Baled Silage - Development Of Reliable Baled Silage Systems

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DEVELOPMENT OF RELIABLE BALED SILAGE SYSTEMS

Baled silage is now made on two-thirds of all farms in Ireland, and accounts for one third of all silage made. It is particularly prevalent as the primary silage-making system on both beef farms and smaller-sized farms. However, it is also widespread as a second silage-making system on many other farms.

The series of experiments contained in this report were conducted as part of a collaborative EU Structural Funds supported research project jointly carried out between the Teagasc research centres at Grange and Oak Park. Some of the research was also conducted in collaboration with the Botany Dept. at University College Dublin.

The contents of this report are presented under the following headings:

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1. CHARACTERISTICS OF BALED SILAGE ON IRISH FARMS - A SURVEY

Perspective

A previous national survey of silage-making systems indicated that baled silage is made on two-thirds of all farms in Ireland, and accounts for one-third of the total area (1177620 ha) harvested for silage - making. It is particularly prevalent on smaller sized and cattle farms, and as a second silage system on dairy farms. Farmers making baled silage use an average of only 4.3 ha grassland for that system per year whereas the average annual area of conventional silage made by farmers utilising direct-cut and precision-chop systems is 14.5 ha. The principles underpinning the conservation of grass as baled silage, and its conversion by cattle or sheep into milk and meat, are the same as for direct-cut (i.e. single or double-chop) and precision-chop silages. However, the practices by which these principles are fulfilled differ because of the unique baling, wrapping, transport and storage characteristics of the system. Baled silage on Irish farms is normally wilted (dry matter 324g/kg and pH 4.8) compared to other (mainly precision-chop) grass silages (dry matter 219g/kg and pH 4.0) but has a slightly lower average digestibility (DMD 656 versus 673 g/kg). Furthermore, problems of mould growth appear more apparent on baled silage.

Survey

A more specific and focused survey was conducted to identify the characteristics that describe the making, storing and feeding of baled silage on Irish farms. This information could then be used to pinpoint the strengths and weaknesses of different baled silage systems, and to indicate the needs and opportunities for new and improved technologies. A written questionnaire was sent to both Teagasc dairy and drystock advisors, with the request that they each complete copies for two of their clients who make baled silage. A total of 238 completed forms were returned by 128 advisors from 22 counties between April and September 1997.

Farm type

Baled silage was made on all the farms in the survey. The profile of farm size was that 17% were 20 ha or less, 42% were from 21 to 40 ha, 25% were from 41 to 60 ha and 16% were above 60 ha. The mean farm size was 41 (s.d. 23.0) ha. The average (s.d.) dairy herd in the survey had 38 (21.7) cows, suckler beef herd had 24 (17.2) cows, weanling-to-store herd had 26 (18.9) cattle, weanling-to-beef herd had 32 (26.3) cattle, store-to-beef herd had 31 (26.0) finishers and sheep flock had 156 (123.7) ewes. Conventional (i.e. single, double - or precision-chop) silage was made on about half the farms involved in this baled silage survey. May and June is the time when most baled silage is made (Table 1). The mean date of closing the swards for the three harvest times shown in Table 1 were 13 March, 2 June and 21 June, with corresponding subsequent mean harvest dates of 17 June, 1 August and 21 August. The mean (s.d.) areas of baled silage on these dates were 7.7(8.84), 5.2(4.11) and 4.1(3.13) ha respectively with corresponding numbers of bales of 210(272.7), 105(85.3) and 69(51.3). This gave an average yield of bales per ha of 27.4, 20.3 and 17.0 for the three respective harvest dates.

For the farmers involved in the survey, 3% were making baled silage for the first time, 56% had been doing so for up to 5 years, a further 36% for up to 10 year and 5% had made baled silage for over 10 years.

Crop and harvesting

Old permanent grassland (43%) was more frequently used for making baled silage than ryegrass swards (29%), although both sward types were used on many farms (28%). In general, when baled silage was made it was more common to manage the grass crop deliberately for silage production (74% of farms) rather than to opportunistically harvest grass that was surplus to grazing requirements (23% of farms), although a small proportion (4%) of farms used both strategies. Farmers usually exercised reasonable flexibility in choosing the date for harvesting - only 25% used pre-selected dates whereas 75% were able to make more tactical and immediate decisions.

Of the various machinery operations involved in making baled silage on the farms involved in this survey, most baling and wrapping was carried out by contractors (Table 2), whereas tedding and rowing, and transporting of bales, was most often done by farmers themselves.

Wilting

Wilting is an important part of the baled silage system on Irish farms - bales were made on the day of mowing on only 10% of farms, the following day on 51% of farms and within 2 days on a further 34% of farms. In this survey, wilting was extended to longer than 2 days on only 4% of farms.

Prevailing weather, crop yield and the extent to which the mown crop is spread over the ground are important factors influencing the rate of wilting (i.e. drying). Only 29% of crops received the full ground cover required for optimal wilting (Table 3) - the proportion was somewhat higher than this during May/June and decreased progressively during the rest of the year. The rotary "haybob" type tedder was by far the most frequently used machine (98% of farms that tedded). Practices such as turning the wilting crop or the use of the smaller width mower, as well as conditioning to a lesser extent, help improve wilting rate during good drying conditions. The subjective assessment of farmers was that on 59% of farms baled silage was made during *excellent* drying conditions, with *fair* and *bad* weather prevailing when baled silage was made on 38% and 3% of farms, respectively.

Baling

Virtually all baled silage in Ireland involved round bales with a nominal diameter of 1.22 m. Most bales used for making baled silage have a fixed-size chamber (95% of farms). Within the fixed chamber category, roller-type balers were used on 78% of the farms, with chain and slat-type balers on the remaining 22%. Chopper balers were used on only 32% of the farms involved in the survey, and twine was more commonly used than netting for tying bales (91 versus 9% of farms). Recent baler sales however, indicate that both chopping and net use are increasing on farms.

Wrapping

Virtually all bales were wrapped in plastic film, with black being the most common colour (99% of farms),and a clear shift from 500mm to 750mm wide rolls was evident. On 34% of farms, the farmer rather than the contractor purchased and supplied the rolls of stretch film. Wrapping was carried out in the field where the bales were made on the majority of farms (72%) rather than at the storage site (28%). Bales were normally wrapped quickly after baling, with bales being wrapped within 2 hours on 70% of farms, within 6 hours on a further 25% of farms, between 6 and 12 hours on 3% of farms and longer than 12 hours on only 3% of farms.

On 90% of farms, four layers of film were normally applied to bales, with 6 layers being stated for 10% of farms. The quantity of film applied to a bale is determined by the number of bale rotations used in the wrapping cycle. For most 1.22 m diameter bales, 16 turntable rotations when using 750 mm wide film are required - 13 or 14 turns would be inadequate. The proportion of farms where wrap monitor settings of 13, 14, 15, 16 and 17 were claimed was 2, 17, 21, 45 and 3% respectively, with a further 12% claiming setting other than these.

Transport and storage

On 14% of farms making baled silage, the bales were off-loaded directly from the wrapper to their storage position. In contrast, a rear-mounted handler, a front-mounted handler, a trailer, or a combination of these approaches, was used for transporting bales on 42, 18, 2 and 23% of farms, respectively.

Bales were usually moved to their storage location on the day of wrapping (72% of farms), with transport being the following day on 22% of farms and at least 2 days post-wrapping on a further 5% of farms. Bale transport and stacking appeared to be a somewhat time-consuming and slow process.

Bales were most often stored in or adjacent to the farm-yard (85% of farms) rather than in an outlying field (15%). They were most frequently located on an earthen base (30% of farms) rather than a gravel or stone (37%) or concrete (22%) base, with a number of storage base types prevailing on about 10% of farms.

Bales were stored on their round (barrel) side more commonly than on their flat end (70 versus 30% of farms). On 55% of farms they were stored in a single layer whereas on 17% and 28% of farms they were stored 2 and 3 tiers high, respectively.

Protective netting to prevent bird damage was placed over the bales on 17% of farms, the bale storage area was baited for vermin on 31% of farms and the bales were fenced-off from livestock on 84% of farms.

Effluent production from wrapped bales was not noted on 88% of farms.

The plastic wrap was inspected for damage before the bales were removed from the field on only a quarter of all farms. During storage, bales were inspected for damage on a weekly or monthly basis on 48 and 34% of farms respectively, but were rarely or never inspected on 18% of farms.

Moulds and mushrooms

Fungal growth visible in the form of moulds or mushrooms appears to be a particular problem on baled silage in Ireland. It may be evident as a localised or extensive presence of visible mould colonies that can vary widely in colour, size, texture etc. Others, such as Schizophyllum, are mushroom type growths. All are aerobic and thus require some minimal supply of oxygen for growth and development. They can significantly diminish the energy content, protein quality and intake potential of baled silage, as well as posing more direct health risks to livestock, and possibly also to farmers. The data in Table 4 describes the incidence of the scale and location of mould on baled silage using four major non-mutually exclusive subjective categories. The presence of some visible mould on baled silage was widespread among the farms in this survey - on 38% of farms all bales had *some* visible mould whereas on only 13% of farms was no visible mould declared for any bales. The data indicates that visibly mouldy bales occurred on 87% of farms, and that approximately 42 (s.d. 44.2) % of all bales (across farms) had some visible mould. A small amount of surface mould was by far the most evident problem, although some proportion of substantially rotted bales were declared on almost one-third of all farms. The former suggest localised and limited access of oxygen to baled grass, while the latter indicates extensive and long-term ingress of oxygen.

To the question of mouldy baled silage being offered to livestock when it was found, 46% of respondents stated they did offer it for feeding.

The data-set of 238 farms for which completed questionnaires were returned was divided into those farms where visible mould growth was evident on < 25% of bales (*low mould*; n=100) and those where it was visible on >75% of bales (*high mould*; n=105). These two sub-populations were then compared in terms of all recorded aspects of their silage making, handling and storing practices. Mould growth was evident under all conditions, with no single recorded factor overwhelmingly predisposing wrapped bales to mould growth. Higher incidences of visible mould growth on baled silage thus seemed due to multi-factorial causes, as well as very probably to the manner in which some practices were carried out - such qualitative distinctions however were outside the sensitivity of the survey. Where a relationship was found between a factor and the incidence of mould growth, this was invariably a trend with many exceptions. In addition, these relationships were likely to be associative rather than causative.

Mushroom-type growth (during 1996/97) through the plastic wrap film surrounding the bale was reported on 28% of farms (not seen at all on 72% of farms). Such mushroom-type growth was seen the previous season on 15% of the farms in the survey, as well as on 15% of the farms before 1995/96. For those farms where mushroom type growth through the plastic was noticed, it was first observed in September in 32% of cases, with a further 53% of farms recording growth by the end of December. It must be suspected that on some of these farms the growth of mushroom-type fungi through the plastic wrap and their first-sighting where not simultaneous.

Again, for those farms where mushroom-type growth through the plastic was noticed, it affected <10% of bales on 79% of these farms, from 10 to 30% of bales in 17% of cases, and over 30% of bales on only 3% of the farms. Correspondingly, it was adjudged to have spoiled fewer than 10% of bales in 88% of cases, and from 10 to 30% or above 30% of bales on 8% of 4% of farms where it was noticed, respectively.

When the survey population was divided into those claiming mushroom-type growth and those claiming none, no difference was found between the farms in the two groups for almost all of the baled silage making, handling or storing components assessed. As with mould growth, multi-factorial effects and, in particular, the detailed manner in which the various practices were carried out, were the likely causative factors.

Feeding bales

Ninety-two percent of the respondents to the survey indicated that baled silage was fed during the winter, with only 8% indicating it was fed throughout the year. Furthermore, the data indicated that on farms with dairy or beef-suckler cows, baled silage was more frequently offered to dry than lactating cows - this may quite simply reflect the cow being dry rather than lactating for a greater proportion of the indoor period. On cattle farms, baled silage was more commonly offered to weanling and stores than to finishers. On the sheep farms in the survey, ewes were offered some baled silage in 90% of cases.

A lot of baled silage is fed to livestock outdoors, mainly through circular feeders (Table 5). Where cattle in a covered yard or shed were fed baled silage from a passageway, the popularity of different barrier types were overhead rail 45%, vertical head-bars 18%, angled head-bars 30% and a combination of these 7%. Similarly, on 47% of those farms the bales were left intact in the passage-way, whereas they were unravelled manually(including the use of a hay-knife or a hand fork), using a front-loader or using a bale splitter on 19, 24 or

4% of cases, respectively. On about 6% of farms other approaches or a number of approaches, were used

Conclusions

1 . Baled silage in this survey is characterised by being, in general, made :

- using permanent grassland swards
- to provide winter feed rather than aid grazing management
- in relatively small quantities
- between May and November, but mainly in June
- with reasonable tactical flexibility in the harvest dates chosen
- with crops generally being wilted, but without being tedded to achieve full ground cover[however effluent usually not produced]
- with contractors doing most of the baling and wrapping
- with 1.22m diameter round bales being produced, and tied with twine (although the use of tying with netting is increasing)
- from balers of fixed chamber size(mainly roller type) without a chopper facility (although the use of the latter is increasing)
- by wrapping quickly in 4 layers of black plastic stretch-film in the field
- by transporting the same day on a tractor-mounted handler to the farmyard
- and stored on their round(barrel) sides, and fenced from livestock.

However, within the above averages a large array of different practices are used in making, handling, storing and feeding baled silage.

2. Mould and mushroom-type growths were a widespread problem on baled silage in this survey:

- 87% of farms making baled silage had visible mould on some bales
- 42% of bales had some visible mould present
- 28% of farms making baled silage had some mushroom-type growth through the plastic wrap

No single recorded factors overwhelmingly predisposed bales to or prevented them from mould or mushroom-type growth. Besides the likelihood of multi-factorial causes being involved, qualitative issues were also probably very important : "*it is not what you do, it is the way that you do it*".

Controlled experiments will be needed to separate and quantify these important factors.

2. WILTING

Wilting is a necessary part of most baled silage-making systems in Ireland. It is required to assist preservation, to reduce the number of bales per hectare and to reduce the weight of individual bales. However, climatic conditions in Ireland are often not conducive to rapid wilting, and this can be compounded by heavy crop yields and large, narrow mown swaths. A series of seven experiments investigated alternate approaches to field wilting.

Experiments 1 and 2: Effects of field wilting on grass dry matter and water soluble carbohydrate concentrations

Introduction. Considerable quantities of water are put into silos when unwilted grass is being ensiled. This can (a) promote a more extensive fermentation which is difficult to control, (b) produce effluent which is a source of loss of digestible nutrients, a potential pollution hazard and the medium that corrodes concrete, and (c) ultimately increase the cost of feeding cattle. However, partially field drying (i.e. wilting) the crop to remove water pre-ensiling, thereby increasing the dry matter (DM) concentration, is very dependent on weather conditions. These 2 experiments describe the diurnal pattern in grass DM and water soluble carbohydrate (WSC) concentrations and compare three wilting techniques over a range of weather conditions.

Materials and Methods. Twenty-eight plots (each 8 x 2 m) were marked out in each of 4 replicate blocks in a permanent grassland sward (50% *Lolium perenne*, 20% *Agrostis*, 20% *Poa* and 10% other) in each of 2 successive years. The plots within each block were arranged in a split-plot design, with one group of four adjacent plots being harvested each week, in sequence, within a seven-week harvesting cycle between mid-May and mid-August (15 weeks). Each week, the plots were assigned at random to the following treatments: (1) uncut, (2) cut and left undisturbed, (3) cut, tedded immediately and undisturbed thereafter, and (4) cut and tedded three times (immediately and after 6 and 24 h). Grass was mown at 0800 h using a rotary mower (1.9 m wide cut; 8 cm stubble height), sampled, and all treatments subsequently sampled after 6, 24 and 30 h. After 30 h, the four plots within each block were cut with a reciprocating mower (5 cm stubble height), raked clear and fertilised.

Results. The mean (standard deviation) results are summarised in Table 6. Note, these results and the subsequent conclusions, are based on the use of a rotary mower cutting a 1.9 m width of grass.

Conclusions

- Grass DM and WSC concentrations increased between 8 am and 2 pm, with a clear diurnal pattern.
- Most of the increase in WSC concentration was due to evaporation of water.
- Wilting increased DM and WSC concentration, particularly after 6 hours (where a 1.9 m mower was used).
- Tedding increased the wilting rate, although the effects of repeated tedding were relatively small.
- Wilting was slower as crop yield at mowing increased.
- Great variability in wilting rates occurred from week to week.
- Wilting resulted in increased variability in DM and WSC concentrations within swaths.
- Rain wet the standing crop most, but herbage in standing crops subsequently dried fastest. Rain wet the cut, undisturbed crop least, but this herbage subsequently dried slowest.

Experiment 3: Grass dry matter and water soluble carbohydrate concentrations in different wilting systems

Introduction. Quickly reducing the water content of grass by field wilting makes it easier to preserve as silage and also reduces effluent production. Successful field wilting depends on evaporating water from the mown crop by exposing as much undried grass as feasible to solar radiation. Consequently, if the desired meteorological conditions prevail (high solar radiation, low relative humidity and no rain), the ideal approach would be to ted the grass to achieve full ground-cover immediately after mowing, and to toss the drying crop frequently thereafter. Because almost 90% of all silage in Ireland is currently harvested by contractors, most of whom use 2 to 3 m wide mowers and are unwilling to ted grass, a compromise approach of laying wide windrows instead of the more conventional narrow windrows behind the mower was studied.

Materials and Methods. Plots (8 m x 4 m) were marked out in a permanent grassland sward (50% *Lolium perenne*, 20% *Agrostis*, 20% *Poa* and 10% other). The plots within each block (replicate) were arranged in a split-plot design. The three adjacent plots within each group were assigned at random to the following treatments: (1) uncut, (2) cut and left undisturbed, and (3) cut with gates at back of mower opened wide and undisturbed thereafter. Within each block (there were four blocks) there were seven such groups of three plots, each group of three being harvested in sequence within a seven week harvesting cycle (i.e. 21 plots per block). The harvesting procedure was repeated on 14 occasions between 22 May and 21 August. Grass was cut (0800 hours) using a rotary mower (Kidd Clipper 240-2) which cut a 2.4 m wide swath at a stubble height of 8 cm and all treatments sampled after 0, 6, 24 and 30 hours. In addition, samples were taken from the top and bottom of the swath in treatment 2 after 30 hours. The yield of grass was measured for treatment 3 after 0 hours and taken to represent the starting yield for all 3 treatments. Grass samples had their dry matter (DM) and water soluble carbohydrate (WSC) contents determined. After 30 hours, the three plots within each block were raked clear, cut with a reciprocating mower to a stubble height of 5 cm and fertilised.

Results. The results, averaged over the 14 weeks of the experiment, are summarised in Table 7. The mean DM and WSC concentrations in the standing crop of grass at 0800 hours (186 g/kg and 19 g/L) were lower than the corresponding values at 1400 hours (210 g/kg and 25 g/L). Wilting significantly increased grass DM and WSC concentrations, particularly when the cut grass was placed in a wide rather than a narrow swath. Rain reduced DM and WSC concentrations more immediately after if fell on an uncut rather than a mown swath, but the initial drying was also more rapid with the standing crop. Mown grass lying in a narrow swath was wetted the least by rain, but, if extensively wetted, was the slowest to dry. Placing mown swaths in wide rows resulted in greater wetting during rain, but faster drying after rain than narrow rows. The relative variation in DM and WSC concentrations within treatments increased with wilting. On average, after 30 hours wilting in treatment 2, the mean (± sd) DM concentration of the grass at the top and bottom of the swath was 406 (96.7) and 190 (27.8) g/kg, respectively, with corresponding WSC concentrations of 97 (29.8) and 29 (9.3) g/L aqueous extract.

Conclusions. Modifying the settings on a mower to place the mown grass in a wide rather than a narrow row increased wilting rate. On average, in excess of 24 hours wilting was required to reach over 250 g DM/kg grass when grass was mown at 0800 hours. Variable drying rates occurred within swaths, being progressively poorer with depth from the swath surface.

Experiments 4 to 7: The effect of mechanical swath treatment on grass wilting rates

Introduction. Field wilting of grass before ensiling can help preservation and reduce/eliminate effluent production. Rapid wilting is necessary to minimise physical and nutritive value losses. Wilting rate is dependent on grass type and yield, weather conditions and mechanical treatment of grass. The objective of the research outlined here was to assess comparative performance of a range of mechanical swath treatments.

Materials and Methods. A series of four replicated field experiments, comparing the wilting rate of a number of different swath treatments, was carried out between May 17 and June 10. Individual treatment details and the experiments in which they were evaluated are outlined below:

		Experiment
T1	2.4 m mower conditioner (MC) producing a 1.2 m wide swath	4, 5, 6
T2	2.4 m MC producing a 1.6 m wide swath	4, 5, 6, 7
T3	3 x 2.4 m MC swaths combined into a 1.4 m wide swath	4, 5, 6
T4	2.4 m MC with immediate spreading and tedding twice per day	4, 5, 6, 7
T5	3 x 2.4 m MC swaths combined into a 2.5 m wide swath	6
T6	3 x 2.4 m MC swaths combined at 1200 h on the second day	6
T7	2.4 m MC followed by an over-the-top tedder producing a 1.6 m swath	6
T8	1.6 m standard mower (M) producing a 0.8 m wide swath	7
T9	1.6 m M followed by one over-the-top tedder treatment (1.1 m)	7
T10	1.6 m M followed by two over-the-top tedder treatments (1.1 m)	7

A moderate yielding, predominantly perennial ryegrass sward was used in the experiments. Large plots (88 m^2 - 200 m^2, depending on treatment) were used to eliminate edge effects with field-scale machinery. A randomised block design was used with three replications. All treatments were cut from 0900 h. Samples were taken from each plot three times per day for dry matter (DM) analysis.

Results and Discussion. Drying rate figures at three of the sampling times and swath density figures are given in Table 8 for the four experiments. Swath DM densities indicate the extent of ground cover by the cut crop and consequent exposure to radiation and drying air. Experiments 4 and 5 illustrate the significant effect swath treatment can have on grass drying rate. Spreading and tedding with a rotary tedder (T4) gave the fastest drying rate, with the thin layer 100% cover swath wilting effectively in less than a day. The shape and structure of a mower swath also influenced drying rate as shown by the differences between T1 and T2 drying rates. Combining swaths at mowing precludes effecting wilting (T3).

Experiment 6 included assessments of alternative swath formations that could prove useful for high-output forage harvester systems. Drying conditions were exceptionally good. Where a number of swaths were grouped together, a very wide windrow (T5) allowed faster wilting than a narrow row (T3). Similarly, delaying the grouping of the individual swaths until 1200 h on the second day allowed drying rate to be improved (T6 v T3). The use of an over-the-top tedder to redistribute grass, while maintaining a swath structure, also improved drying rate (T7). In Experiment 7, additional treatments of particular relevance to baled silage were evaluated. Use of one or two passes of an over-the-top tedder improved the drying rate of an unconditioned swath (T9 and T10 vs T8). However, a wide swath produced by a mower conditioner dried faster (T2).

Conclusion. This series of experiments indicated the significant effects of swath density, conditioning and tedding/spreading on grass drying rates. There is scope to improve drying rate and minimise wilting losses by the selection of appropriate mechanical swath treatments.

3. BALE DENSITY

Experiments 8 to 12. A study of factors influencing bale density in baled silage systems

Introduction. The cost of baled silage production is influenced by the number of bales produced per unit area of crop. While grass yield is the principal factor determining the number of bales produced, other factors are also involved. Grass dry matter (DM) and physical characteristics, baler type, the use of in-baler chopping mechanisms, and baler adjustment and operation may all influence bale yield and, consequently, production costs. The objective of the work reported here was to establish the effects of baler density setting, forward speed, the use of chopping mechanisms and the influence of wilting on bale weight and, consequently, number of bales per unit area.

Materials and Methods. Five baling experiments were carried out at Kilmaley, Co. Clare (2) and Oak Park, Carlow (3) in July and August. Second-cut silage was used for all the experiments. Grass was cut and prepared using a 2.4 m mower conditioner and tedding/raking machinery. Swath treatment and wilting time was varied to produce two wilting levels at three of the sites (Table 9). Six different baling treatments were assessed, using round balers producing 1.2 m x 1.2 m bales. The treatments were:

1.	Standard	Conventional round baler, set to produce dense bales, operated at 6.4 km/h
2.	Low density	As "standard", but baler adjusted to a lower bale density setting
3.	Fast speed	As "standard", but baler operated at 8.8 km/h
4.	High DM	As "standard", but baling heavily wilted material

5.	Chop-K	Fixed-knife chopper engaged, otherwise as "standard"
6.	Chop-F	Flail chopper baler

A fixed-chamber, roller-type baler with a removable bank of knives (Deutz Fahr 2.30 OC) was used for Treatments 1 to 5. A flail chopper baler (Orkel GP1202) was used for Treatment 6. In each experiment a randomised block design was used with 4 to 6 replicates, depending on the trial. Measurements included bale weights, bale dimensions and grass DM samples.

Results and Discussion. The grass dry matters in these experiments were higher than intended because of exceptional drying conditions, particularly at the Oak Park sites (Table 9). The lower density setting reduced bale DM weight significantly, compared to the standard setting, in two of the three experiments where it was evaluated, even though the adjustment made was relatively small (Table 10). The use of a faster forward speed did not produce statistically significant differences, although average bale weight tended to decrease at the faster forward speed. Baling higher dry matter grass resulted in significantly greater bale dry matter weights in two of the three experiments where it was evaluated. Chopping with the fixed knife unit increased bale weight from 8% to 20% compared to the "standard" treatment in four of the experiments. Flail chopping (Chop-F) increased weight by a similar amount in three of the experiments. It should be noted that the flail chopping baler, in addition to the chopping mechanisms, had other differences from the standard baler, particularly in bale density control.

The variability in results between the experiments indicates that the physical characteristics of the grass and the grass swath may influence bale density and response to the treatment factors assessed in these experiments. The effect of the baling treatments would also need to be assessed with grass of lower DM content than that available in these experiments.

Conclusions. A number of baling factors were shown to influence bale DM weight and, consequently, the number of bales produced per unit area. Treatment response varied between the individual experiments reported. Evaluation of the baling treatments with wetter grass would be useful.

4. SILAGE EFF LUENT

Experiment 13: Effluent production from round bale silage

Introduction. One of the reasons for the growth in popularity of baled silage is that silage storage and effluent management require low capital investment in contrast to conventional silage. Baled silage is generally made with drier (more wilted) forage than conventional silage and consequently there is often no effluent leakage from the bales. However, if the grass ensiled is of a low dry matter concentration (DM), effluent is produced and requires management to avoid pollution. The aim of this experiment was to assess the level of effluent production from wrapped round bale silage produced at a range of grass DM concentrations, with or without chopping, and stored with a range of vertical pressures.

Materials and Methods. Bales were produced from second harvest grass at three DM concentrations (193, 231 and 277 g/kg) during the last week of July, with alternate bales being either chopped or unchopped at baling (Claas Rollant 46 baler). Four replicates were used per treatment. Bales were immediately loaded onto a trailer and transported to the storage site where they were wrapped with nominally four layers of plastic film (Bonar-Volac) using a conventional bale wrapper (Kverneland-Volac). Bales were stored (on their round sides) under cover and in plastic liners to collect the effluent. Bales at the two lower DM concentrations were subjected to three loading regimes to simulate different height of storage conditions in a stack:

1. No surcharge but restrained from lateral movement (simulates storage in a single layer)
2. Surcharge load of 300 kg, restrained from lateral movement (simulates the bottom of 2 layers)
3. Surcharge load of 600 kg, restrained from lateral movement (simulates the bottom of 3 layers)

The high DM bales were subjected only to the third loading regime. The surcharge loading was provided by sand bags while the lateral restraint was provided by portable self-supporting precast concrete walls of 1.2 m height.

Effluent was collected and measured on Monday, Wednesday and Friday of each week for the first 10 weeks after ensiling. Subsequently, effluent was collected at weekly intervals until flow ceased after 19 weeks.

Results. Bales produced from grass at the medium DM (231 g/kg) and the high DM (277 g/kg) concentrations produced no effluent. Effluent was produced by all the low DM (193 g/kg) bales, irrespective of whether the grass was chopped or unchopped, and with or without surcharge loading due to simulated stacking configurations. A regression equation for predicting effluent production from conventionally harvested and stored silage (Weissbach and Peters, 1983) was used to compare estimated versus actual volumes produced from big bales. The results are presented in Table 11. Silage and effluent composition results are not presented here.

Conclusion. Big bale silage can produce effluent. This was prevented by wilting grass to 231 g DM/kg (or above). With wet forage more effluent was produced where higher simulated storage stacking heights were used. In the absence of more reliable information, a regression equation developed for precision-chop silage in horizontal silos gives an approximation of effluent production. The total quantity of effluent produced is reduced by not stacking the bales and eliminated by adequately wilting the grass.

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5. GAS SAMPLING TECHNIQUES

Experiments 14 to 16: Development of gas sampling techniques for baled silage

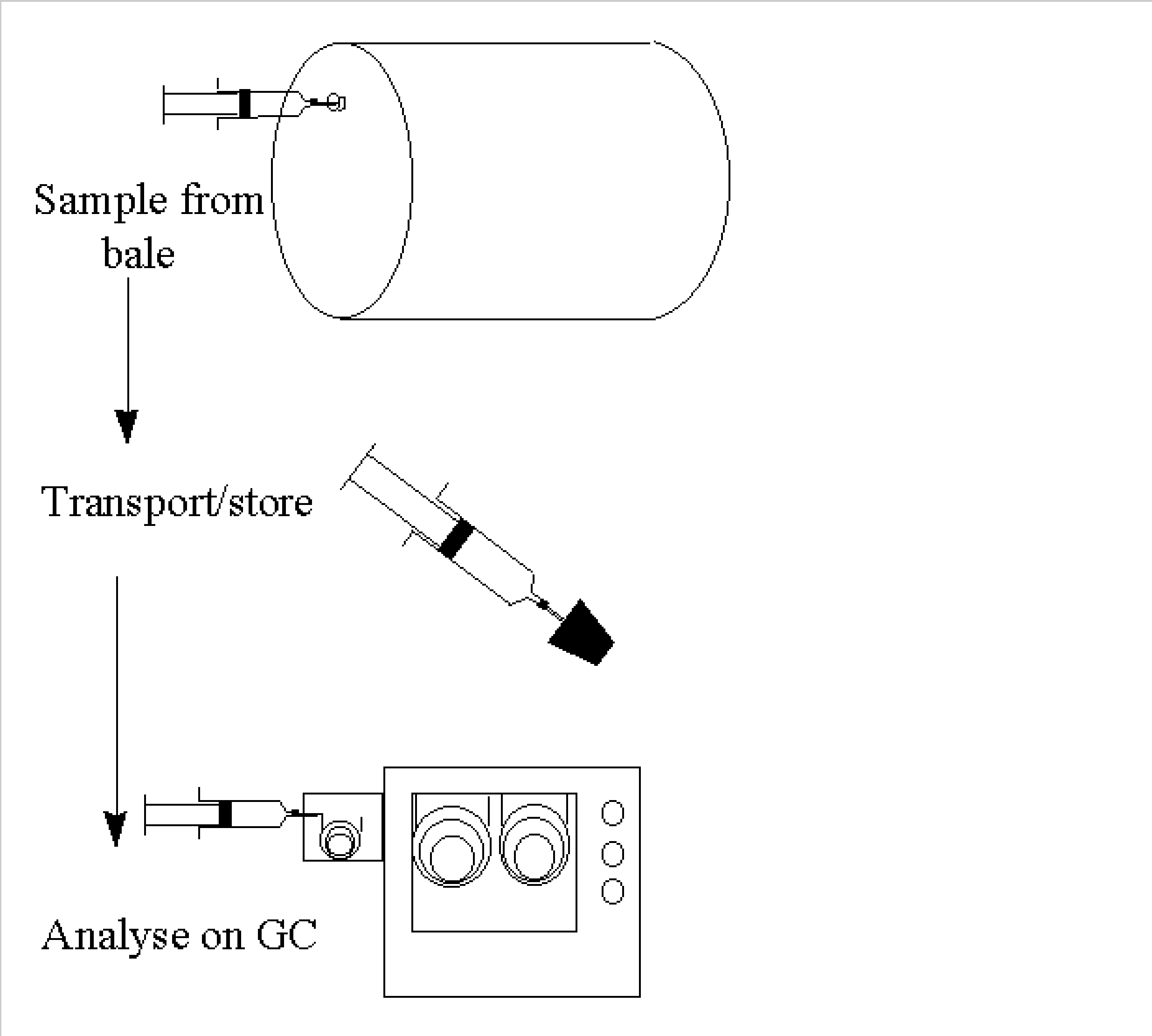
Introduction. Baled silage is now a significant forage conservation system, with most livestock farmers using the technique to conserve at least some of their winter feed. The reliability of the system is currently being examined because of the reported problems with mould development on bales. To determine the factors which permit fungal growth on bales, it is necessary to determine the levels of various gases within the bales during the entire conservation period. The work outlined here describes the assessment and development of bale gas sampling techniques for subsequent gas chromatography analysis. The objectives were to establish techniques which would: (1) allow gas samples be taken without interfering with the seal on bales, and (2) facilitate the procurement, transport and analysis of gas samples with a consistent level of accuracy. A schematic diagram of the sampling technique is shown in Figure 1.

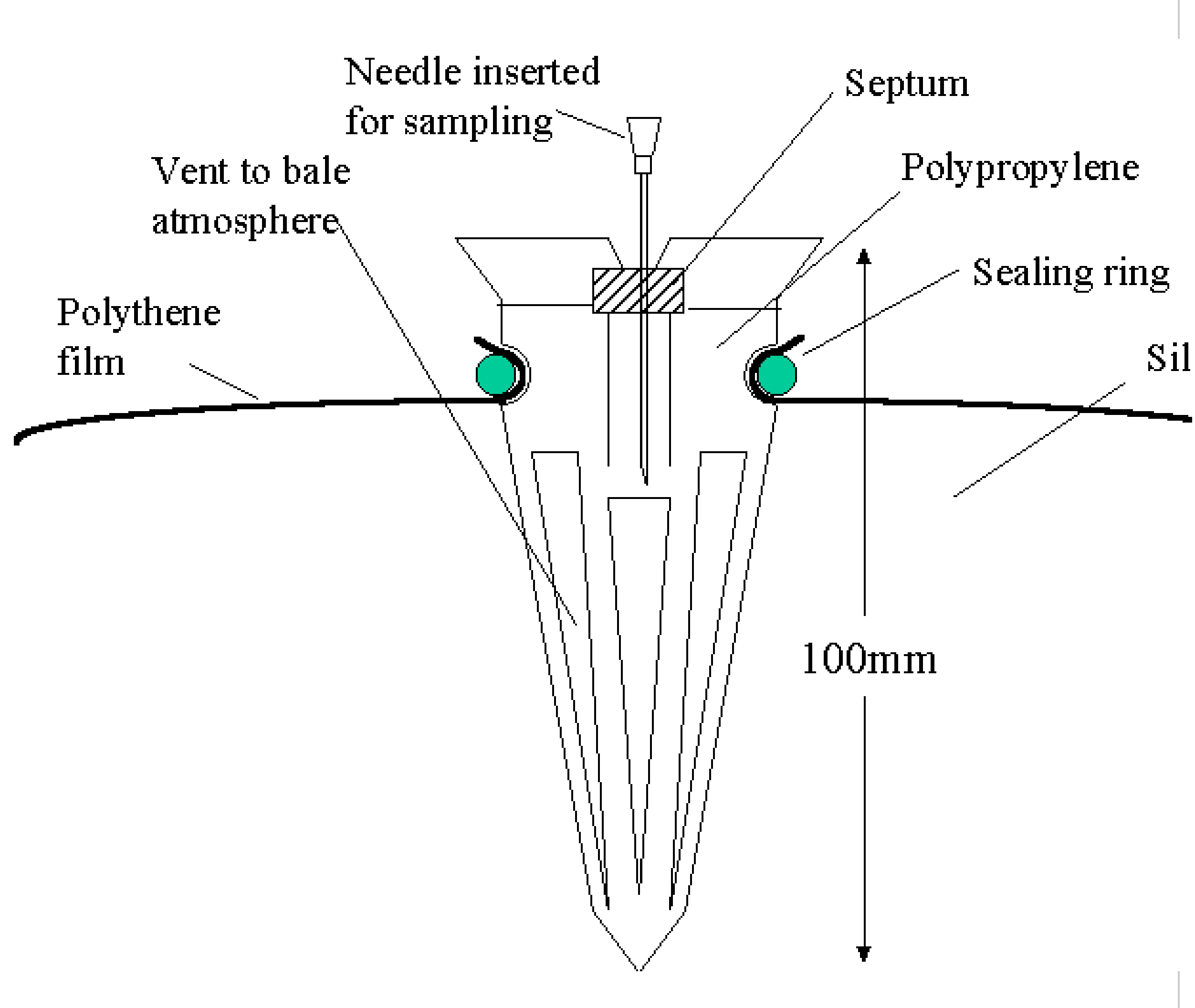
Materials and Methods. Direct piercing of polythene film with a hypodermic needle and the fixing of septum material to the bale were considered unsuitable sampling access methods because of subsequent sealing difficulties. A commercially-available bale venting device (Alfa Laval, Sweden), originally designed to allow gas to vent from bales sealed in 100 m m polythene bags, was modified for use as a gas sampling port, by sealing the integral flap valve. The tapered unit is pushed through the bale plastic and sealed with a rubber ring (Figure 2). The integral septum allows sampling using an hypodermic needle. Experiments assessing the suitability of disposable plastic syringes (10 and 20 ml) and partially evacuated sealed test tubes (vacutainers, designed for syringe-free blood sampling) for taking and transferring were carried out. A Shimadzu GC-8A gas chromatograph fitted with Molecular sieve 5A (oxygen and nitrogen analysis) and Poropak Q (carbon dioxide analysis) columns was used for all sample analysis. It was fitted with an MGS-5 gas sampling loop which allowed a sub-sample to be automatically injected onto the column from a 10 ml or 20 ml gas sample. Recorded values in excess of 99.5% O_2 and CO_2 were attained when calibrated with 100% O_2 and 100% CO_2 standard gases.

The first experiment assessed the consistency of the vacuum in evacuated containers by measuring the quantity of water drawn in under vacuum to 10 vacutainers. The second experiment compared disposable syringes and vacutainers as suitable storage/transfer methods for gas samples. Oxygen (100%) was sampled with twelve syringes and twelve vacutainers from a tube/septum arrangement attached to an O_2 cylinder. The syringe needle ends were immediately sealed in rubber bungs. Following a storage period of approximately 6 hours, the O_2 content of six syringes and six vacutainers was assessed. The samples from the vacutainers were transferred to the sampling loop with a syringe. The second set of samples were analysed after 14 days. The third experiment assessed the technique of sampling from the modified bale vent valve (described earlier) with disposable syringes using different syringe filling speeds. A polythene bag (0.5 m x 0.8 m) was sealed, fitted with a modified bale vent valve and filled with carbon dioxide (100%). Seven syringe samples were taken at each of the two filling rates: 1 ml/s; 2 ml/s. The samples were analysed for CO_2 content using the gas chromatograph.

Results and Discussion. The level of vacuum in the vacutainers was quite consistent with a coefficient of variation of 1.2% recorded among the volumes of water filled into the individual containers. In the second experiment, there was a marked difference in the level of oxygen measured in the evacuated containers and the syringes (Table 12). Most of this difference appeared to be caused by the levels of air present in the vacutainer before the sample was introduced. As the vacuum levels were constant, calibration to correct for these levels should be possible. However, there was substantial variability in the O_2 levels recorded (CV = 7.3%) in the vacutainers. Leakage during needle insertion and sample withdrawal using a syringe may have contributed. Disposable syringes proved to be more satisfactory, but analysis on the day of sampling was necessary to avoid errors. The third experiment indicated the satisfactory performance of the sampling technique using syringes and the modified bale vent valve (Table 13). Better sampling was achieved at a slower syringe filling rate.

Conclusion. A sampling technique using plastic disposable syringes, a modified bale vent valve as access port and a gas sampling loop on a Shimadzu gas chromatograph was developed and tested. An appropriate syringe filling speed was determined.


Sample from
bale
Transport/store
Analyse on GC



6. MUSHROOM-TYPE (i.e. Schizophyllum) GROWTH

Experiment 17: Mushroom-type growth on big-bale silage in Ireland

In November, 1990, and in October 1991, mushroom-type growths on big-bale silage from Leitrim and from Tipperary, respectively, were identified by Hubert Fuller as *Schizophyllum commune*. Webster (1991) reported findings the same fungus on big bales in Devon, England. *Schizophyllum* is a gilled bracket fungus which has a worldwide distribution. It is known primarily as a saprotrophic white rot fungus on woody substrates in warmer climates where its fructifications are commonly seen on fallen branches in broadleaved and less frequently, coniferous woodland. It is also found in temperate regions on timbers and on a variety of other substrata and has been reported as a plant and human pathogen (Cooke, 1961; Rihs *et al.,* 1996). Before the above finds, the only record of *S. commune* in Ireland was on wooden beams at Cork Harbour in 1843. In November 1996, the fungus was discovered in woodlands in Offaly, by J. Feehan, and in January 1998, in Limerick and Wicklow, by H. Fuller.

Apart from the mycological interest in finding this wood-rotting fungus in an unusual niche, on big-bale silage, the finds in 1990 and 1991 attracted no further attention. However, by autumn 1995 it was evident that *Schizophyllum* was of more common occurrence on big-bale silage in Ireland. During the winter seasons of 1996 and 1997 the fungus was identified as a contaminant in numerous big-bale samples, obtained from all counties. The presence of

Schizophyllum in a bale is indicated by the presence of small bumps under the polythene, anywhere on a bale surface. Having emerged through the plastic the fungus is first evident as small white growths several millimeters in size, which eventually expand and develop into gilled bracket mushrooms, often in clusters or rosettes 10 to 15 cm in diameter. The individual mature fruit bodies (basidiocarps) are tough and elastic, grey-white to brownish in colour, fan-shaped with very short stipes, and with a tomentose, wrinkled upper surface. Cap margins are furrowed, scalloped and incurved. The gills are pink to flesh coloured when young and spread out radially from where the fruit body is attached to a bale. A characteristic feature of the gills is the manner in which they appear to split. The gills consist of two lamellae lying side by side which curl away from each other on drying. The common name for the fungus is "split-gill".

When the plastic covering is removed from a bale affected by *Schizophyllum*, thick masses of white to fawn-coloured mycelium are evident on the silage surface, usually accompanied by dense rubbery differentiating tissue. Mechanical pressure exerted by the enlarging fungal mass causes a stretching of the polythene cover and its eventual penetration by the fungus. White *Schizophyllum* colonies have been seen to spread deep (>40 cm) within bales.

Fungal samples (n>130) from bales, either as mushroom growths or as mouldy silage, were collected by the authors or forwarded to them from various locations countrywide. Basidiocarp specimens were examined, identified and stored in a herbarium. Apart from one location where *Coprinus macrocephalus* was present on badly decomposed silage, *S. commune* was the only mushroom growth found on big bales. Samples for culture were plated onto malt agar supplemented with chloramphenicol and streptomycin (both at 0.1 mg/ml). *Schizophyllum* readily grows *in vitro* at 25°C, but isolates were occasionally lost due to heavy primary bacterial or fungal contamination. Using a fruiting medium of Raper & Krongelb (1958) all *Schizophyllum* isolates were induced to form basidiocarps in culture and identification was further confirmed on examination of their morphological features. Clamp connections were observed on hyphae as were many peg-like projections which are characteristic of *Schizophyllum*.

At present some 80 isolates of the fungus have been established in pure culture and are being examined using morphological, biochemical and physiological criteria. These will help define the growth requirements of *S. commune*. Surveys have been conducted to assess the extent of the problem on big bales and field experiments have also been undertaken to determine which factors (silage dry matter, number of wraps etc.) favour growth of *Schizophyllum* on silage in big bales. The fungus has not yet been found on clamp silage. It is concluded that the mushroom *Schizophyllum commune* has grown on big-bale silage throughout Ireland, sometimes resulting in considerable loss of feedstuff.

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7. MECHANISED FEEDING

Experiment 18: The performance of alternative mechanised systems for feeding big-bale silage

Introduction. The traditional method of feeding big-bale silage in uncovered circular feeders is not compatible with modern livestock housing where animals are fed from a straight, covered feeding passage. A number of tractor-powered bale feeders which divide and/or distribute silage bales have recently become available. The objective of the experiment reported here was to determine the work rate, evenness of silage distribution and tractor requirements of three big-bale feeders.

Materials and Methods. The following machines were evaluated:

Bale splitter: A tractor-mounted device which uses an hydraulically-operated rear-facing knife to cut the bale. By repositioning the tractor, up to three separate cuts can be made to divide the bale into four sections (McHale bale splitter).

Chain and slat unroller: A tractor-mounted, hydraulically-powered implement which rotates the bale on a chain and slat elevator, stripping and delivering silage to the right side of the unit (Shelbourne Reynolds unroller).

Bale chopper: A tractor-mounted, p.t.o.-powered machine which uses a slowly-rotating vertical drum to feed the bale to a high-speed chopper which strips, chops and delivers the silage to the right side (Taarup-Kidd 824 chopper).

Note: The *unroller* and *chopper* require a separate tractor and/or loader to load the bale.

Bales made from 2nd harvest grass with mean weight and DM contents of 594 kg and 248 g/kg, respectively, were used in the experiment. Unchopped bales were used for all three feeders. In addition, pre-chopped bales produced by a baler with a fixed-knife chopping mechanism were used with the *unroller*.

Work rates were determined by timing the complete feeding cycle for each of three bales per machine. Bale transport distance (30 m) and distribution length (10 m) were standardised. The evenness of distribution was assessed by weighing four fixed-length sections (600 mm) of the distributed feed for each of three bales per machine type. Fuel consumption and engine speed were recorded using electronic sensors and a data-logger. Power (equivalent p.t.o. power) was calculated using a regression equation developed from dynamometer calibration data. Tractor lift capacity requirement was estimated by calculating force moments about the rear axle from axle weight data. Tractor/machine turning space was also measured.

Results and Discussion. The *unroller* had the fastest work rate with a total feeding cycle time of 366 s/bale of which mechanised distribution took 86 seconds (Table 14). The *splitter* required 540 s/bale (distribution time: 154 s/bale), as considerable time was required for manual redistribution of the silage. The *chopper* was the slowest, as it required 389 s to chop and distribute the bale, giving a total cycle time of 657 s. All systems required considerable time to remove twine and polythene from the bales. Evenness of distribution of silage from the *splitter* was inferior to the other machine types tested, as indicated by the high coefficients of variation recorded (Table 15). There was no significant difference recorded between the *chopper* and the *unroller* (either unchopped or pre-chopped bales). However, manual redistribution may occasionally be required with the *unroller*. The considerable energy required to chop silage resulted in the *chopper* recording high power requirement and fuel consumption figures (Table 16). Power requirement and fuel consumption of the *unroller* was least. The *chopper* required the greatest tractor lift capacity, as indicated by the calculated load at test tractor link-ends with a 600 kg bale. Turning space requirement of all machine types was similar.

Conclusions. All three bale feeders were capable of distributing baled silage satisfactorily. The *unroller* had the fastest work rate, low power requirement and acceptable distribution. The *chopper* had a high power requirement and a slow work rate. The bale *splitter* had the poorest distribution but is an inexpensive machine and only requires one tractor for feeding.

8. CONSERVATION EFFICIENCY AND NUTRITIVE VALUE

Experiment 19: Big bale and precision-chop silage systems: conservation characteristics and silage nutritive value for beef cattle

Introduction. Silage harvesting systems in Ireland have changed markedly during the past 15 years, with the widescale replacement of direct-cut systems (e.g. single- and double-chop harvesters) by systems involving separate mowing and pick-up (e.g. precision-chop harvester and big round baler) operations. Big bale silages on Irish farms are normally wilted (324 g DM/kg and pH 4.8) compared to other (mainly precision-chop) grass silages (219 g DM/kg and pH 4.0), but have lower mean DM digestibility values (656 versus 673 g/kg) (Keating and O'Kiely, 1997a&b). Data from the Teagasc Farm Management Survey indicate that the big bale system has become the most common silage-making system on smaller size farms and on cattle rearing farms. The present experiment compared precision-chop and big bale silage systems. In particular, it was designed to separate the effects of wilting (unwilted versus wilted precision-chop), harvester system (precision-chop versus big bale) and important variations within harvester systems (no additive versus formic acid for the unwilted precision-chop system; unchopped versus chopped for the big bale system) on conservation characteristics and silage nutritive value for beef cattle.

Materials and Methods. A seven-week regrowth of a permanent grassland sward was mown on 17 July using a mower conditioner (Kuhn FC300 GT). Alternating rows of grass were allocated to the following conservation treatments: (1) precision-chop, unwilted; (2) precision-chop, unwilted plus formic acid; (3) precision-chop, wilted; (4) big bale, wilted and (5) big bale, wilted and pre-chopped. Unwilted treatments (approximately 120 tonnes each) were harvested within one hour of mowing, with formic acid (850 g/kg) being applied through the harvester (Pottinger MK VI) at 2.4 l/t grass. Grass for wilted (30 h) treatments was tedded (Krone KW 5.50/4 x 7) within an hour of mowing and was rowed (Krone KS 380-4.20/12) at the end of the first days wilt and harvested or baled (Claas Rollant 46 Roto Cut) the following day. Alternate rows for the big bale treatments were baled with the slicing blades engaged or disengaged. Precision-chop treatments were ensiled in walled, roofed, concrete silos (4.6 x 22.9 m) and sealed beneath two layer of black (0.125 mm thick) polythene film. Bales were transported to the storage area, wrapped (McHale 991 BE) with four layers of black polythene stretch film, and stored in single layers, outdoors, on a concrete base. Treatments were stored for 27 days post mowing before feeding commenced.

Fifteen Charolais crossbred heifers were allocated to each dietary treatment in a randomised, complete block (based on mean starting liveweight) design. Silages were individually offered, *ad libitum*, and supplemented with 2.5 kg concentrates (915 g rolled barley, 70 g soyabean meal and 15 g mineral + vitamin premix/kg) per head daily, for 118 days. Carcass data were obtained post slaughter. *In vivo* digestibility of the diets was determined on 3 occasions during the experiment, using 10 Friesian steers. Silage DM intake was restricted to 0.9 of *ad libitum* and the concentrate allowance adjusted to ensure similar forage to concentrate ratios as observed with the heifers.

Results. Grass and silage compositions are summarised in Table 17, while feed input and animal output data are presented in Table 18. Mean effluent production for unwilted silage made without or with formic acid was 111 and 97 l/t grass, respectively. Mean weight of bales prior to wrapping was 514 and 562 kg for unchopped and chopped grass, respectively. Within unwilted silage, aerobic stability was improved by the formic acid treatment. Within wilted silages, precision-chop silage was aerobically less stable than the big bale silages, while chopping herbage at baling did not affect aerobic stability. Dry matter recovery rates from big bales were not altered significantly by chopping herbage at baling.

Conclusions. The precision-chop harvester and big baler produced wilted silages of similar nutritive value for finishing beef cattle. Chopping forage at baling did not alter its conservation efficiency or nutritive value. Formic acid added under good ensiling conditions did not alter silage nutritive value. Wilting disimproved feed (40°C oven) DM conversion efficiency.

9. CONCLUSIONS

The characteristics of baled silage making, handling, storing and feeding practices on Irish farms were defined. Although a diverse range of practices are employed, no single factors overwhelmingly predisposed bales to, or prevented them from, being efficiently or effectively conserved. Qualitative factors are at least as important as the type of practice used, and will require controlled experiments to separate and quantify.

Mould and mushroom-type growths were a widespread problem on baled silage

- 87% of farms making baled silage reported visible mould on some bales
- 42% of bales had some visible mould present
- at least 28% of farms making baled silage had some mushroom-type growth through the plastic wrap

Wilting increased grass dry matter and water soluble carbohydrate (g/L aqueous phase) concentrations. Wilting practices and mechanisation systems that increase the interception of solar radiation by grass improve the drying rate. Large narrow windrows result in very diverse dry matter concentration profiles in the swath.

Bale dry matter (DM) densities were reduced by low density settings on the baler. Slower forward speed tended to increase bale DM density. Increasing forage DM concentration or chopping the forage at baling increased bale density. The variability between experiments indicates that the physical characteristics of the grass and the swath may influence bale density and the response to the factors studied.

Baled silage can produce effluent where wetter forages are ensiled, particularly where the bales are stored more than one layer deep. Chopping the forage at baling did not influence effluent production. However, wilting to above 231 g DM/kg prevented effluent production in an experiment using a second cut perennial ryegrass-dominant sward.

A new protocol for sampling gas from baled silage was developed.

Schizophyllum commune was identified as growing on baled silage throughout Ireland, sometimes resulting in considerable loss of feedstuff. It has not yet been found on clamp/bunker silage.

Three types of bale feeder were assessed in terms of work rate, power requirement, evenness of forage distribution and turning space. The advantages and disadvantages of each system were defined.

A precision-chop harvester and baler produced wilted silages of similar nutritive value for finishing cattle. Chopping the forage at baling did not alter its conservation efficiency or nutritive value. Wilting disimproved feed conversion efficiency.

10. ACKNOWLEDGEMENTS

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12. TABLES

Table 1. Scale of baled silage (% of farms in the survey)[1]

	Harvest[2]				Harvest[2]		
Baled silage area (ha)	1	2	3	(n) bales	1	2	3
0	22	47	86	0	23	48	86
> 0 to 10	63	48	13	> 0 to 50	9	13	7
>10 to 20	13	5	1	>50 to 100	19	20	6
>20 to 40	1	<1	0	>100 to 300	37	17	2
>40	<1	0	0	> 300	12	2	0

[1]Baled silage made on all the farms in the survey; [2]Harvest times 1, 2 & 3 correspond to May/June, July to mid-August and mid-August to early November, respectively.

Table 2. Role of farmer or contractor in carrying out specific components of baled silage systems (% of farms in the survey)

	Farmer	Contractor
Mow	47	53
Tedd	77	23
Row	74	26
Bale	14	86
Wrap	13	87
Transport	80	20

Table 3. Mowing and wilting systems used in making baled silage

Mower type	farms %	Wilting system	farms %
1.6m wide	30	Mow only	12
> 1.6m wide	16	Mow + condition	49
> 1.6m wide + conditioner	52	Mow + turn	11
Auto - swath mower conditioner	2		

Table 4. Incidence of mould infection of baled silage (% of farms in the survey)

	% of all bales			
Description of mould presence	**None**	**>0 to 50**	**> 50 to 100**	**All**
Visible mould	13	36	12	38
Surface mould - a little	54	44	2	0
- extensive	90	9	0	0
Deep mould - a little	93	7	0	0
- extensive	95	5	0	0
4. Substantially rotted	69	30	0	1

Table 5. Method and location of feeding baled silage[1] (% of farms in survey)

	Location of feeding		
Method of feeding	**Field**	**Yard**	**Covered yard/shed**
Circular feeder	22	31	21
Purpose-built feeder	2	9	17
Other	1	1	26

[1]totals exceed 100% as some farmers used more than one approach

Table 6. Grass dry matter and water soluble carbohydrate concentrations under different wilting treatments in 2 successive years.

Time	**0 h**	**6 hours**					**24 hours**					**30 hours**			
Treatment		**1**	**2**	**3**	**4**		**1**	**2**	**3**	**4**		**1**	**2**	**3**	**4**
YEAR 1 (Experiment 1)															
Dry matter (g/kg) X	197	214	236	264	264		200	267	301	329		222	330	388	413
s.d.	37.3	43.1	53.0	60.5	65.1		31.7	66.5	77.7	93.5		38.7	99.5	110.3	121.9

WSC (g/kg aq.extr.) X	29	34	38	46	48		29	45	58	63		34	66	83	92
s.d.	11.4	11.3	13.8	18.0	20.1		7.6	16.4	26.2	29.1		11.7	30.7	37.4	35.0
YEAR 2 (Experiment 2)														
Dry matter (g/kg) X	169	180	191	215	213		174	219	256	270		192	279	328	345
s.d.	33.0	36.8	47.0	65.1	64.1		31.5	72.5	111.0	117.3		33.1	112.0	144.6	145.0
WSC (g/kg aq.extr.) X	13	17	18	22	23		15	22	31	34		19	31	43	51
s.d.	4.8	6.3	7.0	11.0	12.0		4.5	12.3	24.6	25.0		7.5	19.5	25.0	27.9

Table 7. Mean effects of wilting on grass DM and WSC concentrations.

Time	0 h	6h	6h	6h	24h	24h	24h	30h	30h	30h
Treatment		1	2	3	1	2	3	1	2	3
Dry matter (g/kg) X	187	208	208	228	185	208	225	213	258	311
s.d.	20.3	17.8	30.3	39.3	24.6	39.2	60.7	25.9	52.6	79
WSC (g/kg juice) X	20	25	25	33	18	23	26	26	36	55
s.d.	8.5	8.6	9.1	16.3	6	10.9	16.3	7.5	13.4	25.8

Table 8. The effect of swath treatments on grass drying rate

Expt 4: 22.5 t crop /ha at 172 g DM /kg						Expt 5: 29.4 t crop /ha at 164 g DM /kg				
	Density(DM kg/m^2)	Day 1 1400 h	Day 1 1700 h	Day 2 1400 h			Density (DM kg/m^2)	Day 1 1400 h	Day 1 1700 h	Day 2 1400 h
		DM (g/kg)						DM (g/kg)		
T1	0.70	202	218	295		T1	0.86	195	206	224
T2	0.51	205	234	358		T2	0.64	222	245	304
T3	1.80	189	192	226		T3	2.18	181	168	179
T4	0.38	217	287	429		T4	0.48	240	289	387
s.e.d.		6.9	13.0	18.4		s.e.d.		15.0	4.8	13.0
Expt 6: 28.4 t crop /ha at 183 g DM /kg						**Expt 7: 33.3 t crop /ha at 187 g DM /kg**				
	Density (DM kg/m^2)	**Day 1 1500 h**	**Day 1 1800 h**	**Day 2 1500 h**			**Density (DM kg/m^2)**	**Day 1 1500 h**	**Day 1 1800 h**	**Day 2 1500 h**
		DM (g/kg)						**DM (g/kg)**		
T1	0.95	235	249	287						

T2	0.74	264	291	337						
T3	2.07	198	201	223		T8	1.26	211	222	253
T4 0.52	305	365	413			T9	0.95	211	232	277
T5 1.17	236	260	260			T10	0.95	211	232	309
T6 2.07	227	251	299			T2	1.11	244	273	337
T7 0.74	264	292	380			T4	0.63	247	296	416
s.e.d.		8.5 17.5	25.4			s.e.d.		7.7	10.3	12.8

Table 9. Experimental area yields and grass dry matter values at the time of baling.

	Experiment	8 (Kilm-1)	9 (Kilm-2)	10 (OP-1)	11 (OP-2)	12 (OP-3)
Grass yield	(kg DM/ha)	4628	4652	5016	4876	5471
Dry matter:	(1) Standard wilt (g/kg)	305	276	331	569	580
Dry matter:	(2) Heavy wilt (g/kg)	386	349	--	645	--

Table 10. The effect of baling treatment on silage bale weight (kg DM/bale).

Experiment & Treatment	Standard	Low density	Fast speed	High DM	Chop-K	Chop-F	F-test	s.e.d.
8 (Kilm-1)	189.5	172.8	182.2	214.7	207.9	204.9	***	4.3
9 (Kilm-2)	200.2	197.6	190.7	234.0	216.9	218.0	***	6.8
10 (OP-1)	166.9	---	---	---	200.2	196.1	***	9.2
11 (OP-2)	247.1	211.4	240.4	226.4	255.8	227.9	**	12.8
12 (OP-3)	227.0	---	---	---	261.4	241.1	*	15.4

Table 11. Effluent production from round bale (193 DM g/kg) silage.

Method of storage	Mean bale weight ensiled (kg)	Effluent production (l/t ensiled)	Predicted production (l/t)
Unchopped + No surcharge	731	88	57
Unchopped + 300 kg surcharge	680	91	140
Unchopped + 600 kg surcharge	738	157	190
Chopped + No surcharge	727	50	57

Chopped + 300 kg surcharge	760	117	140
Chopped + 600 kg surcharge	781	129	190
SEM - Chop	11.4*	8.2 NS	
Surcharge	14.0 NS	10.1***	
Interaction	19.8 NS	14.2 NS	

Table 12. Levels of oxygen recovered using syringes and vacutainers (Experiment 15)

	Syringe		Vacutainer		F-test	SED
	6 hr	Day 14	6 hr	Day 14		
% O_2 content	98.5	82.5	57.4	54.8	***	2.38
% CV	0.07	1.58	7.26	10.61	-	-

Table 13. Levels of CO_2 recovered at two sampling speeds (Experiment 16)

	Slow sampling	Fast sampling	F-test	SED
% CO_2 content	99.2	97.4	***	0.24
% CV	0.27	0.62	-	-

Table 14. Work rates of silage feeding systems (s/bale).

	Splitter	**Unroller**	**Chopper**	**F-test**	**s.e.d.**
Loading & manoeuvring (s)	57	114	119	**	8.3
Removing plastic & twine (s)	168	150	149	NS	11.0
Distribution (incl. chopping) (s)	154	86	389	***	16.9
Manual distribution (s)	161	16	---	**	20.3

TOTAL (s)	540	366	657	***	24.4

Table 15. Evenness of distribution of silage.

	Splitter	Unroller	Unroller chopped	Chopper	F-test	s.e.d.
Sample weight range (kg)	22-91	30-63	37-67	31-62	-	-
CV (4 samples) (%)	40.9	22.0	27.8	25.2	*	4.9

Table 16. Power requirement, fuel consumption and tractor requirements.

	Splitter	Unroller	Chopper	F-test	s.e.d.
Avg. power requirement (kW)	9	5.2	28.1	***	2.1
Peak power requirement (kW)	16	14	48	***	2.12
Fuel used per bale (l)	0.45	0.07	1.11	***	0.04
Lift requirement (t)	1.29	1.61	2.38	--	---
Turning circle radius (m)	4.3	4.5	4.4	--	---

Table 17. Grass (at harvesting) and silage chemical composition - mean (s.d.)

	Unwilted	Unwilted	Wilted	Wilted	Wilted
				Big bale	Big bale
	No additive	Formic acid	Precision-chop	Unchopped	Chopped
Grass composition					
Dry matter (g/kg)	192 (21.2)	196 (26.0)	397 (22.2)	338 (35.5)	338 (35.5)
In vitro DMD (g/kg)	749 (19.7)	753 (18.4)	726 (13.5)	720 (23.2)	720 (23.2)
Crude protein (g/kg DM)	174 (9.9)	167 (13.0)	169 (8.7)	166 (13.9)	166 (13.9)
Ash (g/kg DM)	104 (4.1)	96 (5.5)	102 (5.3)	103 (10.7)	103 (10.7)
WSC (g/L)	23 (5.0)	25 (1.5)	61 (8.2)	37 (8.3)	37 (8.3)
Silage composition					
Dry matter (g/kg)	205 (15.8)	219 (16.7)	387 (9.4)	355 (33.7)	362 (38.1)
In vitro DMD (g/kg)	716 (11.9)	725 (11.0)	727 (8.6)	736 (14.8)	726 (14.7)

Ash (g/kg DM)	95 (4.0)	89 (4.9)	95 (3.2)	100 (4.4)	101 (4.6)
Crude protein (g/kg DM)	169 (7.1)	168 (4.3)	162 (7.7)	155 (10.7)	171 (10.5)
Lactic acid (g/kg DM)	108 (11.0)	94 (12.6)	53 (8.6)	53 (16.5)	40 (10.8)
Acetic acid (g/kg DM)	40 (8.3)	20 (6.7)	9 (6.3)	7 (2.5)	7 (3.5)
Propionic acid (g/kg DM)	4 (1.8)	2 (1.3)	1 (0.8)	1 (0.2)	1 (0.9)
Butryic acid (g/kg DM)	1 (0.4)	0 -	0 -	2 (2.2)	1 (0.7)
Ethanol (g/kg DM)	15 (5.2)	13 (6.4)	3 (1.0)	5 (2.5)	5 (2.1)
WSC (g/kg DM)	16 (3.4)	36 (14.5)	72 (32.5)	82 (49.6)	52 (10.9)
pH	3.9 (0.07)	3.8 (0.07)	4.4 (0.08)	4.7 (0.23	4.7 (0.19)

Table 18. Animal performance, silage intake and digestibility and feed conversion efficiency.

	Unwilted	Unwilted	Wilted	Wilted	Wilted	
				Big bale	Big bale	
	No additive	Formic acid	Precision-chop	Unchopped	Chopped	SEM
Liveweight						
Start (kg)	436	436	436	436	436	0.7
End (kg)	541	545	532	533	528	5.9
Gain (g/d)	892	924	815	817	777	48.7
Carcass weight						
End (kg)	284	286	284	279	279	3.1
Gain (g/d)1	557	580	561	517	517	25.5
Kill-out rate (g/kg)	524	526	535	524	529	4.2
Kidney + channel fat wt. (kg)	10	10.1	9.9	10.5	9.6	0.64
Silage dry matter2 intake	6.1	6.5	7.2	7.4	7	0.07**

kg/d						*
g/kg liveweight	12.5	13.2	14.9	15.3	14.6	0.13***
In vivo DM digestibility (g/kg)	739	727	721	743	741	7.3
Feed conversion effic. (kg/kg)						
Silage DM intake/liveweight gain3	7.1	7.2	9.4	9.5	9.5	0.52***
Silage DM intake/carcass gain3	11.5	11.4	13.2	14.8	13.9	0.60***
Total DM intake/liveweight gain	9.1	9.2	11.6	11.7	11.8	0.66**
Total DM intake/carcass gain	14.7	14.4	16.4	18.2	17.3	0.75**

[1]Assumes kill-out rate at start of 500 g carcass weight/kg liveweight; [2]Oven DM at 40°C;
[3]Partial efficiency