but it should be noted that the design of the dryer is of importance. If the material is not removed from the dryer as soon as the dehydration is completed it will be subjected to the action of the hot drying gases and the digestibility of the product and particularly of the protein may suffer. In practice this rarely occurs and is easily identified since the normal green colour of the herbage also is affected by the high temperature. Simultaneously with the loss of green colour in badly dried grass, the carotene is destroyed, whereas in properly treated material it is retained almost unchanged. During subsequent storage of the dried product there may be a loss of carotene which is related to the exposure of the material to the action of air and light. If the grass is properly stored in a cool dark place the losses can be kept to a low level.

In recent years there has been a revival of the old process of ensilage of green crops in which they undergo a controlled fermentation (Watson, 1939). The details of the process are more clearly understood today, control of the changes is more certain and the operation is every-day practice on the farm. The losses are of the order of 20 per cent. of the dry matter and fall evenly on most of the constituents. The nutrient loss is therefore of the same order and is due in the main to respiration and to a lesser extent to loss from leaching of some of the soluble nutrients, together with some breakdown of the fermentable substances by micro-organisms. After the original loss there is very little change during storage if a good container has been used to ensile the green crop. The final product is equal in feeding value to the original crop and retains its carotene in a large measure.

Enough has been said to show that the conservation of foodstuffs on the farm will always entail losses, some of which can be avoided by taking the necessary precautions. More information is needed if adequate steps are to be taken to reduce the loss of feeding value of farm crops in the storage period. Until that is done we shall not make the best of our resources or produce the maximum yield of food from the land.

REFERENCES

Flegel, K. (1931). *Z. Zücht. B.* **22**, 34.
Isaachsen, H., Ulvesli, O. and Husby, M. (1936). *Norg. Landbrukshøisk. Beretn. ForForsøk.* no. 43.
Kellner, O. (1915). *The Scientific Feeding of Animals.* London: Duckworth.
Kirsch, W. and Jantzon, H. (1932). *Biederm. Zbl.* (*B.*) *Tierernährung*, **4**, 240.
Kröner, W. and Steinhoff, G. (1937). *Biochem. Z.* **294**, 138.
Miller, N. H. J. (1900). *J. R. agric. Soc.* **61**, 57.
Miller, N. H. J. (1902). *J. R. agric. Soc.* **63**, 135.
Pyne, G. T. (1927). *J. Dep. Lands Agric., Dubl.*, **27**, 33.
Richardson, J. E. and Mayfield, H. L. (1933). *Bull. Mont. agric. Exp. Sta.* no. 277.
Shutt, F. T. (1901). *Rep. exp. Fms Can.* 1901, p. 163.
Thiossen, E. J. (1936). *Bull. Wyo. agric. Exp. Sta.* no. 213.
Watson, S. J. (1939). *The Science and Practice of Conservation.* London: The Fertilizer and Feeding Stuffs Journal.
Watson, S. J., Ferguson, W. S. and Horton, E. A. (1937). *J. agric. Sci.* **27**, 224.
Wiegner, G. (1925). *Mitt. dtsch. LandwGes.* **40**, 325.

Discussion

Mr. W. Holmes (Hannah Dairy Research Institute, Kirkhill, Ayr), opener: Dr. Watson has dealt very fully with conservation of home produced feeding stuffs, and I propose to discuss only a few points and

then describe briefly some work done at the Hannah Institute on preservation of concentrated feeding stuffs including imported products such as oilcakes.

Dr. Watson dealt fully with cereals, but leguminous crops such as beans and peas received rather less attention. These crops are more difficult to dry in a bad harvest than corn crops, and so are much more liable to deterioration by moulding. Any data Dr. Watson could give on the storage of these crops would be appreciated.

Grass is the chief crop of the British farmer, and losses in its conservation are of considerable importance. It therefore comes as a shock to him to learn that haymaking may carry a 30 per cent. loss. In spite of this, however, haymaking will remain one of the main methods of conservation, and we must hope for some reduction in losses with the application of modern techniques. An intensive silage-making campaign launched in the early years of the war has been relatively unsuccessful, chiefly, I think, through the failure of farmers to appreciate fully the principles involved. When their early attempts turned out to be unsuccessful, they were discouraged and did not try again.

While in its farming policy the Hannah Institute has concentrated on the production of home grown feeding stuffs, much research work has been done by Snow (1944, 1945) and Snow, Crichton and Wright, (1944, 1, 2) on the storage of imported feeding stuffs with particular reference to deterioration by moulding.

Stored concentrated feeding stuffs are liable to three main types of deterioration:

1. Heating due to respiration. This causes caking of the material, charring, and in some cases spontaneous combustion. Each of these changes renders the material unpalatable so that the total loss is greater than the actual physical loss due to oxidation of carbohydrates.
2. Deterioration caused by insect pests such as mites and weevils.
3. Deterioration caused by moulds which lower the value of feeding stuffs by making them unpalatable. In the case of some moulds the mycelium may be poisonous.

All three forms of deterioration are largely influenced by the moisture content of the feeding stuff. This has been found to be closely related to the prevailing relative humidity of the atmosphere. It has been established that for storage up to three months, the relative humidity should be below 72 per cent., while for longer periods a humidity of 65 per cent. is desirable for safety. These conditions are difficult to attain in some war time emergency stores.

The practical observation that moulding is more frequent in summer was borne out by experiments which showed mould growth to appear more rapidly on feeding stuffs held at 22° C. than on material held at 15° C.

The chemical composition of the feeding stuff also influences its liability to moulding. Experiments in which relatively pure samples of protein, carbohydrate and fibre were held at fixed humidities, showed that the water uptake, and therefore the liability to moulding, of carbohydrate was greater than that of protein between 40 and 80 per cent. humidity.

Above 80 per cent., the position was reversed. Fibre was shown to be relatively inert. Experiments with feeding stuffs in which either carbohydrate or protein predominated confirmed these findings.

The species of mould and the length of storage also were of importance. Only some of the more resistant *Aspergilli* could grow at less than 75 per cent. humidity. A long storage period resulted in greater moulding than a short period.

In addition to defining the physical factors influencing mould deterioration of feeding stuffs, Snow and Watts (1945) made some experiments on the prevention of mould growth. One of particular interest was the use of solutions of sulphonamide drugs sprayed on cakes of the feeding stuffs. It was found that 2 per cent. solutions in alcohol of sulphonamide E.O.S., or of propamidine, sprayed on the surface of linseed cake, doubled its storage life at the relatively high humidity of 80 to 85 per cent.

A further interesting point arising from this work on feeding stuffs is the differential deterioration of their different constituents. In trials on the storage of bran (Snow and Wright, 1945) and other feeding stuffs (Snow, Smith and Wright, 1945), an apparent increase in nitrogen content was found after four weeks' storage. Although nitrogen fixation by moulds might be a contributory factor, further investigation showed that there had been an actual loss of dry matter, with the result that the ratio of dry matter to nitrogen was decreased. In discussing the conservation of potatoes and grass products Dr. Watson has emphasized the loss of dry matter which takes place. These latter experiments of Snow and others show that a loss in dry matter can take place also with imported feeding stuffs unless the storage conditions are carefully controlled.

REFERENCES

Snow, D. (1944). *Fertil. Feed. St. J.* **30**, 407.
Snow, D. (1945). *Ann. appl. Biol.* **32**, 40.
Snow, D., Crichton, M. H. G. and Wright, N. C. (1944, 1). *Ann. appl. Biol.* **31**, 11.
Snow, D., Crichton, M. H. G. and Wright, N. C. (1944, 2). *Ann. appl. Biol.* **31**, 102.
Snow, D., Smith, J. A. B. and Wright, N. C. (1945). *J. agric. Sci.* **35**, 65.
Snow, D. and Watts, P. S. (1945). *Ann. appl. Biol.* **32**, 102.
Snow, D. and Wright, N. C. (1945). *J. agric. Sci.* **35**, 126.

Mr. M. Jones (North of Scotland College of Agriculture, Aberdeen): One thing which is important in the application of these methods of conservation in Scotland, especially in the west, is the cost of drying under Scottish climatic conditions. Silage making is an alternative to haymaking. The farmer has to realize that if he were to aim at cutting the crop at half the size he would get better feeding material. One of the problems of feeding stock today is to get protein but to get it without much fibre.

PRINTED BY W. HEFFER & SONS LTD., CAMBRIDGE, ENGLAND