For high levels of animal performance from grass silage focus on digestibility

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Introduction

Grass silage is the basal forage for the majority of beef cattle, dairy cows and pregnant ewes during the winter indoor feeding period in Ireland. Silage production is the largest harvest that occurs in Ireland. Approximately 22 million tonnes are ensiled annually, which has a value of approximately €0.6 billion. Whilst 2012 proved to be a difficult year for silage production the high cost of producing bad quality silage is clear, as indicated by the additional concentrate supplementation required to maintain animal performance. My objective in this paper is to present the effects of silage digestibility on the performance of lactating dairy cows, finishing beef cattle, pregnant ewes and finishing lambs. Furthermore the potential 'concentrate sparing effect' of increasing silage digestibility is discussed. Finally, the major factors that affect silage digestibility, and which are under the control of the farmer, are also presented.

Variability in silage feed value

The composition of silage produced on farms in Ireland varies dramatically in terms of feed value and chemical composition (Table 1). The variation in feed value is dependent on the composition of the herbage harvested, regrowth interval, sward type, harvest date, harvest number, wilting period, prevailing weather conditions, additive treatment and ensiling management. The chemical composition of silage produced in Ireland and offered to livestock in the winter of 2012-2013, as analysed by the Hillsborough Feeding Information System (HFIS), is presented in Table 1. Silage composition was extremely variable as indicated by the data for the concentrations of dry matter, ammonia nitrogen and crude protein, and by dry matter digestibility (DMD). Silages with low DMD have low intake characteristics. The effect of silage feed value on animal performance is also presented in Table 1. The poorer quality silages produced on commercial farms would not even support animal maintenance whilst the best silages, when offered as the sole diet, would sustain 23 litres of milk per cow daily, a daily live-weight gain of 1.1 kg per finishing steer and a daily live-weight gain of 173 grams per finishing lamb. The data in Table 1 clearly indicate the importance of producing high feed value silage to support high levels of animal performance.

In 2012, silage harvest was delayed on many farms due to higher than normal rainfall. In some cases the delay reflected the desire of producers to obtain a wilt, therefore delaying harvest in the hope of dry weather, which rarely materialised, and ground conditions deteriorated. It is interesting to note that the mean DMD for all silages analysed in 2011 ((HFIS) was 71% DMD; results were similar for samples from Northern Ireland and the Republic of Ireland. However in 2012, whilst the mean DMD was 67.3%, the mean DMD for silages produced in Northern Ireland and the Republic were 68.9% and 65.8% DMD, a decline of 2.2 and 5.5% units, respectively, from the previous year.

Table 1. Chemical composition of silages ensiled in 2012 (11,500 samples)

	Mean	Minimum	Maximum
Predicted silage DM intake per day(g/kg $W^{0.75}$)	87	50	105
pH	4.2	3.5	5.6
Dry matter (g/kg)	262	112	681
Ammonia N (g/kg N)	84	50	260
Crude protein (g/kg DM)	108	80	195
Dry matter digestibility (DMD)(g/kg DM)	673	520	820
Metabolisable energy (MJ/kg DM)	10.4	8.3	12.3
Potential animal performance supported under ad-libitum feeding			
Milk yield (kg/d)	9.8	0	22.6
Steer live-weight gain (kg/d)	0.45	0	1.1
Lamb live-weight gain (g/d)	48	0	173

(Hillsborough Feeding Information System)

Silage feed value

The feed value of grass silage is a combination of its intake potential and nutritive value, both of which are determined primarily by digestibility.

Effects of silage digestibility on animal performance

Lactating dairy cows

The effects of increasing silage digestibility on the performance of lactating dairy cows, summarised from 23 comparisons, are presented in Table 2. There is a substantial body of evidence from studies with lactating dairy cows that increasing digestibility increased milk yield, protein concentration and the yields of fat plus protein. The data presented in Table 2 clearly show that the mean daily response for each 1 percentage unit increase in silage DMD is 0.33 kg milk and 0.003 percentage units of milk protein, respectively. Therefore increasing silage DMD by 5 percentage units (e.g., from 68 to 73 %) increases milk yield by 1.65 kg/day. However, the response to silage digestibility depends on the level of concentrate offered. As concentrate feed level increases, silage intake declines, consequently silage forms a smaller proportion of the diet, therefore the response to increasing silage digestibility is reduced. For silage-based diets consisting of forage:concentrate

(DM:DM) ratios of 80:20, 60:40 and 40:60 (equivalent to daily concentrate feed levels of 4.2, 8.4 and 12.6 kg, respectively; Table 5) each 1 percentage unit increase in silage DMD increases milk yield by 0.58, 0.37 and 0.16 kg/day, and milk protein concentration by 0.01, 0.01 and 0.03 percentage units, respectively. Consequently, even when cows are offered high levels of concentrate (60% of the diet dry matter) increasing silage digestibility increases the yields of milk and fat plus protein, and milk protein concentration.

Table 2. The effects of silage digestibility on dairy cow performance (mean of 23 comparisons)

	Silage DMD (%)	
	67.6	75.7
Silage DM intake (kg/day)	10.1	11.6
Milk yield (kg/day)	25.0	27.4
Milk composition (%)		
Fat	3.98	3.98
Protein	3.20	3.28

(Keady and Hanrahan, 2013a,b)

Finishing beef cattle

The effects of increasing silage digestibility on the performance of finishing beef cattle, summarised from 34 comparisons, are presented in Table 3. There is a substantial body of evidence to indicate that increasing silage digestibility increases daily live-weight and carcass gains of beef cattle. The data presented in Table 3 clearly show that the mean daily response for each 1 percentage unit increase in silage DMD is 29.3 grams and 22.8 grams of live-weight gain and carcass gain, respectively. Consequently, if silage DMD is increased by 5 units (e.g., from 68 to 73% DMD) daily carcass gain increases by 0.114 kg/day, which is equivalent to 17.1 kg carcass gain during a standard 150 day finishing period, thus increasing carcass value by approximately €70. However, the response to silage digestibility depends on the level of concentrate offered. As concentrate feed level increases the response to increasing silage digestibility declines, as silage forms a smaller proportion of the diet. For silage based diets consisting of forage:concentrate ratios of 100:0, 80:20, 60:40 and 40:60 (equivalent to daily concentrate intakes of 0, 2.1, 4.2, 6.3; Table 5) each 1 percentage unit increase in DMD increases daily carcass gain by 33, 24, 16 and 8 grams, respectively. Thus for cattle offered diets with forage:concentrate ratios of 100:0, 80:20, 60:40 and 40:60 for a 150-day finishing period each increase of 5 percentage units in silage DMD increases carcass gain by 24.8, 18, 12 and 6 kg, thus increasing carcass value by €102, €73.8, €49.2 and €24.6, respectively. Consequently, even when cattle are offered high levels of concentrate (60% of diet dry matter) increasing silage digestibility increases carcass weight and carcass value.

Table 3. The effects of silage digestibility on the performance of finishing beef cattle (mean of 24 comparisons)

	Silage DMD (%)	
	66.4	73.3
Silage DM intake (kg/day)	5.6	6.1
Live-weight gain (kg/day)	0.74	0.94
Carcass gain - (kg/day)	0.47	0.63
- (kg/150-day winter)	70.5	94.5

(Keady and Hanrahan, 2013 a,b)

Finishing lambs

The effects of silage digestibility on the performance of finishing lambs, from the mean of 10 comparisons, are presented in Table 4. The available evidence clearly shows that increasing silage digestibility increases daily liveweight and carcass gains. The data presented in Table 4 show that the mean daily response for each 1 percentage unit increase in silage DMD is 14.4 and 9.3 grams, respectively. Consequently, if silage DMD is increased by 5 units (e.g., from 68 to 73%) daily carcass gain increases by 46.5 grams which is equivalent to 3.3 kg carcass during a 70-day finishing period, thus increasing carcass value by approximately €15. However the response to silage digestibility depends on the level of concentrate offered. As concentrate feed level increases the response to increasing silage digestibility declines, because silage forms a smaller proportion of the diet. For silage-based diets consisting of forage:concentrate ratios of 100:0, 80:20, 60:40 and 40:60 (equivalent to daily concentrate intakes of 0, 0.3, 0.6 and 0.9 kg; Table 5) each 1 percentage unit increase in DMD increases daily carcass gain by 16, 13, 9 and 6 grams, respectively. Thus, for finishing lambs offered diets with forage:concentrate ratios of 100:0, 80:20, 60:40 and 40:60 over a 70-day finishing period each increase of 5 percentage units in silage DMD increases carcass gain by 5.6, 4.6, 3.2 and 2.1 kg; thus, increasing carcass value by €25.2, €20.7, €14.4 and €9.5, respectively. Consequently, even when finishing lambs are offered high levels of concentrate (60% of the diet) increasing silage digestibility increases carcass weight and carcass value.

Table 4. The effects of silage digestibility on the performance of finishing lambs (mean of 10 comparisons)

	Silage DMD (%)	
	72.8	76.8
Silage DM intake (kg/day)	0.52	0.72
Live-weight gain (g/day)	75	128
Carcass gain - (g/day)	38	73
- (kg/70 day finishing period)	2.7	5.1

(Keady and Hanrahan, 2013a,b)

Table 5. Response in the performance of lactating dairy cows, finishing beef cattle and lambs to a change of 5 percentage units in silage DMD, at various forage:concentrate ratios.

			Forage:concentrate ratio			
Animal type	Performance trait		100:0	80:20	60:40	40:60
Dairy cows	Milk yield (kg/day)			2.9	1.9	0.8
	Fat plus protein yield (kg/day)			0.19	0.13	0.08
	Milk composition (%)	- Fat		0.00	-0.04	-0.07
		- Protein		0.07	0.03	0.13
Beef cattle	Carcass gain	- (kg/day)	0.17	0.12	0.08	0.04
		- kg per 150 day finishing period	24.8	18.0	12.0	6.0
Finishing lambs	Carcass gain	- kg/day	80	65	45	30
		- kg per 70 day finishing period	5.6	4.6	3.2	2.1

(Keady and Hanrahan, 2013a,b)

Pregnant ewes

The effect of increasing silage digestibility on the performance of pregnant ewes is presented in Table 6. In these studies the ewes received on average 19.4 kg concentrate during late pregnancy. The evidence shows that increasing silage digestibility increases ewe weight immediately post lambing and lamb birth weight. Previous studies at Athenry have shown that each 1 kg increase in lamb birth weight increases weaning weight by 3.2 kg. The data presented in Table 6 show that the mean increase in ewe weight post lambing and in lamb birth weight for each 1 percentage unit increase in silage DMD is 1.3 kg and 52 grams, respectively. Consequently, if silage DMD is increased by 5 percentage units ewe weight at lambing and lamb birth weight are expected to increase by 6.5 kg and 0.25 kg, respectively.

Table 6. The effects of silage digestibility on the performance of pregnant ewes (mean of 9 comparisons)

	Silage DMD (%)	
	713	778
Ewe weight post lambing (kg)	68.5	76.1
Lamb birth weight (kg)	4.69	5.03

(Keady and Hanrahan, 2013a,b)

Effects of silage digestibility on concentrate sparing effects

The level of concentrate supplementation required to ensure that target performance levels are achieved with silage-based diets is dependant on the feed value of the silage and the stage of the production cycle of the animals involved. The price of concentrate is volatile; for example, prices have increased by up to 35% over the past 12 months. Therefore, when concentrate price is high relative to product price (milk or meat) one of the potential benefits of increasing silage feed value (DMD) is that animal performance can be maintained whilst reducing the level of concentrate supplementation offered. This is referred to as the ‘potential concentrate sparing effect’ (i.e., the reduction in level of concentrate supplementation required to maintain animal performance). The cost of production and price risk are also reduced.

The effects of increasing silage digestibility on the ‘potential concentrate sparing effect’ for lactating dairy cows, finishing beef cattle, finishing lambs and pregnant ewes are presented in Table 7. For lactating dairy cows, reducing silage digestibility by either 1 or 5 percentage units, or harvesting 1 week later increased concentrate requirements, in order to maintain milk yield, by 0.55, 2.75 and 1.8 kg/day, respectively, or by 17, 85 and 56 kg/cow per month of lactation, respectively. Therefore, for a herd of 50 cows this equated to increased concentrate requirements of 0.85 t, 4.25 t and 2.8 t, respectively; a considerable increase in feed costs.

In the case of finishing beef cattle, reducing silage digestibility by either 1 or 5 percentage units, or harvesting 1 week later increases daily concentrate requirements, to maintain carcass gain, by 0.36, 1.8 and 1.2 kg/head; this equates to 54, 270 and 178 kg during a 150-day finishing period. Consequently, for each 50 cattle finished the increased concentrate requirements are 2.7 t, 13.5 t and 8.9 t; a considerable increase in feed costs.

For finishing lambs, reducing silage digestibility by either 1 or 5 percentage units, or harvesting 1 week later, increases daily concentrate requirements, to maintain carcass gain, by 0.07, 0.35 and 0.23 kg/lamb, which equates to 4.9, 24.5 and 16.2 kg for a 70-day finishing period. Consequently, for each 100 lambs finished concentrate inputs must be increased by 0.49 t, 2.45 t and 1.62 t, respectively.

For pregnant ewes, reducing silage digestibility by either 1 or 5 percentage units, or delaying harvest by 1 week increases concentrate requirement during late pregnancy, to maintain lamb birth weight, by 4.5, 22.6 and 14.9 kg, respectively. Thus, for each 100 ewes the concentrate requirement during late pregnancy are increased by 0.45 t, 2.26 t and 1.49 t, respectively; a considerable increase in feed costs.

Table 7. The effects of silage digestibility on concentrate feed required (kg) to maintain animal performance

		Additional concentrate requirements for		
		1 unit reduction in DMD	5 unit reduction in DMD	1 week delay in harvest
Cows	- kg/day	0.55	2.75	1.8
	- kg/month	17	85	56
Finishing cattle	- kg/day	0.36	1.8	1.2
	- kg/150 day finishing period	54	270	178
Lambs	- kg/day	0.07	0.35	0.23
	- kg/70 day finishing period	4.9	24.5	16.2
Pregnant ewes	- kg in late pregnancy	4.5	22.6	14.9

(after Keady et al 2013)

Major factors affecting digestibility of grass silage

The factors that determine silage digestibility are harvest date, sward type, silage fermentation, level of fertiliser N applied and wilting.

Harvest date

Harvest date is the most important factor affecting silage digestibility, which declines as harvest date is delayed. Silage digestibility declines by 3.3 percentage units for each 1 week delay in harvest date. The rate of decline in digestibility is similar for swards that are closed for first or second cut silage.

Lodging, or flattening, of the grass crop prior to harvest accelerates the rate of decline in herbage digestibility. This accelerated decline in digestibility is due to the accumulation of dead leaf and stem at the base of the sward. Digestibility may decline by as much as 9 percentage units per week in severely lodged crops.

Sward type

It is assumed, normally, that silage produced from old permanent pastures has an intrinsically lower digestibility than silage produced from a perennial ryegrass sward. However, the negative impact of old permanent pasture on silage digestibility is dependent on botanical composition. When old permanent pastures are harvested at the correct stage of growth silage with a high feed value can be produced consistently.

A 2-year study was undertaken at Grange, using 4 harvests per year, to evaluate the effects of sward type on the feed value of grass silage. In the first year of that study, beef carcass output per hectare for silage produced from old permanent pasture (45% meadow grasses, 26% bent grasses, 10% perennial ryegrass, 6.5% meadow foxtail, 2% cocksfoot, 10.5% other) was similar to that for silage from a newly sown perennial ryegrass sward. Carcass output was lower for the silage from the old permanent pasture in the second year of the study, but this was attributable to the fact that the silage produced from the first harvest off this pasture had a lower digestibility than that from the perennial ryegrass sward (swards closed the previous October).

The effects of sward type on feed value of silage harvested from second re-growths (third harvest) of two pasture types are summarised in Table 8. Silage produced from an old permanent pasture (52% perennial ryegrass, 28% creeping bent, 10% meadow grasses, 10% Yorkshire fog) and that from a perennial ryegrass pasture resulted in silages with similar (high) feed value, based on metabolisable energy (ME) concentration (determined *in vivo*) and intake, when offered to growing cattle. The results from these studies show that high feed-value silage can be produced from old permanent pasture provided it has a moderate level of perennial ryegrass and is ensiled at the correct stage of maturity using good ensiling management.

Table 8. Effect of sward type on silage composition, digestibility and intake

	Sward type	
	OPP	PG
Silage Composition		
pH	4.1	4.0
NH_3-N (g/kg N)	75	74
ME (MJ/kg DM)	12.0	11.7
Silage DM intake (kg/day)	3.66	3.56

OPP = old permanent pasture, PG = perennial ryegrass (Keady et al., 1994)

Perennial ryegrass varieties are classified according to heading date. Whilst the general recommendation is to harvest swards at approximately 50% ear emergence, the actual date of emergence for a sward depends on the grass varieties present and their heading dates. The effects of heading date (intermediate or late) of perennial ryegrass varieties, and date of harvest, on the performance of beef cattle were evaluated in two studies and are summarized in Table 9. The intermediate- and late-heading swards each consisted of 3 different varieties (with similar heading dates) of perennial ryegrass. Whilst the mean heading date of the intermediate- and late-heading swards differed by 24 days (19 May and 12 June), herbage from the late-heading sward had to be ensiled within 8 days of that from the intermediate-heading sward to give the same silage digestibility and daily carcass gain of finishing beef cattle.

Table 9. Effect of sward heading date and harvest date on silage digestibility and animal performance

Heading date × Harvest date	Silage		Carcass gain (kg/day)
	DMD (%)	DM Intake (kg/day)	
Intermediate (19 May)			
20 May	76.5	6.8	0.63
28 May	72.6	6.2	0.51
5 June	68.1	6.3	0.46
Late (12 June)			
28 May	76.2	6.6	0.61
5 June	72.0	6.4	0.55
13 June	69.3	5.9	0.40

(Steen, 1992)

If the harvest of the late-heading sward was delayed until 50% ear emergence the resulting silage DMD would be 5 percentage units lower than the silage from the intermediate-heading sward at the same stage, consequently reducing silage intake and carcass gain (from 0.63 to 0.40 kg/day). Similarly, results from studies using small scale silos show that herbage from late-heading varieties (heading date 10 June) must be ensiled on 31 May to produce silage with a digestibility similar to that for intermediate-heading varieties (heading date 22 May).

Silage fermentation

Relative to well-preserved silage, poorly-preserved untreated silage with a low lactic acid concentration and a high concentration of ammonia nitrogen normally has lower digestibility. The reduction in DMD in untreated silages due to inappropriate silage fermentation can be as high as 7 to 8 percentage units. However for silages that are treated with an effective inoculant at ensiling, but which have poor fermentation characteristics (at feed out), there is no negative impact on digestibility or on subsequent animal performance.

Fertilizer N application

Application of excess fertilizer N has a negative effect on silage digestibility. Thus, increasing the rate of fertilizer N from 72 to 168 kg/ha for the primary growth of predominantly perennial ryegrass swards reduces silage DMD by 1.5 percentage units.

Wilting

Wilting reduces silage DMD. The decline in digestibility due to wilting is a consequence of the loss of available nutrients and an increase in ash concentration. The decline in digestibility due to wilting depends on the length of time between mowing and ensiling the herbage, and on soil contamination due to mechanical treatment. The rate of loss in digestibility has varied, among studies, from 0.2 to 1 percentage unit per 10 h wilting period. Thus, each day (24 h) of wilting can reduce silage DMD by between 0.5 and 2 percentage units, which is equivalent to delaying harvest by up to 4 days.

Conclusions

It is concluded that:

a. Digestibility is the most important factor influencing the feed value of grass silage and consequently the performance of animals offered grass-silage based diets.
b. The effect of increasing silage digestibility on animal performance depends on the forage:concentrate ratio of the diet.
c. Each 1 percentage unit increase in DMD results in the following average changes:
    i. daily milk yield of lactating dairy cows by +0.33 kg
    ii. daily carcass gain of beef cattle by +22.8 g
    iii. daily carcass gain of finishing lambs by +9.3 g
    iv. lamb birth weight by +52.3 g
    v. ewe weight post lambing by +1.3 kg
d. Harvest date is the main factor affecting silage digestibility. Each one week delay in harvest reduces digestibility by 3.3 percentage units.
e. To sustain animal performance due to a delay of harvest by one week requires an additional
    i. 1.82 kg concentrate DM daily per lactating dairy cow
    ii. about 1.2 kg concentrate daily per finishing beef animal
    iii. 0.23 kg concentrate daily per finishing lamb
    iv. 14.9 kg concentrate per ewe in late pregnancy
f. For finishing beef cattle, lactating dairy cows, pregnant ewes and finishing lambs aim to produce high feed value silage with a DMD of 75%.

References

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