied. Final values were determined from composite core samples taken from each bale after drying. Nutrient analyses conducted were; acid detergent fibre and acid detergent insoluble nitrogen determination using the methods of Goering and Van-Soest (1970); and total nitrogen determination using the methods of the Association of Official Analytical Chemists (1984).

## RESULTS AND DISCUSSION

Table I summarizes the daily weather conditions during Trials 1 and 2. The drying conditions during both trials were better than expected in a region where the probabilities of having two consecutive dry days in August and September are 0.74 and 0.76, respectively, and the probability of three consecutive days drops to 0.14 during both August and September (Treidl 1981). There was a short period of rain during Trial 2 which occurred after the bales had been placed in the experimental drier.

The ANOVA, which was performed on the data reflecting the drying time of the hay to reach its final moisture level as

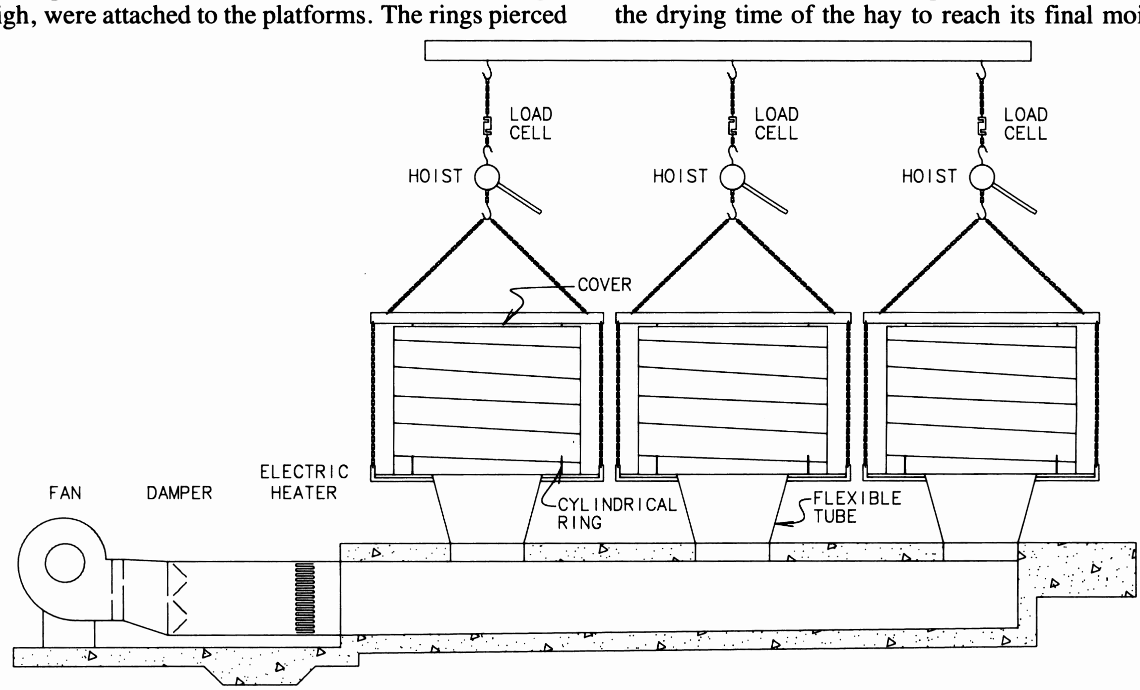


Fig. 1. Schematic of the large round bale experimental drier.

**Table I. Daily weather conditions during experiment**

| Date | Temperature (°C) Mean | Min. | Max. | Mean realtive humidity (%) | Mean rainfall (mm) |
|---|---|---|---|---|---|
| *Trial 1* | | | | | |
| 18 Aug. | 16.1 | 11.6 | 18.5 | 74.2 | 0.0 |
| 19 Aug.[1,2]† | 14.5 | 8.2 | 20.7 | 65.3 | 0.0 |
| 20 Aug.[3] | 16.0 | 10.5 | 20.5 | 66.8 | 0.0 |
| 21 Aug. | 10.4 | 8.6 | 11.6 | 95.6 | 0.0 |
| 22 Aug. | 11.5 | 6.4 | 16.9 | 79.5 | 0.0 |
| 23 Aug. | 11.9 | 5.8 | 19.0 | 84.4 | 0.0 |
| 24 Aug. | 12.7 | 6.5 | 18.9 | 83.1 | 0.0 |
| *Trial 2* | | | | | |
| 6 Sept. | 10.5 | 5.2 | 16.2 | 69.4 | 0.0 |
| 7 Sept. | 10.2 | 3.4 | 17.6 | 67.6 | 0.0 |
| 8 Sept. | 12.7 | 2.5 | 22.8 | 69.1 | 0.0 |
| 9 Sept.[1,2,3] | 14.2 | 5.8 | 22.9 | 76.3 | 0.0 |
| 10 Sept. | 17.5 | 14.1 | 23.4 | 73.4 | 0.0 |
| 11 Sept. | 12.9 | 9.3 | 15.8 | 67.1 | 0.0 |
| 12 Sept. | 11.2 | 5.7 | 15.3 | 71.7 | 0.0 |
| 13 Sept. | 11.1 | 4.2 | 14.8 | 87.9 | 1.2 |
| 14 Sept. | 10.4 | 5.9 | 15.0 | 75.0 | 0.0 |

†[1,2,3]Dates on which Treatments 1, 2 and 3 were put on drier.

discussed above, contained two comparisons among the three treatments. The desiccant-treated bales were compared with the concurrent bales, and the mean of these two treatments was compared with the third treatment. The data were transformed to the log 10 scale to stabilize the variances within each rep-treatment group. Both of these contrasts were highly significant with the untreated bales (treatment 3) requiring the least drying time, the desiccant-treated bales intermediate, and the concurrent bales requiring the longest drying time (Table II). The reduction in drying time with the desiccant treatment compared with the concurrent treatment was 23.1%.

The results presented in Table III represent the drying times broken down by trial and treatment. The results are subdivided into time in the field, time in the drier and total time to dry. The weather conditions were fairly constant throughout Trial 1 (Table I). The ambient temperature during the field drying period ranged from 8.2 to 20.7°C with a 3-day mean of 15.5°C. The mean daily relative humidity throughout the entire field drying period was fairly steady, averaging 68.8%. Treatments 1 and 2 were baled and placed in the drier after 2 days and Treatment 3, which represented field drying under ideal conditions, remained in the field for an additional 18.0 h. Its final field moisture content was 25.2%. The desiccant-treated hay (Treatment 1) reached its final field moisture content of 36.0% in 32.3 h. The moisture content of the untreated hay (Treatment 2) was higher at this point averaging 41.9%. This was consistent with the findings of Rotz et al. (1987) who measured a

**Table II. Analysis of variance for drying time of hay over two cuts**

| | Analysis of variance df | MSS | F |
|---|---|---|---|
| Replication | 1 | 0.1355 | |
| Treatment | 2 | 0.0786 | 31.4** |
| Field drying vs. mean of desiccant and concurrent | 1 | 0.1191 | 47.6** |
| Desiccant vs. concurrent | 1 | 0.0381 | 15.2** |
| Residual | 14 | 0.0025 | |
| Total | 17 | | |

**Denotes significance at $P<0.01$.

**Table III. Mean drying results during trials 1 and 2**

| Treatment | Initial moisture content (%) | Time on field (h) | Baling moisture content (%) | Time on drier to reach 18% moisture content (h) | total time (h) |
|---|---|---|---|---|---|
| *Trial 1* | | | | | |
| 1 | 80.7 | 32.3 | 36.0 | 56.3 | 88.6 |
| 2 | 80.7 | 32.0 | 41.9 | 87.1 | 119.1 |
| 3 | 80.7 | 50.3 | 25.2 | 15.0 | 65.3 |
| *Trial 2* | | | | | |
| 1 | 82.4 | 72.0 | 30.0 | 58.7 | 130.7 |
| 2 | 82.4 | 71.4 | 40.0 | 94.6 | 166.0 |
| 3 | 82.4 | 73.8 | 26.5 | 29.7 | 103.5 |

significant decrease in drying time when a chemical conditioner was applied to second-cut alfalfa. However, this was not consistent with Beauregard et al. (1988) who found that chemical conditioning did not improve the drying rate of second-cut alfalfa.

Once in the drier, the desiccant-treated hay (Treatment 1) required 56.3 h to reach a final moisture content of 18%. The untreated hay which entered the drier at the same time (Treatment 2), required 87.1 h in the drier to reach the same level. The total drying times for Treatments 1 and 2 were 88.6 and 119.1 h, respectively. The untreated hay which entered the drier later (Treatment 3), reached the 18% moisture level after only 15.0 h in the drier for a total drying time of 65.3 h.

The weather conditions during Trial 2 were less conducive to field drying than during Trial 1, especially over the first two days. The mean daily temperatures were 3–4°C lower than during Trial 1 averaging 11.9°C (Table I). The fluctuations in temperature were greater, ranging from a minimum temperature of 2.5°C during the second night of field drying to a maximum temperature of 22.8°C during the third day of field drying. The mean daily relative humidity remained fairly steady at approximately 71% throughout the field-drying period.

Rotz et al. (1987) found that the effect of chemical conditioning was positively related to environmental drying conditions. Consistent with this, the desiccant-treated hay (Treatment 1) required 72.0 h to reach its final field moisture content (Table III). During the last few days of the field-drying period, the ambient temperature began to rise and the drying process began to accelerate. Treatment 3 dropped to an average of 26.5% moisture in less than 2 h after treatments 1 and 2 were baled.

Once in the drier, the results obtained during Trial 2 were similar to those during Trial 1. The desiccant-treated hay (Treatment 1) dried to 18% moisture in 58.7 h for a total mean drying time of 130.7 h whereas the untreated hay baled concurrently (Treatment 2), required 94.6 h in the drier for a total mean drying time of 166.0 h. The untreated hay which was baled later (Treatment 3), reached the 18% moisture level after 29.7 h in the drier for a total mean drying time of 103.5 h.

From the above results, it would appear that under ideal conditions, overall drying time may be significantly reduced by field drying the hay to as close to 18% moisture as possible prior to placement in the drier. The drier would still be required to complete the drying process and to eliminate high-moisture pockets which may occur as a result on nonuniform drying in the field. However, where there is a strong possibility of rainfall during the field-drying period, or where it is advantageous to bale at a higher moisture content, overall drying time may be significantly reduced by desiccant application.

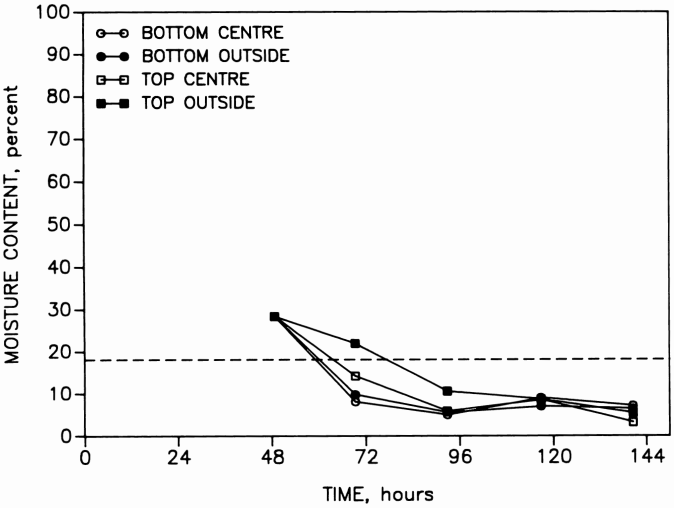


Fig. 2. Moisture content distribution of a typical bale entering the experimental drier at 25–30% moisture (untreated alfalfa, Treatment 3).

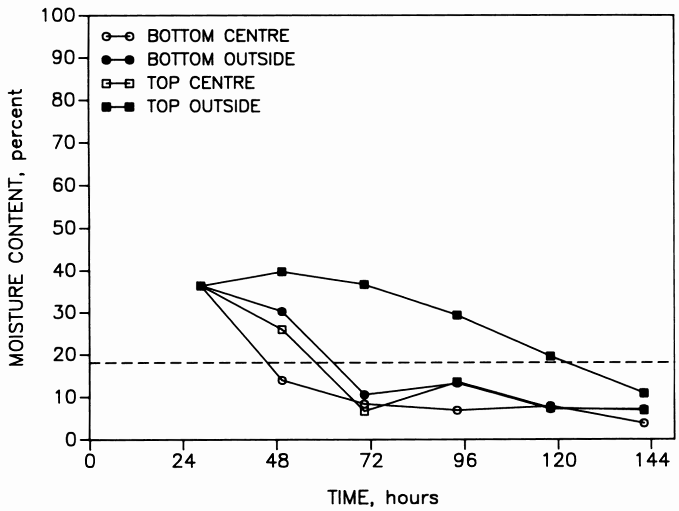


Fig. 3. Moisture content distribution of a typical bale entering the experimental drier at 35–40% moisture (treated alfalfa, Treatment 1).

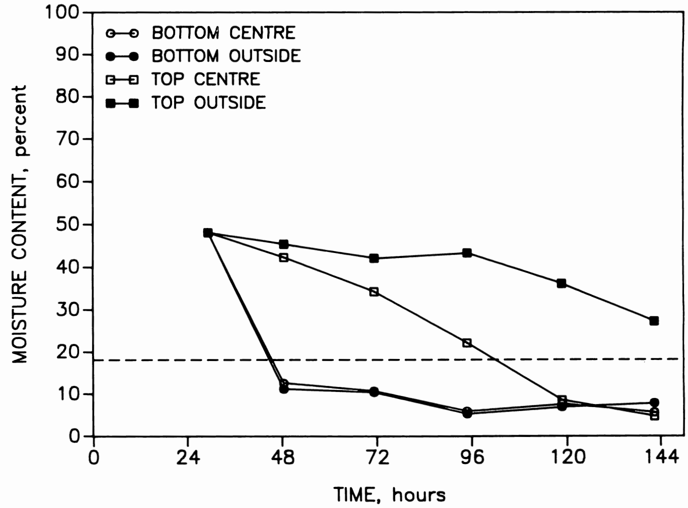


Fig. 4. Moisture content distribution of a typical bale entering the experimental drier at 40–45% moisture (untreated alfalfa, Treatment 2).

**Table IV. Summary of nutritional parameters**

| | Nutrient (% dry matter basis) | | |
|---|---|---|---|
| Treatment | ADF† | ADF-N | TN |
| *Trial 1* | | | |
| 0‡ | 36.2*b* | 0.17 | 2.8*a* |
| 1§ | 40.2*a* | 0.19 | 2.5*b* |
| 2 | 36.9*b* | 0.19 | 2.7*a* |
| 3 | 40.0*a* | 0.20 | 2.5*b* |
| *Trial 2* | | | |
| 0 | 24.7 | 0.17 | 3.8*b* |
| 1 | 25.8 | 0.15 | 3.7*b* |
| 2 | 27.0 | 0.18 | 4.0*a* |
| 3 | 26.9 | 0.16 | 3.4*c* |

†ADF = Acid detergent fiber; ADF-N = acid detergent nitrogen; TN = total nitrogen.
‡Mean value from composite grab samples taken from the field at the start of the experiments.
§Mean value from composite core samples from four sections within each bale.
*a–c*Means in the same column followed by different letters are significantly different ($P<0.05$).

As the initial moisture content of the bales placed in the drier increased, it became increasingly difficult to obtain uniform drying. This is consistent with Bledsoe et al. (1985) who also found it difficult to achieve uniform drying, especially in the top outside sections of uniform density bales. They found that the airflow distribution within a bale was a function of several parameters including dry matter distribution which is in turn affected by initial bale moisture content.

Figures 2 through 4 show the effect of initial bale moisture content on the uniformity of drying within the bale. The data presented is from Trial 1, although similar results were obtained during Trial 2. The figures represent bales entering the drier at 25–30% (Treatment 3), 35–40%, (Treatment 1) and 45–50% (Treatment 2) moisture content, respectively and show the moisture content in four sections of each bale over time.

All sections of the bale depicted in Fig. 2 dried to below the 18% moisture level within a short period of each other. The bale depicted in Fig. 3 also dried to below the 18% moisture level, but the top outside section dried more slowly than the other sections. The top outside section of the bale depicted in Fig. 4 did not dry to the desired level during this study.

The above results indicate that the hay should be field dried to at least 35% moisture in order to achieve uniform drying in the drier. Given the field drying limitations in Eastern Canada, desiccant application would serve to reduce the initial moisture content of the bales going into the drier and thus, increase the uniformity of drying.

The nutritional parameters measured during this study are summarized in Table IV. Included in the table are the results of a Duncan's multiple range test performed on each trial individually.

The acid detergent fiber (ADF) content of a forage gives an indication of its digestibility. In general, as ADF increases, digestibility decreases. The initial ADF averaged 36.2 and 24.7% during Trials 1 and 2, respectively (Table IV). There was a significant increase in ADF content during Trial 1. The final ADF content of the desiccant-treated hay (Treatment 1) and the untreated hay field-dried under ideal conditions (Treatment 3) was significantly higher ($P<0.05$) than that of the sample taken from the field at mowing. This is inconsistent with Rotz et al. (1987), Hong et al. (1988) and Nocek et al. (1988) who found that chemical conditioning did not have a significant effect on dry matter losses or hay quality. It may, however, be attributable to an increase in leaf-shatter loss during baling. Generally, as the moisture content at baling decreases, the leaves become more brittle and the leaf-shatter loss increases (Macdonald and Clark 1987).

Acid detergent insoluble nitrogen (ADF-N) is a measure of the nitrogen component of the acid detergent fiber. It is used to determine the extent of heat damage which occurs as a result of processing hay above 50°C. The initial ADF-N averaged 0.17% during both Trials (Table IV). Treatment did not have a significant effect on the ADF-N during Trials 1 and 2 indicating that no heat damage occurred.

Total nitrogen (TN) is used to estimate the amount of crude protein in a feed by assuming that crude protein is 16% nitrogen (Cullison 1975). The initial TN averaged 2.8 and 3.8% for Trials 1 and 2, respectively. During Trial 1, there was a significant decrease in TN in the desiccant-treated hay and the untreated hay dried under ideal field drying conditions (Treatments 1 and 3, respectively) compared to samples taken from the field at mowing. Again, this was probably due to the leaf-shatter losses associated with baling. The results obtained during Trial 2 were less clear. Although the TN content of samples from Treatment 3 was lower as found in Trial 1, there was a significant increase in TN in the untreated hay baled concurrently with the treated hay (Treatment 2). This increase may have been due to a loss in dry matter due to microbial activity within the bales which would result in a concentration of the TN.

## CONCLUSIONS

A comparison was made between the drying time of alfalfa treated with a chemical drying agent to that of untreated alfalfa. The drying time was measured both in the field and in an experimental large round bale drier. The following conclusions were made:

(1) The chemical drying agent used in this study was found to significantly reduce the overall drying time of second- and third-cut alfalfa by 23.1% when compared to untreated alfalfa baled and placed in the experimental drier at the same time.

(2) Extending the field drying period of the untreated alfalfa under favorable weather conditions further reduced the overall drying time such that it was significantly less than that of the desiccant-treated alfalfa. Normally, these favorable weather conditions are rare in Eastern Canada.

(3) Reducing the moisture content of bales entering the drier increased the uniformity of drying within the bale.

(4) During a trial with second-cut alfalfa, both desiccant application and extension of the field drying period had an adverse effect on the acid detergent fiber and total nitrogen content of the alfalfa. During a second trial with third-cut alfalfa, desiccant application did not adversely affect the nutritional value of the alfalfa.

## ACKNOWLEDGMENT

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