5. T. Hanaoka and K. Fujimoto, *Japan J. Physiol.* **7**, 276 (1957).
6. W. B. Marks, thesis, Johns Hopkins Univ., Baltimore (1963); E. F. MacNichol, Jr., *Vision Research*, in preparation.
7. M. Schultze, *Arch. Mikr. Anat.* **2**, 175 (1866).
8. We thank the staffs of the International Eye Bank, Washington, D.C.; the Department of Pathology, the Osler Medical Clinic, and the Wilmer Ophthamological Institute of the Johns Hopkins Hospital; and the Department of Ophthalmology, University of Maryland School of Medicine for assistance in procuring the necessary human eyes in as dark-adapted a state as possible. Research supported by Grants G18886 and NB 03582 from the National Science Foundation and the National Institutes of Health, and by the National Institutes of Health postdoctoral fellowship BPD 12, 543 (C2).

5 February 1964

Moisture Release from Cut Alfalfa

Abstract. *Mechanical treatment of alfalfa to increase its drying rate is of only limited value because little damage is done to the cellular organization. Killing the plant material with steam markedly increases the drying rate by modifying the permeability of the cuticle or cell membrane, and this may have practical significance in forage preservation.*

Extensive studies by plant physiologists on the moisture relationships of plants have established that adequate turgidity of plant cells is of prime importance; lack of turgidity results in immediate cessation of growth. Adaptations which prevent excess loss of moisture, such as a waxy cuticle and a sensitive means of stomatal control, are vitally necessary for growth but constitute large obstacles to the removal of water during the drying of forage. The initial rapid movement of water from a severed plant soon ends because of stomatal closure, and thereafter water must move through the cuticle or through wounds caused by mechanical treatment (*1*). In this report we present the results of an investigation of water movement from alfalfa, which was treated in various ways and subseqently dried in a laboratory drier.

Crimping and crushing are common practices for increasing the drying rate of forages since they produce wounds, particularly in the stems. In order to determine the extent of damage caused by such treatment, portions of alfalfa stems that had been crimped in a meshed set of gears and then exposed to steam for 2 minutes were cross-sectioned and examined under the microscope. Such a cross section is shown in Fig. 1, from which it is apparent that the epidermis had been cracked and the cells split apart toward the pith, but few cells had actually been broken.

To test the effects of such mechanical treatments on the drying rate, crimped and control samples of Narragansett alfalfa, each having an average weight of 65 g, were dried in a laboratory drier regulated to give a rate of air movement of 17 m^3/min at 35.5°C and 28 percent relative humidity. Four replications were used and the results were statistically analyzed on a computer. Figure 2 shows that there was an initial rapid loss of moisture from all samples, but in the control samples the rate decreased markedly after only 30 minutes of drying. This early flattening out of the drying curve probably resulted from stomatal closure. In the crimped sample, where there is considerably greater access of the moisture to the air, the drying rate may have been limited by the decreasing permeability of the cell walls and cytoplasmic membranes. It has been demonstrated that the resistance of mesophyll cells to viscous flow increases rapidly with loss of moisture (*2*).

Killing the alfalfa by exposure to steam for 2 minutes significantly increased the drying rate, whether or not a mechanical treatment was also used. The increased rate of moisture movement after steaming may be due to the disruption of the plasma membrane and the more rapid movement of the cytoplasmic water as well as the vacuolar water (*3*).

It has been demonstrated that the leaves of alfalfa do not appreciably influence the removal of water from the stem during drying (*1*). In the steamed samples it is not yet clear whether the leaves function as an evaporating surface for an extended length of time or whether the cuticle of the stem, or its waxy covering is modified. Leaf impressions were made of steamed leaves to see if stomatal action had been affected, but the extreme distortion of the leaves prevented measurements. This aspect of the problem is being studied further.

Results of this study reveal that mechanical treatments can increase the rate of drying only up to a point and that the rate of water movement within the plant may also be a limiting factor. Killing the plant prior to drying has important practical implications since the total energy required to dry the plant is much lower. A hot-water treatment was designed by Watson (*4*)

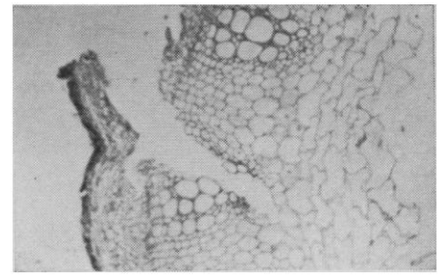

Fig. 1. Cross section of a portion of alfalfa stem which had been crimped and steamed after harvesting.

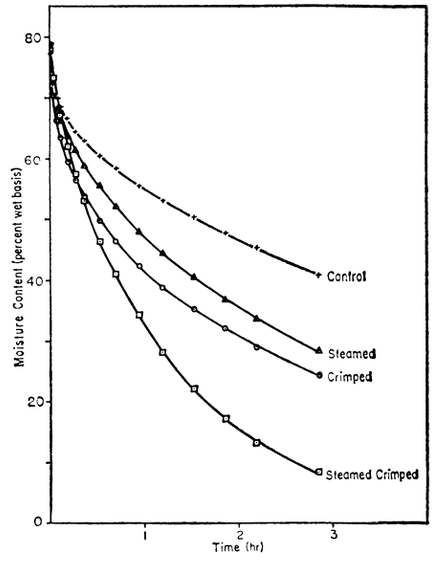

Fig. 2. Comparison of the drying rates of alfalfa after subjecting it to steaming or crimping, or both. The drying conditions were air movement, 17 m^3/min; 35.5°C; relative humidity, 28 percent.

to speed the drying process, but it was considered impractical and was not studied further. Because of the increased use of mechanical harvesters and driers, the killing of plants with either steam or hot water may be a fruitful approach to the problem of moisture release from drying forage, provided no serious effect on nutritive value is found.

G. L. Byers
D. G. Routley
M. W. Colburn
Agricultural Experiment Station, University of New Hampshire, Durham

References and Notes

1. T. T. Pedersen and W. F. Buchele, *Agr. Eng.* **41**, 172 (1960).
2. H. Meidner, *J. Exptl. Botany* **6**, 94 (1955).
3. G. M. P. Myers, *ibid.* **2**, 129 (1951); T. A. Bennet-Clark and D. Bexon, *New Phytologist* **39**, 337 (1940).
4. S. J. Watson, *Fertiliser Feeding Stuffs J.* **1**, (1939).
5. Scientific Contribution No. 323 of the New Hampshire Agricultural Experiment Station.

18 November 1963