SILAGE: THE RESEARCH VIEWPOINT

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Introduction

IN 1958, there was available commercially in Britain and Australia a vacuum silage kit which was expensive and useless. It had one redeeming feature, however. It inspired Jean Doutre to work on the vacuum idea, and, in collaboration with George Jowsey, to develop the technique which has captured world-wide interest. It is' relatively inexpensive for this approach to silage making and is practical. It has the great merit that it can be built into the existing New Zealand silage-making procedures without any modifications to those procedures.

The idea of using vacuum compression in silage making is an exciting one, as it offers a technique of applying perfectly the cold fermentation theory advocated in New Zealand since 1960. If the idea is to get the air out and keep it out, here certainly is the way to do it.

In the pre-vacuum era, conventional ensilage techniques aimed to do this by rapid filling to minimize exposure of crop to air, by laceration which aids compaction, by heavy consolidation with tractor and vehicles delivering the loads, and by prompt covering with plastic film. Vacuum compression uses all of these techniques, and in addition should be more effective in arresting heating by heavier and more even consolidation, and by withdrawal of air. If the cold fermentation theory is valid, there is good reason to expect that vacuum compression should give better results than conventional methods. It is on the basis of this expectancy that vacuum silage has been offered commercially, and has received such wide acceptance.

Before presenting the experiments conducted at Ruakura Agricultural Research Centre to evaluate the vacuum technique, it is proposed to theorize a little on silage fermentation.

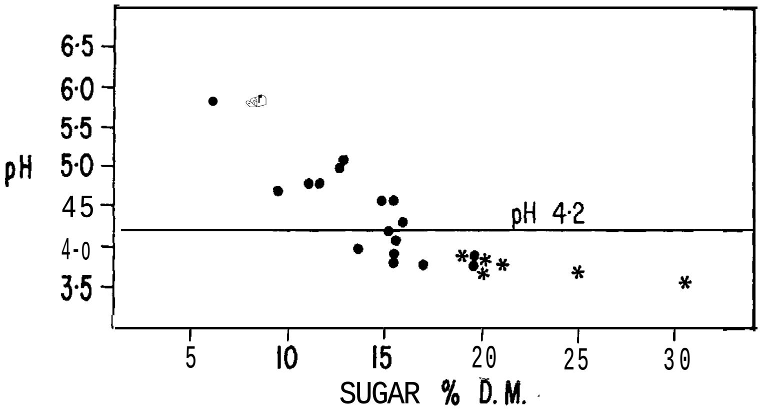

FIG. 1: *Silage in micro-vat-pats. Temperature 73°F.*

Silage results from the spontaneous fermentation of sugar to lactic acid when a crop is compressed. The greater the production of lactic acid, the better the quality of the silage. Better quality silage would therefore be expected from a crop rich in sugar.

It seemed important to examine the relation between sugar content of ensiled herbage and silage quality. To do this, a series of experiments was set up in laboratory vacuum silos-"micro-vat-pats". These are made by filling a bag with 2 kg grass and closing the open end with a foot of strip-seal. The air is sucked out through a valve at the other end and the bag stored in a cool place for 90 days.

Ninety-six of these, containing 24 varieties of- herbage, were set up at 73" and 97°F for 90 days. Figure 1, in which sugar content of the herbages is plotted against pH values of the resulting silage, summarizes some of the data. (Throughout this paper, pH values will be used to express silage quality. pH measures the acidity of the silage. The normal range, 3.5 to 6.0, is shown on the graph-the lower the pH, the greater the acidity and the better the fermentation. The pH value 4.2 was established over 30 years ago by Virtanen as the point at which biological activity ceased in silage.)

If this pH–sugar relation had been a linear one it would have caused no comment. It is the pronounced curve which is of interest. Over the higher range of sugar contents, sugar level had little effect on pH, but, in the lower range, pH was much more sensitive to sugar content. Below 10% sugar it is doubtful whether the term "silage" is applicable.

At the higher temperature (97°F) many more stinking silages were produced than at 73°F. At 97°, pH values averaged 0.5 units higher than at 73". The differences were less at the higher sugar levels and the samples marked "x" gave values of 4.2 or less at the higher temperature.

This leads to the conclusion that, when ensiled herbage contains plenty of sugar, the lactic acid fermentation is strong enough to control the harmful bacteria and maintain a stable silage even at the higher temperatures. Stability may be achieved with a weaker fermentation only at lower temperatures.

It is not suggested that these results apply quantitatively to field conditions, *i.e.*, that they can be used to predict a sugar threshold. The curvilinear relation, however, is regarded as valid in field silage, and, on this basis, one would predict that vacuum compression would be likely to give improved fermentation only in cases where grass sugar levels are low.

Field Scale Experiments

The field scale experiments, commenced at Ruakura in 1964, and still continuing, will now be considered.

Five separate tests have been completed each using roughly 180 tons of grass. Each test involved three duplicated treatments, hence 30 tons of grass were used in an individual replicate.

EXPERIMENTAL DETAILS

Treatments were as follows:

(1) "Bunker": 12 ft x 24 ft x 3 ft concrete bunkers, filled with grass and covered with polythene film. Bunkers used were closed at one end with a permanent ramp, and at the other with movable boards. When in position the boards were covered with polythene film.

(2) "Vacuum": 24 ft × 36 ft rectangular stacks, vacuum compressed.

(3) "Stack" : 24ft x 36ft rectangular stacks built similarly to the vacuum stacks direct on the ground and covered with polythene, but not evacuated.

ENSILING PROCEDURE

Herbage from typical New Zealand mixed dairy pastures, perennial ryegrass, short rotation ryegrass and white clover was harvested with flail type machines, weighed, sampled and assigned in rotation to one of six stacks, two "bunker", two "stack", two "vacuum". Each load tipped on the stack was hand forked, and rolled with a 35 cwt tractor.

At the end of each day, all were covered with black polythene film, which was weighted with motor car tyres. The covers of the vacuum stacks were sealed to the ground sheet, and vacuum compressed to **15** in. of mercury. At the end of the last day of filling, and after evacuation, the covers on all stacks were weighted with a 6-inch layer of sawdust.

REMOVAL OF SILAGES

Covering material was carefully stripped off the section to be removed and waste was separated, weighed, sampled and discarded. Edible silage was loaded into a trailer, weighed, sampled and fed out.

RESULTS

Mean maximum temperatures were : "bunker", 95"; "vacuum", 85°; "stack" 99°F. In all treatments, temperature had decreased to below 70° within 3 months.

Silage Quality

Table 1 gives some data on grasses ensiled and silages resulting. They are arranged in descending order of sugar content from 21% to 11%. The herbages used in experiments 1, 2, and 3 were typical silage grasses cut at flowering of the ryegrass; those in numbers 4 and 5 were cut at an earlier stage of growth to attempt to produce grass low in sugar.

Of the silages, "vacuum" is seen to be of uniformly low pH irrespective of sugar level. "Stack" shows higher pH

TABLE 1: GRASS AND SILAGE QUALITY

Experiment		Grass D.M. (%)	Grass Sugar (% D.M.)	Grass Protein (% D.M.)	Silage (pH) Bunker	Silage (pH) Vacuum	Silage (pH) Stack
1964-5	1	18	21	13	4.04	3.91	4.25
	2	16	19	14	4.28	4.00	4.38
1965-6	3	16	14	14	4.13	3.92	4.56
	4	18	12	18	4.32	4.04	4.58
	5	21	11	16	4.66	4.14	4.74

which increases noticeably with decreasing sugar content. “Bunker” is intermediate between “vacuum” and “stack” and the increase in pH with decreasing sugar is less marked. These results are in line with the predictions based on the laboratory study.

Although small differences in silage quality may be demonstrated by pH and other measurements, the real issue must be decided by the cow or the sheep. Last year, the silages from experiment 2 were submitted by J. B. Hutton and associates to nutrition test with milking cows. These animals failed to recognize the difference between pH 4.00 and 4.38, highly significant though this difference was to the statistician. The cows gave similar results in all quantities measured. Silage No. 4 is currently under a similar test.

The results obtained with these 30-ton quantities must be extrapolated to the commercial 200-ton level with caution. Heat losses from small stacks would be more rapid than from larger’ ones, hence any temperature differential due to treatment would remain for a shorter period than normal. This would bias results against vacuum silage.

On the other hand, the ensiling rate in the trials, 50 tons/day distributed around six stacks, was considerably slower than normal in the industry. This could affect all treatments adversely, but “vacuum” least since it was daily sealed and evacuated.

Quantities Recovered

Table 2 gives recoveries of dry matter as edible silage, and as rot. No data are available from experiment 4; the silage is being fed in the current milking test.

TABLE 2: DRY MATTER RECOVERIES
(D.M. Recovered as % D.M. Ensiled)

Experiment		Edible Silage Bunker	Vacuum	Stack	Rot Bunker	Vacuum	Stack
1964–5	1	90	88	89	1’	2	3
	2	69	73	67	6	6	8
1965-6	3	84	88	76	2	0	4
	4	—	—	—	—	—	—
	5	83	92	83	1	0	2

In 1964-5, punctures which occurred on all vacuum stacks were not repaired with sufficient promptness, and surface rot occurred to a similar extent in “vacuum” and “stack” treatments. The nest year, 0.005 in. instead of 0.003 in. polythene was used, and weekly maintenance inspections were carried out on both “vacuum” and “stack”. “Vacuum” gave negligible rot, but careful maintenance of covers on “stack” did not reduce surface rotting.

Perfect maintenance would be difficult on the commercial farm when 0.003 in. polythene is used and the results in experiments 1 and 2 might accord with those likely in practice. Because experiments 3 and 5 only were successfully maintained during storage, they provide the only valid measurements of the efficiency of the vacuum method. The results with vacuum may represent the best that can be achieved with high moisture material. Some loss from drainage is inevitable, and although measurements of drainage were not taken in this work, it may be deduced from other Ruakura studies and from overseas reports that drainage losses of up to 5% are ‘possible in No. 3, considerably less in No. 5.

The results shown in Table 2 must again be scaled to the commercial level with caution. Where losses are due to surface effects, percentage losses are maximized owing to high surface/volume ratio of the small stack. In this respect, “vacuum” was favoured in these experiments, and smaller percentage differences might be expected in normal sized stacks.

The bunkers used in these experiments possessed faults readily eliminated from the commercial trench. Considerable zones of rot occurred at the corners, and particularly at the boarded end. This fault could be eliminated in bunkers or trenches without end structures. In these, the grass is ramped at both ends to provide the surface for covering with weighted plastic.

The efficiency of the conventional non-vacuum stack, top covered only, will depend on the dimensions of the stack. Cross-section studies at Ruakura have revealed little change in silage quality in the vertical, hence there seems to be no merit in building a deep stack. Maximum efficiency would be achieved by building it shallow, increasing the width of ramped ends and so reducing side area.

To sum up, vacuum compression has been shown to yield silages chemically superior to orthodox silages, particularly with difficult material. It is likely that the average farmer would produce uniformly better silage by using vacuum than by conventional methods. This is because vacuum compression imposes reproducible conditions on the ensiled material, whereas the various interpretations of the orthodox method would yield less predictable results. The vacuum technique has been shown to give minimal losses with negligible rot. Whether this obtains in practice will depend entirely on the skill and zeal of the individual operator.

Finally, what are the economics of these three methods? Table 3 provides the answer. The calculations are based on 100 tons of silage. Losses are based on the data presented in this paper except for the 50% for no cover for which no data are available.

Since quality differences have not been shown to be of economic importance, silages by all three methods are valued at £2 a ton if hay is 5s. a bale. Costs for bunker are based on capital of f200 on which interest and depreciation are charged over 20 years. Roll 0.003 in. film is used to cover stack and bunker. Net index is derived by subtracting from the value of the original silage, £200, the value of silage lost plus cost of storage.

TABLE 3: ECONOMICS ON 100 TONS SILAGE

Method	Loss (Ton)	Value of Silage Loss	cost of Silage Storage	Net Index
No cover	50	100	Nil	100
Covered stack""	20	40	12	148
Bunker	15	30	30	140
Vacuum	10	20	53	127

It is clear that the law of diminishing returns is well exemplified here. The largest gain results from the simplest and least costly step of covering a stack. Each further gain is achieved at greater expense.

Besides being the most costly, the vacuum technique is fiddling and time-consuming. There are, however, a number of important advantages. Self-feeding is more easily initiated; vacuum shares with the conventional stack the advantage of being more flexible than bunker; vacuum allows of intermittent filling-a very useful factor where silaging operations must be suspended for an indefinite period.

Vacuum silage has certainly introduced good silage to many farmers who had never seen it before, and it has underlined the principles of silage making. If anyone who has discovered vacuum silage should weary of the vacuum part of it, it is hoped that they will continue to apply the principles learned from it to make silage by more orthodox procedures.

DISCUSSION

What results have been obtained from lucerne used for silage?

Vacuum and conventional methods of ensiling lucerne have not been compared. One would expect the vacuum technique to show up favourably with lucerne.

What results have been obtained from the use of odditives?

Additives appear to be all or nothing in action. Sufficient must always be used to control the fermentation. If half the required amount is used, the effect may be not half of that of the full dose, but nothing. The results of applying additives are therefore likely to be variable. I believe vacuum compression would achieve a more positive control of fermentation.

Would not vacuum silage quality be better because of reduced respiration?

Negligible amounts of sugar are lost in raising grass temperatures to 100 deg. F by respiration, provided no heat is lost. It appears that the higher temperatures caused by respiration are responsible for poorer fermentation. The main effect of vacuum compression is to suppress the temperature rise.

Is not high sugar material better in nutritive value and therefore better than pH as an indicator to quality?

By the time the silage fermentation is completed, most fermentable sugar has disappeared. pH is regarded as the best single indicator of the quality of the fermentation.

With increased stocking should not the amount of silage conserved decrease and because of this would not vacuum silage become more expensive?

The smaller the tonnage of silage made the greater the cost per ton fed, whatever the method of storage, particularly vacuum silage. If it is true that increased stocking rates are leading to decrease in conservation of hay and silage, this is a serious matter. We must surely be heading for trouble on a national basis if stocking rates are pushed to such a level that adequate conserved fodder cannot be saved.

Should clover-dominant swards be made for silage?

I would avoid this if possible. Ryegrass-white clover pastures containing up to 25% clover ensile readily, but above this level chances of failure increase.

What is the minimum economic size for vacuum silage?

I do not know, but I suggest 50 tons as a reasonable minimum.