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Finish Drying of Conditioned Alfalfa Hay At High Temperatures



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CONTENTS

Introduction	3
Methods	3
Results	5
Discussion	8
Summary	8
References Cited	8

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Finish Drying of Conditioned Alfalfa Hay At High Temperatures

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Introduction

Numerous investigators have proven the advantages of conditioning forage crops for hay by flailing, crushing, rolling, and crimping (12, 13, 14).¹ This has resulted in an increased use of conditioners to reduce the time of field curing and attendant weather risks and to increase the nutritive value of hay.

Artificial drying of freshly cut forage in a dehydrator burning fuel such as oil can be economical when the final product is of very high value, such as alfalfa poultry meal. Barn driers, wagon driers, and similar equipment can finish dry hay in batches at fairly economical costs if the cost of fuel and electricity alone are considered. However, the quantity that can be handled at one time is usually limited to the size of the barn, the size and number of wagons, and other factors. Also, a second handling of hay is usually necessary to make room for a new batch, and this adds to the costs.

It is proposed in this paper that hay first be conditioned in the field and wilted to moisture percentages between 35 and 55 and then finish dried by some sort of heat at relatively high temperatures—200 to 500° F. Several investigators (6, 9) have recommended this method of making hay because of the economy in fuel, savings in labor, retention of nutrients in the hay, and reduced weather risks.

A number of investigators have dried hay at relatively high temperatures. Bilanski and others (4, 5) have been able to cure alfalfa leaves at 1400° F and stems at 865° F without visible damage. Bratzler and others (6) dried hay at temperatures of 110 to 200° F without serious loss of nutrients. Clyde (8) dried hay in a triple-drum drier at temperatures of 932 to 1451° F with satisfactory results. Barr (3), with a single-drum rotary drier, used temperatures of 1850° F without serious losses. Hodgson and others (10) found no significant difference in the digestibility of feed constituents between sun-cured grass and grass dried at 250, 300, or 350° F.

Methods

This experiment was conducted in three parts. The initial experiment consisted of crushing the stems of

¹ Numbers in parentheses refer to References Cited, page 8.

alfalfa plants, which were then slowly dried at 100° F for six hours to about 54% moisture and then dried in a heated air column at 500, 400, 300, or 200° F for a specified number of seconds. The second series of experiments consisted of slow drying crushed alfalfa at 100° F and then rapid drying in a rotary drier at 400 or 300° F. The third series of tests were all conducted with samples that were dried at 100° F for either 6 or 17 hours and then rapidly dried for a few minutes in a rotary drier with the temperature of the incoming air at 400° F and the exhaust temperature at about 100° F. Tests also were conducted to determine the effect of field drying for four hours on both crushed and uncrushed alfalfa. Samples were tested for moisture, protein, and beta carotene, the latter two being indicative of nutrient quality.

In the initial experiment, the alfalfa was cut close to the ground with small hand shears and was brought immediately into the laboratory. One-half of the sample was kept in a plastic bag in cold storage (32° F) until tested for moisture. The other half of the sample was compressed in a crusher which consisted of two steel rollers 8 inches in diameter spaced 20 thousandths of an inch apart and turning at 300 r.p.m. The space between the rollers was not flexible (Figure 1). The crushed alfalfa was then wilted to an average of 54.0% mois-

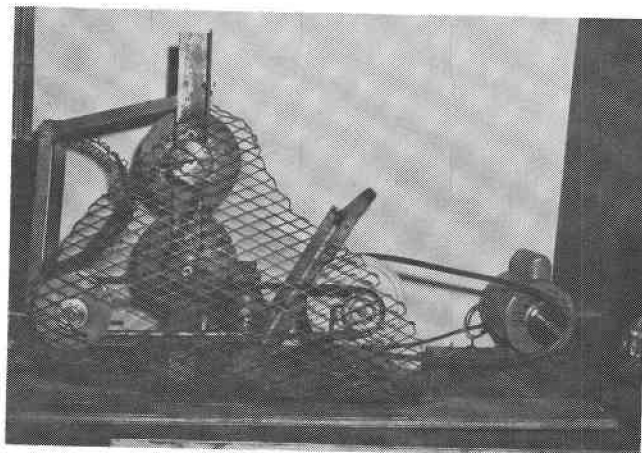


Figure 1. The crusher consisted of two 8-inch drums spaced .020 inch apart which rotated in opposite directions. A variable speed pulley system controlled the speed of the drums.

Table 1. Average percent of moisture of partially dried, crushed alfalfa after rapid drying at high temperatures

Temp.	Time (seconds)							
	8		15		30		60	
	Average moisture ¹	Standard deviation	Average moisture ¹	Standard deviation	Average moisture ¹	Standard deviation	Average moisture ¹	Standard deviation
	%		%		%		%	
200° F			48.5	0.3	44.0	2.5	31.8	3.5
300° F			43.7	0.7	32.9	1.1	21.1	8.7
400° F	40.5	3.0	31.7	2.2	17.9 ³	3.6		
500° F	37.0 ²	1.7						

¹ Original moisture content—54.3%; each report was an average of five samples.

² Most samples scorched at the edges.

³ A few slightly scorched at the edges.

ture² in a box drier at 100° F. This was determined by testing for the moisture content of the original sample and then measuring the loss in weight when slowly dried at 100° F. The remaining half was dried, one stem (with leaves) at a time, at 200, 300, 400, and 500° F. The sample was first weighed and then each stem was held in a 4-inch tube of heated air for a prescribed interval of time, after which the sample was weighed immediately to the nearest 0.01 mg. Results of this test are shown in Table 1 and Figure 2. This procedure is similar to that of Balanski (4).

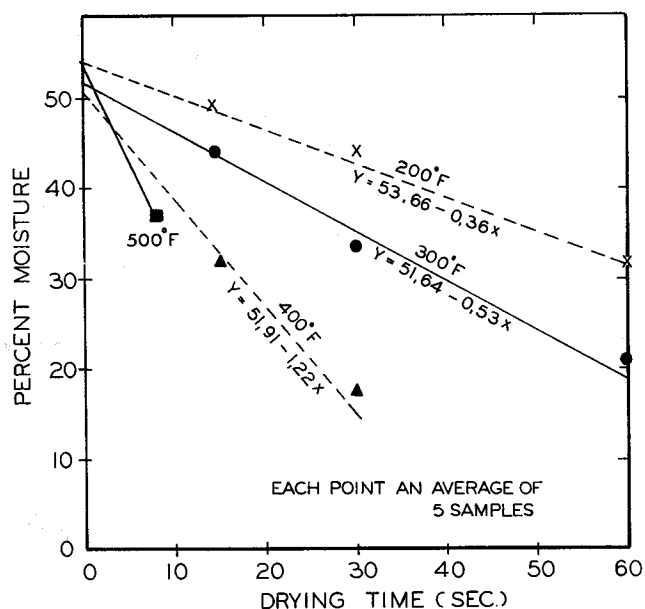


Figure 2. Rapid drying of a single stem of alfalfa with its leaves.

The second series of tests was run with larger samples of about four pounds each. Crushing and wilting were carried out as before. The rapid drying was done in a counterflow rotary drier (Figure 3) which carried

² All moistures reported are on a wet basis.

the alfalfa through by revolving.³ The wilted alfalfa was cut to 1-inch lengths before putting through the drier. Marked pieces of alfalfa were checked as to the length of time in the drier for a certain r.p.m. of the rotor. The length of time could be changed by altering the speed of rotation of the drier. The drying was carried out at two different speeds—one and two minutes in the drier—and at three temperatures—200, 300, and 400° F.

The third series of tests was conducted to determine the quality of the alfalfa directly from the field, to determine the amount of drying and loss of nutrients for alfalfa under short-term conditions of natural drying of both crushed and uncrushed alfalfa, and to approximate conditions of short-time drying followed by fast finish drying in a rotary drier. The sample size in this series was reduced to three pounds and the rotary drier drum was lengthened to 24 inches.

Samples of alfalfa hay were cut each weekday morning from June 12 to September 1, 1968. One of these samples was placed in a plastic bag and held at 0° F until tested for percent moisture and protein. The second sample was cut, placed in a plastic bag, and kept in the shade until approximately 10 a.m.; then it was returned to the field, removed from the bag, and spread out on cheesecloth at the approximate location where it had been cut. At about 2 p.m., the alfalfa was gathered up, placed in a plastic bag, and refrigerated at 0° F until tested for protein and dry matter. The third sample was treated exactly as the second except that it was crushed before it was kept in the shade prior to being placed in the field. The purpose of placing the alfalfa in the same location in the field (samples 2 and 3) was to determine the extent of drying that occurs in four hours of field drying of both crushed and uncrushed alfalfa. The cheesecloth prevented loss of stems in the field.

³ The dryer consisted of a steel tube with an inside diameter of 3½ inches. Three 1-inch by ½-inch flat pieces of steel were placed in the tube longitudinally, 120 degrees apart. The tube was set at an angle of 15 degrees with the horizontal and covered with a 3/16-inch layer of asbestos and aluminum foil. The tube was rotated by an electric motor through a variable speed gear and chain system. Heat was passed through the tube in a counterflow direction to the movement of the alfalfa.

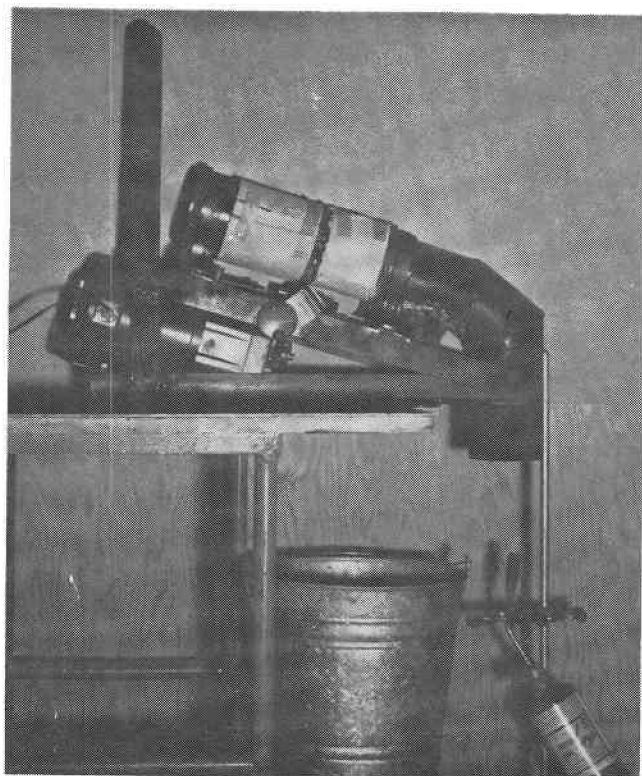


Figure 3. The rotary drier used in these experiments. The tube was 12 inches long for the first two experiments and 24 inches long for the third experiment.

A fourth sample, which was cut at the same time, was placed in a plastic bag, brought to the station, slow dried at 100° F for approximately six hours, fast dried (400° F incoming air, 115° F exhaust) in the rotary drier, and then stored in a plastic bag at approximately 0° F until tested for protein, dry matter, and carotene.

A fifth sample was handled in the same manner as the fourth except that it was slow dried for approximately 17 hours before it was fast dried. Fast drying times of 2.2 minutes and 5.8 minutes were used in this part of the experiment.

Carotene determinations were made on samples for July 12 and 13 and August 15 and 16. The procedure involved extracting the beta carotene with Skelly B in a blender, chromatographing and eluting the beta carotene with 9:1 Skelly B to acetone mixture, and then determining its concentration with a spectrophotometer at 450 λ (1, 11). Protein was determined in accordance with procedures as outlined in A.O.A.C. (2). The moisture content was determined by placing the sample in an oven and drying to a constant weight.

Results

The first experiment, in which the plant was exposed to a 4-inch column of heated air, resulted in a fairly straight line relationship between length of drying time

and the reduction of moisture content with temperature. (See Figure 2 and Table 1.) As expected, the higher temperatures resulted in much faster drying. However, at 500° F for 15 seconds, there was considerable singeing of the leaves. Therefore, no further drying was carried out at this temperature. Occasionally, at 400° F the edges of the leaves were singed.

In the second experiment, in which the rotary drier was used, crushing and wilting to 56.3 and 61.9% (Figures 4 and 5) moisture content did not result in sufficiently dry alfalfa for storage when it was dried for

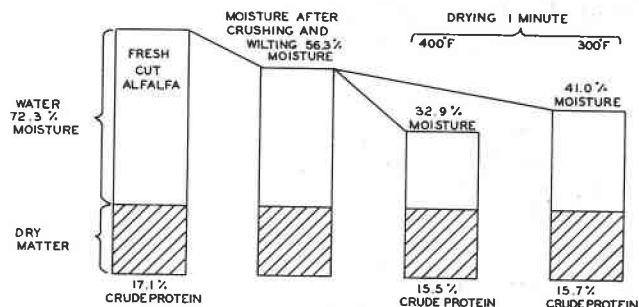


Figure 4. The effect of rapid drying after crushing and wilting alfalfa to 56.3% moisture.

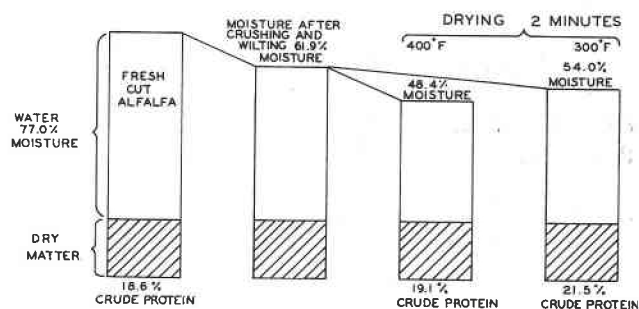


Figure 5. The effect of rapid drying after crushing and wilting alfalfa to 61.9% moisture.

two minutes at either 400° or 300° F. However, when the wilting was carried to 49.7 and 48.0% moisture respectively, drying was fairly satisfactory at 400° F for one and two minutes respectively (Figures 6 and 7). There was no significant change in the percentage of protein due to drying. These results suggested that wilting to a lower moisture content followed by fast drying at 400° F would result in satisfactory drying.

For the third experiment, the rotary drum on the drier was lengthened to 24 inches. Also, the drier was kept full during the drying period so that the exhaust temperature of the air coming from the drier was close to 115° F, the air velocity averaged 70 to 100 feet per minute, and the relative humidity of the discharge air averaged 84%. The air entering the drier was heated to 400° F. The results of this experiment can be seen in Figure 8 and Tables 2 and 3. It was necessary to slow

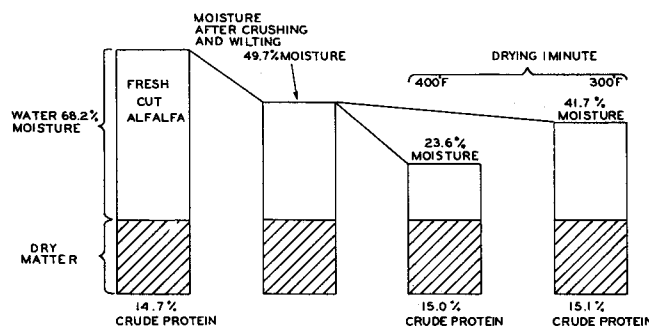


Figure 6. The effect of rapid drying after crushing and wilting alfalfa to 49.7% moisture.

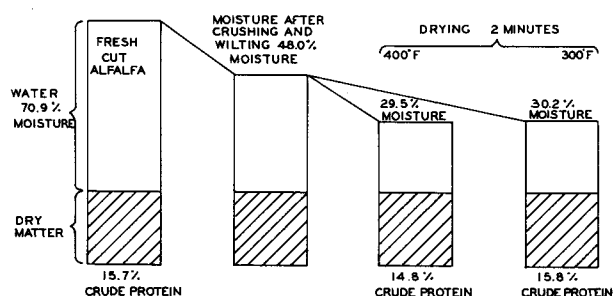


Figure 7. The effect of rapid drying after crushing and wilting alfalfa to 48.0% moisture.

dry to below 40% moisture content before it became possible to fast dry below 30% moisture content (Figure 8). On an average, fast drying for 2.2 minutes lowered the moisture content 7.3 percentage points and for 5.8 minutes, 8.3 percentage points. The protein did not show a definite trend between tests (Table 3).

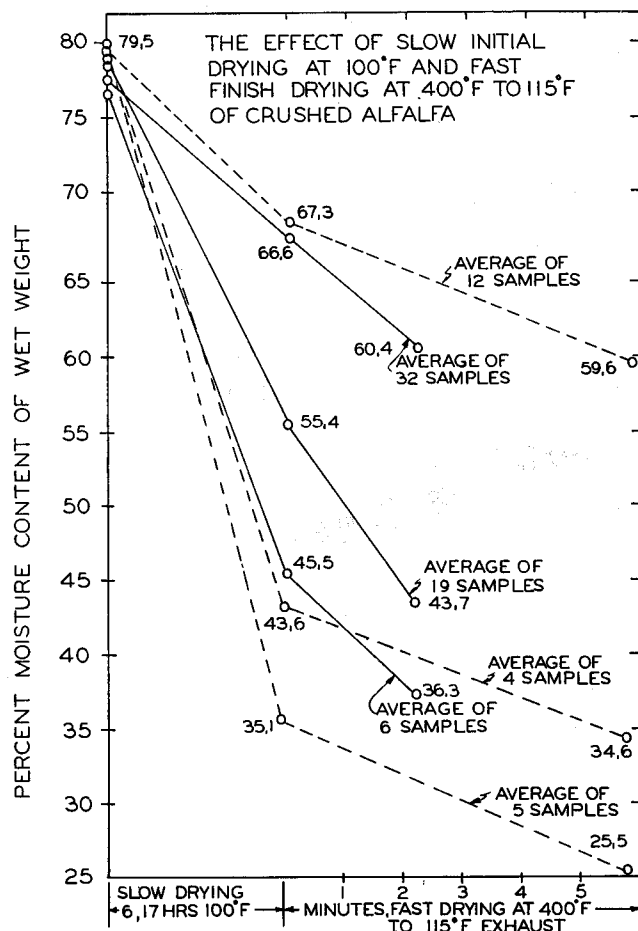


Figure 8. The effect of slow initial drying (100° F) and fast finish drying (400° F incoming air, 115° F exhaust) in a rotary drier on crushed alfalfa.

Table 2. Results of the carotene tests for the third experiment

Treatment	Beta carotene (ppm)					
	1968					
	7/12	7/13	8/15	8/16	Total ¹	Average
Fresh alfalfa	320	150	137	221	828	207
6 hrs. slow drying at 100° F, fast drying (400° F incoming air, 115° F exhaust)	100	120	140	200	560	140
17 hrs. slow drying at 100° F, fast drying (400° F incoming air, 115° F exhaust)	124	59	105	211	499	125

Test of the hypothesis:

$$H = 2\mu_t - \mu_6 - \mu_{17} = 0$$

$$H = 2(828) - 560 - 499 = 0$$

$$F = \frac{Q^2}{S^2} = \frac{\frac{[2(828) - 560 - 499]^2}{4[(2)^2 + (-1)^2 + (-1)^2]}}{\text{Error mean square}} = \frac{14,850}{2,964} = 5.01$$

Values of the F distribution:

$$F_{.10}(1,6) = 3.78$$

$$F_{.05}(1,6) = 5.99$$

$$F_{.01}(1,6) = 13.74$$

¹ The treatment totals suggest that there was a significant difference at the 10% level between fresh alfalfa and alfalfa that had been dried.

Table 3. Effect of wilting and fast drying at 400° F incoming air to 115° F exhaust

	Average initial moisture	Average moisture after wilting at 100° F	Average moisture after fast drying for 2.2 minutes at 400° F	Average initial protein	Average final protein	Number of samples
	%	%	%	%	%	
Average	76.7	45.5	36.3	17.4	18.1	6
S.D. ¹	2.2	3.1	3.1	4.2	4.6	
Average	78.9	55.4	43.7	17.3	18.2	19
S.D.	1.2	2.4	7.5	3.1	4.1	
Average	76.8	66.6	60.4	16.3	17.2	32
S.D.	1.4	2.4	3.7	2.3	2.9	
Average moisture after fast drying for 5.8 minutes at 400° F						
Average	80.3	35.1	25.5	23.8	24.4	5
S.D.	1.8	1.7	3.1	2.3	2.5	
Average	80.2	43.2	34.6	23.0	24.7	4
S.D.	2.3	1.7	6.1	1.5	2.1	
Average	79.5	67.3	59.6	22.2	23.1	12
S.D.	1.0	2.5	5.3	1.6	2.1	

¹ Standard deviation.

The carotene experiment was set up in a factorial 3 x 4 test. The experiments were performed on July 11 and 12 and August 15 and 16. The results of this experiment can be seen in Table 2. While there was a difference in the average carotene content between fresh alfalfa and samples that were slow dried and then fast dried, they were only different statistically at the 10% level of the F test. Part of the difference that occurred for the July experiment was due to some loss of leaves of the dried samples. It was concluded that perhaps there is a difference in the carotene content of fresh alfalfa and alfalfa first slow dried and then fast dried at 400°F, but the difference would not be large.

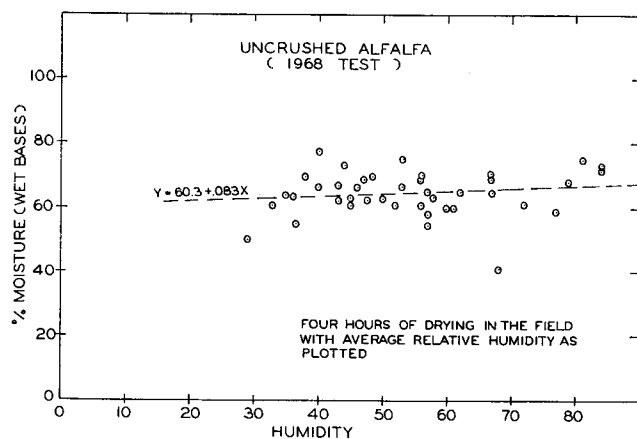


Figure 9. The effect of four hours of field drying upon uncrushed alfalfa.

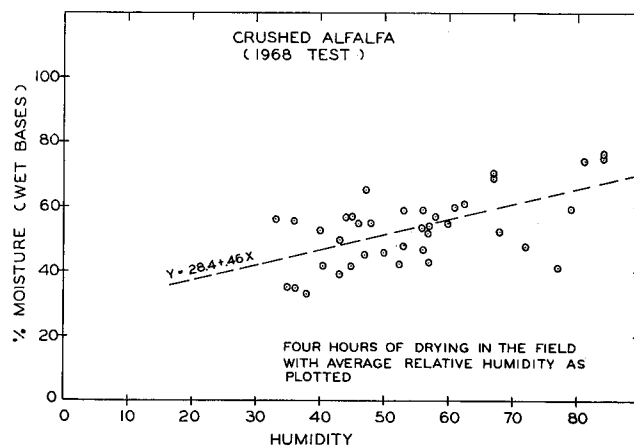


Figure 10. The effect of four hours of field drying upon crushed alfalfa.

The effect of four hours of natural drying of alfalfa on the site at which it was cut is shown in Figures 9 and 10. The coefficients of correlation between the final moisture of the alfalfa and the relative humidities for the crushed and uncrushed alfalfa were 0.603 and 0.168 respectively. Evidently crushed alfalfa responds to a difference in humidity at a much more rapid rate of drying than whole cut alfalfa. It also seems possible that with an average relative humidity of 40% or below in the field, the moisture content of crushed alfalfa would dry to an average of about 40%. This would be a satisfactory moisture content for fast drying in a rotary drier to a safe moisture content for storage of hay.

Discussion

Wilting and then rapid drying at high temperatures (400° F) could result in higher quality hay at a reduced risk and at a small difference in cost over conventional methods. It has generally been concluded that sunlight and rain are the principal causes for the loss of nutrients in hay. By conditioning, wilting, and rapid drying, most of these losses would be reduced. By rapid drying and using conveyors to move the dried forage, there would not be the limitation of capacity for shipping and rehandling that is typical for lower temperature batch-drying systems.

The most serious difficulty with this system is that drying will take place toward the end of the drying time, when limitations on the rate of drying are determined by the speed at which moisture comes to the surface of the materials being dried. If drying is carried out at too high a temperature, scorching of the leaves could take place. If the drying is too slow, the drier will determine the rate at which the process of hay making will proceed. Scorching did not take place at temperatures below 400° F. This agrees, in general, with the work of Longhouse (13). This study indicates that the procedures used could result in a practical method of handling hay in damp weather.

Summary

It is possible to finish dry crushed alfalfa to a relatively safe storage moisture content at high temperatures (400° F) in short intervals. This indicates that it would be possible to handle freshly cut alfalfa by partially wilting alfalfa in the field to approximately 40% moisture and then finish drying it with some type of high temperature (400° F) drier in the barn or storage area.

There was no indication of a reduction of protein and only a small reduction of carotene when the freshly cut alfalfa was compared with alfalfa that was wilted and then fast dried at 400° F. Also, it was possible to wilt freshly cut crushed alfalfa in the field to 40% moisture if the humidity averaged 40% or below for 4 hours.

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