The microbiological and chemical composition of baled and precision-chop silages on a sample of farms in County Meath

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Baled and precision-chop silages were examined on a sample of farms in the Irish midlands to determine microbiological and chemical composition at feedout. Silage making practices and chemical composition were similar to those in national surveys. Wilting was an integral part of baled silage production and was reflected in a more restricted fermentation (higher pH and water-soluble carbohydrates, with lower fermentation acids and buffering capacity) compared to precision-chop silage. Yeast numbers were higher in baled silage, suggesting a more aerobic environment within the bale. Although the fermentation appeared similar in the outer and inner horizons of baled silage, yeast, lactic acid bacteria and *Enterobacteria* numbers were higher in the outer horizon suggesting less exacting anaerobiosis adjacent to the surface of the bale.

Introduction

Silage is the second most important crop in Ireland after grazed grass, and is made on 86 percent of farms. The two methods most commonly employed for ensiling forage are conventional precision-chop silage stored in horizontal silos (0.60 of national silage area) and individual bales of silage wrapped in polythene stretch-film (0.32 of national silage area; O'Kiely *et al*., 2000).

In principle, the achievement of successful conservation of forage in bales or in conventional silos requires the rapid attainment and maintenance of anaerobic conditions and the promotion of a lactic-acid dominant fermentation to reduce pH rapidly and sufficiently. The fulfilment of these requirements should inhibit the activities of undesirable microorganisms (e.g., mould, *Clostridia*, *Enterobacteria*)

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and terminate plant respiration, thereby preserving the crop.

Grass for precision-chop silage in Ireland generally receives a modest level or no effective wilting, is usually chopped to a mean particle length of 5 to 10 cm, is stored 2 to 4 m deep and sealed beneath two layers of black 0.125 mm thick polyethylene sheeting. Forage for baled silage normally receives 24 to 48 h wilting (dry matter (DM) of *ca*. 300 to 350 g/kg; Keating and O'Kiely, 1997a) and the bales (300 to 800 kg) are cylindrical with a nominal diameter and width of 1.22 m. They are mechanically wrapped, nominally in four layers of black polyethylene stretch-film (0.025 mm thick prior to application), with the film stretched to 1.7 times the original length during application giving an average barrier thickness of *ca*. 0.070 mm, and are usually stored one, two or three tiers high.

In bales, about 0.54 of the silage is within 20 cm of the plastic film, whereas with conventional silage, typically less than 0.1 of the silage would be this proximate to the plastic sheeting. Baled silage, therefore, has a relatively large proportion of its mass in a vulnerable position adjacent to the thin barrier of stretched plastic film (Forristal and O'Kiely, 2005). This provides the opportunity for a somewhat less anaerobic environment for the silage at the surface of a wrapped bale compared to the surface of conventional silage. The porosity within bales (0.5 to 0.8 pore space) can also be greater than in bunker silages due to the ensilage of longer, wilted grass and the frequently lesser extent of compaction. These factors would more readily facilitate the passage of oxygen through the ensiled mass if the plastic seal is compromised. Unfortunately, damage to the plastic wrap is common on farms, due to mechanical and wildlife factors (McNamara *et al*., 2004). As a result, the

hygienic quality of baled silage can often be compromised. For example, O'Brien *et al.* (2005) investigated the incidence of mould on baled grass silage in the Irish midlands and reported that fungal colonies were visible on 0.90 of the bales examined, with on average 0.05 of the bale surface having visible fungal growth.

While information is available on the digestibility, crude protein, pH and DM of silage in Ireland (Keating and O'Kiely, 1997a, b), there is an absence of more detailed information on the chemical and microbiological composition of both baled and precision-chop silages. Little is known of the numbers of bacteria and yeast present at feedout, the concentration of fermentation products, or the overall hygienic quality of the silage. The purpose of this study was to determine the microbiological and chemical composition of baled and precision-chop silages at feedout on a sample of farms. Furthermore, the impact on these variables within baled silage was examined in the outer layer close to the plastic wrap and compared to that in the centre of the bale.

Materials and Methods

Two bales of silage were sampled on each of 10 farms during February and March of both 2004 and 2005. In February 2005, twenty conventional precision-chop silages were sampled. Farms were randomly selected and were located within a 10 km radius of Teagasc, Grange Beef Research Centre, Dunsany, Co. Meath (53°31' N, 06°40' W).

On each farm, the characteristics of the bale storage environment and the physical appearance of the bales and horizontal silos were recorded. Physical damage, if any, to the plastic wrap or cover, and apparent causes, were noted. A questionnaire detailing the history of each silage

(e.g., cut date, weather at harvesting) was also completed with the aid of the farmer.

Baled silage sampling

Bales were selected on the basis of being the next in line for feeding. Bales (1.22 m wide × 1.22 m diameter) were removed for ease of sampling and the wrap was examined and damage (if any) noted. The plastic wrap was then removed. The bales of silage were aseptically sampled using an electrically powered cylindrical core bit (length 65.0 cm; internal diameter 3.5 cm) at eight points around the bale. Sampling points were adjacent to the clock positions 0300, 0600, 0900 and 1200 h on the bale barrel, *ca.* 40 cm from each end, where there was no visible evidence of aerobic deterioration (i.e., no visible mould or yeast growth). At each point sub-samples were taken from both the outer 20 cm and then through to the centre of the bale (inner 40 cm). The eight outer and eight inner core sub-samples were composited to produce a single outer and a single inner sample per bale. Each sample was stored at 4 °C prior to sub-sampling for microbiological analyses and then at –18 °C for subsequent chemical analyses.

Precision-chop silage sampling

Precision-chop silage was aseptically sampled using a manual cylindrical corer (internal diameter 3.0 cm). A single full-depth core sample was taken at the centre of the top surface of each silo, from the top layer through to the base of the silage. The sample was taken from an area where there was no visible evidence of damage to the plastic cover, and no visible surface waste or mould. These core samples were stored at 4 °C prior to sub-sampling for microbiological analyses and then at –18 °C for subsequent chemical analyses.

Microbiological analyses

Microbial enumeration was carried out within 3 h of sample collection. For each sample obtained, a single 30 g sub-sample was taken after thorough mixing. Each sample was placed in a sterile plastic stomacher bag with 270 ml of sterile 0.1% (w/v) peptone-water (Oxoid, Oxl 37), allowed to stand at room temperature for 30 min and then homogenised for 3 min in a stomacher lab blender (Colworth stomacher 400). Serial 10-fold dilutions were then made using sterile 0.1% (w/v) peptone-water. All media was made and sterilised to the manufacturers instructions. De Man, Rogosa and Sharpe (MRS; Oxoid, CM 361) nystatin (Sigma, N1638; 100,000 Units/l) agar, violet red bile glucose (VRBG) agar (Oxoid, CM 485) and malt extract agar (MEA; Oxoid, CM 59) with both streptomycin (Sigma, S9137; 100 mg/l) and chloramphenicol (Sigma, C0378; 100 mg/l) were used for the enumeration of lactic acid bacteria, *Enterobacteria* and yeast, respectively, using the double-layer pour plate method (Seale *et al.*, 1990). For spore counts, the dilution series was subject to a heat-shock in a water bath at 80 °C for 10 min prior to plating. Reinforced clostridia agar (RCA; Oxoid, CM151) containing 0.005% neutral red (Jonsson, 1990) and nutrient agar (NA, Oxoid CM3) were used for the enumeration of spores of *Clostridia* and *Bacilli*, respectively, using the pour plate method. The VRBG plates were incubated at 37 °C for two days and NA plates at 30 °C for the same period. All other plates were incubated at 30 °C for three days. The RCA plates were incubated anaerobically in GasPak 150 jars at 37 °C for five days. The colony forming units (cfu) on each plate were enumerated and the number of microorganisms per 1 g silage expressed as $\log_{10}$.

Chemical analyses

Silage samples (200 g) were dried at 85 °C for 16 h in an oven with forced air circulation to estimate dry matter concentration, and corrected for the loss of volatiles by the equation of Porter and Murray (2001). Replicate samples were also dried at 40 °C for 48 h before being milled (Wiley mill, 1 mm screen). Dried, milled samples were used for determination of *in vitro* dry matter digestibility (DMD), neutral detergent fibre (NDF), acid detergent fibre (ADF), ash, buffering capacity (BC), total nitrogen and water soluble carbohydrates (WSC). The DMD was determined by the method of Tilley and Terry (1963) but with the final residue being isolated by filtration rather than centrifugation. Both ADF and NDF were determined according to Van Soest (1963). Ash concentration was determined by complete combustion in a muffle furnace at 550 °C for 5 h. The BC was measured by the method of Playne and McDonald (1966). Total nitrogen (g/kg DM) was determined using a nitrogen analyser (LECO FP-428), based on the methods of the Association of Analytical Chemists (AOAC) 990-03 (AOAC, 1990). The WSC concentration was determined by the automated anthrone method as described by Thomas (1977). The pH was determined from the juice obtained from a 1:1 (undried silage: distilled water) extract, stored overnight at 4 °C, using a hand held pH electrode (Hanna Instruments, HI98127). Further juice was extracted for analysis of volatile fatty acids (VFA), lactic acid, ethanol and NH_3-N. Both VFAs and ethanol were measured by gas chromatography using the method of Ranfft (1973) for short chain fatty acids in ruminal fluids. Lactic acid was measured using the Boehringer method for the determination of lactic acid in foodstuffs and other materials (cat. no. 139084), while NH_3-N was measured using the Sigma Diagnostics method for plasma ammonia (Procedure no. 171-UV).

Data analyses

In order to compare baled silage with precision-chop silage a weighted bale average was calculated from the outer (0.54) and inner (0.46) bale values. Data for the comparison of weighted bales and precision-chop silages were analysed by one-way analysis of variance (ANOVA) appropriate for a completely randomised design Proc GLM of SAS (2000). Data for the comparison of the outer and inner sections of bales were analysed as a paired t-test procedure in SAS (2000).

Results and Discussion

Silage history and storage characteristics

All of the bales sampled (n = 40) were made during the summer of the previous year, with the highest proportion being made in June (0.50) followed by August (0.20), May (0.10) and July (0.10). In a survey conducted by O'Brien *et al*. (2005), June and July were noted to be the busiest months for bale harvesting. Only one farm wrapped bales directly after mowing. A wilting period of one day was employed for proportionally 0.55 of the bales, with 0.20 of the bales being made after a 2-day wilt and the remainder after a period greater than two days. All bales were wrapped in black plastic stretch-film, with four layers being the most common rate applied (0.75) with the remaining farms nominally using six layers. Just over half the bales (0.55) were wrapped at the site of baling prior to transfer to their storage location with the remainder transported to the storage area before wrapping. All bales were fenced off from livestock, generally being stored in single tiers beside farm buildings, on storage surfaces of concrete, grass or gravel.

The plastic film was visibly damaged on 0.48 of the bales, with some visible mould growth present on 0.78 of the bales. These findings agree with O'Brien *et al.* (2005) who found the plastic film visibly damaged on 0.40 of the bales examined while visible fungal growth was seen on 0.90 of bales. Overall, the baled silage making and storage characteristics were similar to those found in other regional or national surveys (O'Brien *et al.*, 2005; O'Kiely *et al.*, unpublished).

The mean (s.d.) dimensions of the precision-chop silage silos (n = 20) were 25.9 (6.42) m long, 10.4 (4.98) m wide and 3.2 (1.39) m high. Precision-chop silage was made earlier in the season than baled silage, with proportionately 0.4 of the silages being made in May and 0.3 in June. Wilting was not as important in this system, with 0.7 of the herbage being ensiled on the day of mowing. The silages were generally sealed beneath polythene sheeting on the day after filling. On all farms, silages were covered with two sheets of black 0.125 mm polyethylene and weighted with tyres, although on 0.3 farms bales of straw and dung were placed over the plastic on parts of the silo.

Chemical and microbiological composition
Wilting is an integral part of baled silage production, discouraging an undesirable clostridial fermentation, reducing losses through the discharge of effluent, making bales lighter and easier to handle, and reducing the number of bales per hectare (Ohlsson, 1998). The DM concentration of the bales (Table 1) indicates that wilting conditions were generally satisfactory and that the one to two day wilt was of sufficient duration in relation to recommendations for Irish conditions. In contrast, precision-chop silage DM concentration reflects a conservation process with a minimal effective wilt. The higher DM concentration in baled silage was reflected in a more restricted fermentation, with a lower (P < 0.001) buffering capacity and concentration of fermentation products, and a higher (P < 0.001) final pH compared to precision-chop silage. Overall, these differences between baled and precision-chop silages agree with Keating and O'Kiely (1997a, b) who compiled a national summary of baled (n = 853) and conventional (n = 15,530) silage analyses. They reported mean (s.d.) DM and pH values for baled silage of 324 (141.1) g/kg and 4.8 (0.62), with corresponding values for conventional silage of 216 (48.7) g/kg and 4.0 (0.34).

In the present study, lactic acid was the dominant fermentation product in precision-chop silage, followed by acetic acid and ethanol, and with smaller amounts of propionic acid (Table 1). The concentrations of the fermentation products and the pH were indicative of a satisfactory preservation, using the thresholds described by Haigh and Parker (1985). The fermentation products in baled silage were less dominated (P < 0.05) by lactic acid and conditions tended to be less inhibitory to the formation of butyric acid than in precision-chop silage. However, the extent of breakdown of protein to ammonia was adequately and similarly restricted (P > 0.05) in both silage types.

Despite the difference (P < 0.001) in mean lactic acid concentration between the two types of silage, the number of lactic acid bacteria did not differ significantly. This suggests that irrespective of potentially different bacterial growth profiles or relative contributions of constituent species of lactic acid bacteria during ensilage, the inhibitory factors associated with silage DM and pH combined to create similar final inhibition. Such inhibition of lactic acid bacteria toward the end of ensilage is mediated through

Table 1. Composition of baled and precision-chop silage

Variable	Silage type		s.e.d.	Significance
	Baled	Precision-chop		
Lactic acid bacteria[1]	5.70	5.96	0.205	
Yeast[1]	3.81	2.34	0.514	**
Clostridia[1]	3.70	3.04	0.308	*
Bacilli[1]	2.67	3.46	0.275	**
Enterobacteria[1]	1.27	1.31	0.498	
Dry matter (DM) (g/kg)	360	220	26.3	***
pH	4.55	3.85	0.115	***
Lactic acid (g/kg DM)	42	103	8.1	***
Ethanol (g/kg DM)	15	19	2.1	*
Acetic acid (g/kg DM)	15	43	2.9	***
Propionic acid (g/kg DM)	3.2	7.0	0.78	***
Butyric acid (g/kg DM)	10.4	6.2	2.14	
Volatile fatty acids (g/kg DM)	28	57	4.3	***
Fermentation products[2] (g/kg DM)	85	179	9.2	***
Lactic acid/fermentation products (g/g)	0.49	0.58	0.046	*
NH_3-N (g/kg N)	69	85	8.8	
Dry matter digestibility (g/kg)	644	677	20.5	
Neutral detergent fibre (g/kg DM)	547	548	12.9	
Acid detergent fibre (g/kg DM)	322	340	7.3	
Ash (g/kg DM)	93	96	4.6	
Crude protein (g/kg DM)	135	156	6.7	**
Buffering capacity (m Eq/kg M)	562	822	32.5	***
Water soluble carbohydrate (g/kg M)	62	11	6.5	***

[1]Number, expressed as $\log_{10}$ colony forming units/g silage.
[2]Fermentation products = lactic acid + acetic acid + propionic acid + butyric acid + ethanol.

the combined effects of anaerobiosis, the presence of undissociated organic acids and water activity (Pahlow *et al*., 2003). The final lactic acid bacterial numbers agree with those proposed by Lindgren (1991) as being indicative of a successful silage fermentation. The implication of a greater contribution of homofermentative rather than heterofermentative lactic acid bacteria in precision-chop silage compared with baled silage is difficult to confirm using fermentation products as a sole guide. This is because of the ability of other bacteria and/or yeast to produce acetic acid and ethanol and because some respiration of lactic acid can occur if oxygen ingress takes place during ensilage (Pahlow *et al*., 2003).

Yeast play a major role in the aerobic deterioration of silage, metabolising valuable sugars and lactic acid, raising the pH and allowing a succession of deterioration to commence. Yeast are also active during fermentation, producing mainly ethanol and carbon dioxide, as well as small amounts of other alcohols, volatile fatty acids and lactic acid (Rooke and Hatfield, 2003). Despite the higher (P < 0.001) concentration of WSC in the baled silage being conducive to yeast fermentation activity (Chamberlain, 1988), the absence of considerably higher concentrations of ethanol suggest that the higher (P < 0.01) yeast numbers in baled silage reflect less strictly anaerobic conditions during the storage of silage in bales

compared with conventional horizontal silos. Under good silage storage conditions yeast numbers of 3.0 $\log_{10}$ cfu/g silage or less would be expected, increasing from 3.0 upwards where insufficient acid is produced or where air infiltrates the silage due to poor storage conditions (Lindgren, 1991). Besides heterofermentative lactic acid bacteria, the contribution of other bacteria to ethanol production in silage is small. Furthermore, the thinness of the stretch film barrier surrounding bales and the ease with which it can be damaged, together with the increased porosity of the wilted forage, may facilitate the passage of oxygen into and through the bale. The higher pH and lower levels of fermentation products in baled silage together with the restricted activity of lactic acid bacteria would also facilitate yeast development.

The higher ($P < 0.05$) number of clostridial spores in baled silage compared to precision-chop silage is surprising given the negative effects of a high DM concentration and of oxygen on clostridial activity. However, Jonsson (1991) and Driehuis and te Giffel (2005) demonstrated that the number of clostridial spores can increase during aerobic deterioration, and oxygen ingress is likely to be prevented less by the plastic barrier surrounding bales than by that placed on horizontal silos. In addition to the above, the higher pH in baled silage would have been less inhibitory to clostridial activity than the mean pH, observed in precision-chop silage. Lindgren (1991) reported that clostridial spore numbers greater than 2.0 $\log_{10}$ cfu/g silage were indicative of poor silage storage conditions. However, high spore numbers alone are not indicative of badly preserved silage and values for ammonia-N, pH and butyric acid concentration also need to be taken into account (Rammer, 1996). The trend towards a higher concentration of butyric acid in baled silage, in the absence of an elevation in ammonia-N concentration, suggests that clostridial activity was dominated by saccharolytic rather than proteolytic bacteria.

Numbers of *Bacillus* spores were higher ($P < 0.01$) in precision-chop silage than baled silage. Although all *Bacilli* grow aerobically, some are facultative anaerobes capable of fermenting a wide range of carbohydrates to organic acids (e.g., acetic, lactic and butyric), ethanol, 2-3 butanediol and glycerol (Pahlow *et al.*, 2003). They are undesirable in silage due to their lower efficiency compared to lactic acid bacteria in decreasing pH and for their ability to succeed yeast during aerobic deterioration, thereby increasing losses through respiration. The lower number of spores in baled compared to precision-chop silage suggests less contamination of harvested silage by soil or animal manure. Such a difference could be related to differences in land and sward type, soil conditions at harvest, to manure spreading practices between the two silage harvesting systems or due to differences in crop mowing, handling or harvesting techniques.

The number of *Enterobacteria* can be used as an indicator of silage quality with values of less than 2.0 $\log_{10}$ cfu/g silage proposed as an indication of a satisfactory preservation (Lindgren, 1991), although in most cases they are not detectable after a few days of ensilage (Ostling and Lindgren, 1995; Woolford, 1984). Under certain conditions, however, such as a delayed or slow fermentation, where insufficient fermentation acids are produced or where air infiltrates the silo, they may persist (Pahlow *et al.*, 2003). In the present study, numbers were moderately low in both types of silage prior to feedout. This suggests that a relatively rapid decrease in pH

occurred with baled and precision-chop forages during ensilage and agrees with the overall finding of a satisfactory preservation. The low ammonia-N concentration also agrees with this interpretation, as *Enterobacteria* can have a significant role during ensilage in protein degradation and in reducing nitrate to ammonia under certain conditions.

The absence of a difference in *in-vitro* DMD between baled and precision-chop silages agrees with the similar NDF and ADF values for both silages. The values recorded also agree with Keating and O'Kiely (1997a, b) who reported mean (s.d.) national values of 656 (71.1) and 668 (54.7) g/kg for baled and conventional silages, respectively. In contrast, whereas Keating and O'Kiely (1997a, b) reported corresponding crude protein values of 151 (30.5) and 140 (18.9) g/kg DM, higher values were found for precision-chop silage in the present study. Since this is unlikely to have been due to differences in harvest date (due to the similar DMD and fibre values), it is probably due to higher inputs of inorganic and/or organic N fertilisers on farms making precision-chop silage compared to those making baled silage.

Bale outer versus bale inner
In general, the extent and pattern of fermentation (as indicated by fermentation indices prior to feedout) suggest little difference between the outer and inner layers of baled silage (Table 2). The concentrations of the major fermentation acids and ammonia-N, the relativity of the fermentation acids to one another, buffering capacity and the concentration of residual WSC were similar for the two sections of the bales. This suggests a similar impact in each bale horizon by the factors controlling fermentation, giving a satisfactory overall preservation. However, the microbial composition was different between the outer and inner layers. While there was no difference in the lactic and acetic acid concentrations between the two bale horizons, numbers of lactic acid bacteria were significantly higher (P < 0.01) in the outer, less anaerobic layer. This suggests that the final inhibition within bales is not as strong in the outer layer close to the plastic wrap. O'Kiely and Muck (1998) reported that lactic acid bacteria numbers remained higher where the fermentation was unsatisfactory or where strict anaerobic conditions were not maintained.

Yeast numbers were also higher (P < 0.05) in the outer bale layer. However, higher yeast numbers were not mirrored in higher levels of ethanol, with ethanol concentration being greater (P < 0.05) in the inner layer. This would suggest yeast respiration rather than fermentation in the more aerobic environment closer to the plastic wrap. This was supported further by increased numbers of *Enterobacteria* in the outer bale layer (P < 0.05). While *Enterobacteria* numbers were relatively low, pH values and ammonia-N concentration were similar in both sections, suggesting that anaerobic conditions were less exacting in the outer layer. In contrast, higher (P < 0.05) numbers of clostridial spores were found in the inner layer compared with the outer layer. The numerically modest increase in the number of clostridial spores in the inner layer was not supported by an increase in concentration of either butyric acid or ammonia-N.

Indices of silage nutritive value such as fibre, protein, WSC and ash were similar in both parts of the bale. However, silage digestibility was lower (P < 0.05) in the outer layer. Since there were no significant differences between the layers in any other index of nutritive value, the lower DMD in the outer horizon may reflect a qualitative loss due to respiration, involv-

Table 2. Composition of the outer and inner layers of baled silage (n = 40 bales)

Variable	Bale layer		s.e.d.	Significance
	Outer	Inner		
Lactic acid bacteria[1]	5.83	5.55	0.102	**
Yeast[1]	4.07	3.50	0.213	*
Clostridia[1]	3.56	3.86	0.123	*
Bacilli[1]	2.77	2.57	0.117	
Enterobacteria[1]	1.44	1.07	0.173	*
Dry matter (DM) (g/kg)	359	362	9.0	
pH	4.54	4.55	0.030	
Lactic acid (g/kg DM)	42	42	1.8	
Ethanol (g/kg DM)	14	17	1.0	*
Acetic acid (g/kg DM)	15	15	1.2	
Propionic acid (g/kg DM)	2.8	3.7	0.53	
Butyric acid (g/kg DM)	10.3	10.6	0.76	
Volatile fatty acids (g/kg DM)	28	29	1.8	
Fermentation products[2] (g/kg DM)	84	88	3.4	
Lactic acid/fermentation products (g/g)	0.50	0.48	0.011	
NH_3-N (g/kg N)	71	67	4.5	
Dry matter digestibility (g/kg)	636	653	7.0	*
Neutral detergent fibre (g/kg DM)	552	541	5.8	
Acid detergent fibre (g/kg DM)	325	319	5.6	
Ash (g/kg DM)	95	92	2.6	
Crude protein (g/kg DM)	137	132	4.4	
Buffering capacity (m Eq/kg DM)	559	565	14.1	
Water soluble carbohydrate (g/kg DM)	62	63	4.8	

[1]Number, expressed as log_{10} colony forming units/g silage.
[2]Fermentation products = lactic acid + acetic acid + propionic acid + butyric acid + ethanol.

ing the possible production of Maillard products (Muck, Moser and Pitt, 2003).

Conclusion

Baled silages underwent a more restricted fermentation than precision-chop silages, due mainly to their higher DM concentration. However, the differences in microbiological composition between the two silage types likely reflect somewhat less anaerobic conditions within baled silage. The relatively modest differences between the outer and inner sections of baled silage suggests that generally similar ensiling conditions prevailed in both horizons, albeit with slightly less anaerobic conditions closer to the bale surface. However, sampling to a depth of 20 cm may have masked the effect of proximity to the plastic stretch-film. A more localised layer effect may have taken place closer to the bale surface (e.g., 1 cm) but this may not have had a measurable effect on overall mean values. Also, had baled silage been sampled from points on the bale where visible mould growth was present, the differences between both baled silage and precision-chop silages, and between the outer and inner horizon of bales, would have been more pronounced.

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