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CURRENT RESEARCH AND PRACTICE IN SILAGE MAKING OVERSEAS

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BEFORE discussing practical silage making, it is necessary that a confused theoretical picture be cleared up. The aim therefore in this paper is first to summarize work from abroad on the role of the factors consolidation, aeration, temperature, and water in the silage fermentation, and then to comment on certain aspects of applied silage making.

The "warm fermentation" hypothesis which is the basis of silage making in New Zealand, is universally taught and practised in Britain. It is regarded sceptically in the United States, and completely rejected in the Western European countries visited. Since this hypothesis is so widely accepted and practised yet also widely rejected, it is of interest to examine its validity in terms of findings of recent and current investigations.

It is universally accepted that the silage fermentation is predominantly a lactic acid one, and that this acid has to be produced in sufficient quantity and with sufficient speed to suppress the undesirable secondary butyric acid fermentation. From here, the "warm fermentation" hypothesis proceeds as follows: Butyric acid is produced under anaerobic conditions only; lactic acid is produced under both anaerobic or slightly aerobic conditions. Therefore, in the initial stages of the silage fermentation, limited amounts of oxygen should be admitted to the fermenting system to suppress the anaerobes—the butyric producers—and encourage the facultative anaerobes—the lactic producers. Admission of air causes a rise in temperature, the amount of which is taken as an indication of the effectiveness of the control of aeration. Optimum aeration is achieved when temperatures are in the vicinity of blood heat—whence warm fermentation. There is considerable conflict as to whether temperature *per se* has any role in silage fermentation, but it is obvious from discussions with many silage makers and their advisers in Britain that temperature *per se* is regarded as having an important beneficial role. Temperature effect, therefore, becomes another issue for consideration.

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This issue was discussed with a number of German people and it appears that they accept without further question German work of the 1925-30 period, which they claimed shows the range 25° C to 40° C to be the least suitable for the silage fermentation since this range is optimum for the butyric fermentation. Swedish workers are still actively interested in the point, and some of their results (1) are quoted below.

Working with clover dominant herbage mixtures, a series of anaerobic silage fermentations were set up and maintained at temperatures ranging from 2° C to 32° C.

Their results may be summarized as follows:

(1) At all temperatures a satisfactory lactic acid fermentation was initiated, though slowest at the lowest temperature.

(2) Lactic acid subsequently disappeared more rapidly at 24° C and 32° C.

(3) Butyric acid production was negligible at lower temperatures, substantial at 24° C and 32° C.

The role of consolidation and aeration is being studied by a number of groups, notably one at the Agricultural Research Centre, Beltsville, U.S.A. Some of their results have been pulished recently (2) and they describe experiments in ensiling first, second and third cuts of cocksfoot and of lucerne. Each of these harvests was submitted to four degrees of initial aeration ranging from anaerobic, obtained by heavy consolidation and immediate sealing and weighting, to aerobic, obtained by pumping air into the system for a short time.

A large amount of chemical and bacteriological data was obtained from serial samplings, and, although some apparent inconsistencies occurred, certain generalizations apply to all experiments.

(1) The lag phase of butyric acid-producing bacteria is substantially longer than that of lactic acid producers and is not affected by aeration.

(2) The initiation of the lactic acid fermentation was not affected by aeration.

(3) The more complete the exclusion of air, the more stable the silages in storage.

These findings are in line with observations at Ruakura, which show a similar butyric lag phase picture, and similar initiation of lactic production under different degrees of aeration and similar stability-aeration relationships. It appears from this evidence that the attempt to control primary and secondary silage fermentations by aeration is unlikely to be successful. Hence the basic premise of the "warm fermentation" hypothesis must be discarded.

In the Beltsville data, the relationship between degree of aeration and stability of the silage was variable and appeared to be affected by the nature of the ensiled material. Certain harvests gave unsatisfactory fermentations and unstable silages irrespective of aeration, whilst others responded markedly to aeration treatment. This type of situation may be of great importance in explaining the failures commonly associated with cold fermentations of certain herbages.

In the United Kingdom, excluding Northern Ireland, it appeared that active research on silage making is in progress at two centres only, namely, N.I.R.D., Shinfield, and the Edinburgh School of Agriculture. At both places there is great interest in the "warm fermentation" hypothesis, and experiments pertinent to it have recently been undertaken.

The method adopted by Dr Murdock (pers. comm.) at Shinfield was to relate vertical distribution of temperatures in 15 ft high pilot tower silos with the composition of the silage produced, using a mixed herbage (timothy, cocksfoot, meadow fescue) as starting material. Some consolidation was imposed on the material at the commencement only of filling the silos, the weight of the ensiled material being considered sufficient to provide a consolidation gradient. Chopped material was used in one silo, unchopped in the other. With chopped material, low temperatures were associated with high lactic, low butyric acid levels, whilst with high temperatures the reverse was the case. No such relationship was found with unchopped material.

There are insufficient data to explain the difference in behaviour of the chopped and unchopped material. However, the difference could be associated with rate of lactic acid production. The lactic acid potential of the chopped and unchopped herbage was presumably the same, but with unchopped material the rate of lactic acid production could have been so slow that at no stage did it reach a sufficiently high concentration to inhibit butyric formation. Consequently, all formed lactic acid would eventually have been destroyed.

At Edinburgh, a considerable amount of fundamental biochemistry and bacteriology of the silage fermentation has been completed under two 5-year A.R.C. grants. In current work, Dr McDonald (pers. comm.) is studying the effects of compaction, aeration, water and also bacterial inoculations on the resulting silages. using Italian ryegrass as test material.

In recent experiments, four rates of consolidation were imposed, giving mean maximum temperatures ranging from 70° F to 111° F. It was found that in all four treatments the pH figures were similar, indicating good fermentations. However, substantially greater lactic acid production was associated with the lowest temperature, whilst dry matter losses in the 70° F silage were half those in the 111° F silage.

It is generally believed that the water content of a crop plays an important role in the silage fermentation, but it is little understood and the writer did not find much active interest in the question during the greater part of his travels. At Wageningen, Netherlands, it was discovered that S. W. Wieringa has adopted an approach which is likely to be most useful when further developed.

This approach emphasizes a role of osmotic pressure in silage stability. Osmotic pressure is determined by the concentration and character of solutes in aqueous solution and would obviously be a variable in silage fermentations. It is known to have an important influence in many biological processes. In the silage fermentation, various phenomena have been vaguely associated with water content, but the introduction of the osmotic pressure concept may provide a more accurate and more logical basis for explaining these phenomena.

Wieringa has been studying the interrelationship between pH, osmotic pressure and butyric acid fermentation [3]. It is evident from his data that for any given osmotic pressure there is a specific pH value below which butyric production is inhibited. This means that if water is removed from grass a higher pH than normally accepted will suffice to stabilize silage. It follows also that even though an acceptably low pH may be reached in silage, it cannot remain stable if the osmotic pressure is too low, a situation probably quite common in high moisture silages. This explanation of the failure of material, high in water content, to ensile satisfactorily, appears far more logical than the usual one of over-consolidation and under-heating.

As proposed at the beginning of this paper, the "warm fermentation" hypothesis was set up for critical examination. No data have been found which support it, and much which refute it. Controlled aeration has been shown to have no beneficial effect on the lactic acid fermentation, and no detrimental effect on the butyric acid fermentation.

Indeed, it has two notable disadvantages. These are:

(1) It destroys lactic acid precursors.

(2) It produces heat which encourages butyric acid production.

In considering practical silage making, it seems that insufficient weight is given to the influence of the ensiled crop on the resultant silage. Some evidence has been submitted in this paper which indicates this influence may be profound, and more evidence is available. It is suggested that practical men, concerned more with mechanics and engineering of harvesting and ensiling, have been so impressed with the dangers of over-consolidation and under-heating that other possible causes of failure have been overlooked.

If the ensiled crop contains insufficient sugar or is otherwise unsatisfactory for ensilage, a stable silage cannot be made without some modifying treatment, for example, wilting or the use of additives. There is no theoretical reason yet advanced, or experimental evidence, to support the contention that the modifying treatment of aeration and heating will increase the chance of successfully ensiling such material.

The writer had the best opportunity in Britain to observe and discuss the application of research findings to practical silage making. It is felt that confused thinking on the theoretical side is reflected in some confusion on the applied side. The most obviously spectacular advances have been made in design and development of harvesting equipment. The flail type harvester puts into practice the findings of Dutch and British research work which demonstrated the advantages of bruising and lacerating herbage. One of the advantages claimed for laceration is that it enables greater consolidation to be obtained, yet full advantage is not taken of this, since the necessity to delay filling and consolidation in order to allow for heat development is universally advocated and practised. On the other hand, a commercial group in England is experimenting with vacuum silage, the vacuum being achieved by enclosing the ensiled material in a plastic envelope and evacuating the air. On theoretical grounds this seems to approach the ideal procedure, but it is obviously the direct antithesis of accepted theory and practice in Britain.

The ability of flail-type harvesters to cut and transport immature herbage is another advantage claimed for these machines, but some caution is necessary in applying the idea. For various reasons already discussed, young herbage may not form a stable silage without modification. The introduction of the wilting step, though desirable, would hardly fit in with the use of flail harvesters. However, these machines are readily adapted to be fitted with a hopper for metering and delivering powdered additives, and it is quite possible that present ensiling tendencies will encourage the introduction of additives in the near future.

Self-feeding is gaining in popularity, and in turn is helping to boost silage usage in Britain, but this, too, brings its problems in silo construction and filling. Silos for self-feeding must necessarily be restricted to 5 to 6 ft in height, hence the tendency to build large shallow bunker silos which result in maximum exposure of ensiled material to aerial oxidation both during filling and in storage.

Although one may assume *a priori* that covering reduces waste, nevertheless quantitative measurements on top and side wastage do not appear to have been made, and the writer met with no active interest in this problem. Without such measurements the economics of silage covering cannot be calculated, yet the British Government subsidizes the building of covered silos, while quite expensive plastic covers are now being marketed everywhere. The observations of Ruakura workers would support the use of plastic covers, but they have no quantitative data on this. Incidentally, any trend towards covering of silage may not be compatible with the development of self-feed silos. The economic use of plastic covers demands that the geometry of the silo should be such that the finished silage presents the minimum surface area to be covered, whereas the self-feed silo tends to produce maximum surface area per unit volume of silage.

Modern research on silage has returned to the more fundamental, and, in view of the large amounts of capital which may now be put into harvesting equipment and silos, this is highly desirable. It is necessary that the principles of the silage fermentation be thoroughly established, so that design of equipment can be objectively directed. At the same time, this greater capitalization of silage conservation necessitates more applied research into the economics of the process, and this appears to be lacking at the moment.

Literature Cited

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DISCUSSION

Q.: *Attempts to ensile paspalum in Australia have met with failure. Why does paspalum not make good silage? Trials with vacuum silage making in Australia are apparently successful, using a heavy plastic dome to achieve the vacuum and replacing with a lighter sheet a week later.*

A.: I question the worth of the method if it requires changing of the dome. Ruakura has used 5/1,000 sheet to achieve the vacuum, with apparent success. I cannot offer explanations of failures in silage making without adequate information which we do not have on paspalum.

Q.: *Is the difference in lactic acid production in chopped and unchopped material due to greater availability of juices in chopped material? If so, perhaps the juices are not released readily from paspalum, hence too slow lactic acid production.*

A.: The relative effects on fermentation of juice flow and compaction have not been measured, but poor rate of juice flow might well be the explanation of difficulties with paspalum.

Q.: *Have you any comments on overseas use of additives?*

A.: Nitrite-formate mixtures are being strongly pushed in Germany and the U.K., but evidence of their value is conflicting. Of the acids, formic is considered excellent but is still too expensive. A.I.V. is popular only in Norway and Finland. In Sweden, a new development is interesting, namely, use of malted ground grains. Much better fermentations are claimed with the malted material than otherwise.

Q.: *What is the optimum stage of growth for cutting in terms of digestible nutrients and silage quality?*

A.: At flower head movement when sugars are high and digestibility is high.

Q.: *The height to which pasture is cut for silage is important. It is best cut high because sugars are low in the stem. If it is cut low, aftermath recovery is adversely affected. Does Mr Lancaster agree?*

A.: I am not sure that sugars are lower in the stem than in the leaf, but I would agree from the pasture management point of view. However, with pre-flowering material one should cut below the developing flower head.

Q.: *How quickly can sugar levels change and what are the ranges?*

A.: A change from 10 to 15 per cent. is possible from day to day according to weather. In ryegrass the range is about 10 to 30 per cent. but it can go over 30 per cent. in Italian ryegrass. The levels found in investigations at Grasslands were generally lower, but this was with tightly grazed pasture.

DR A. T. JOHNS: Those pastures were about two inches high. Soil fertility and climatic conditions affect sugar levels, hence overseas results cannot be directly applied to New Zealand conditions.