Forage Management Guide

Helping farmers to
preserve quality forage

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Introduction

The key objective for any livestock farmer when preserving forage is to make a stable and nutritious feedstuff, with minimal loss of quality or quantity, to maximise livestock performance efficiency.

Feeding high quality home grown forage is essential to achieving profitable animal performance. Forage provides a relatively low cost feedstuff that can be very nutritious if well managed.

Volac International Limited is a privately owned business established in 1970. We are Europe's market leader in specialist areas of animal nutrition, forage systems, animal health care and feed ingredients, as well as providing the same innovative products worldwide.

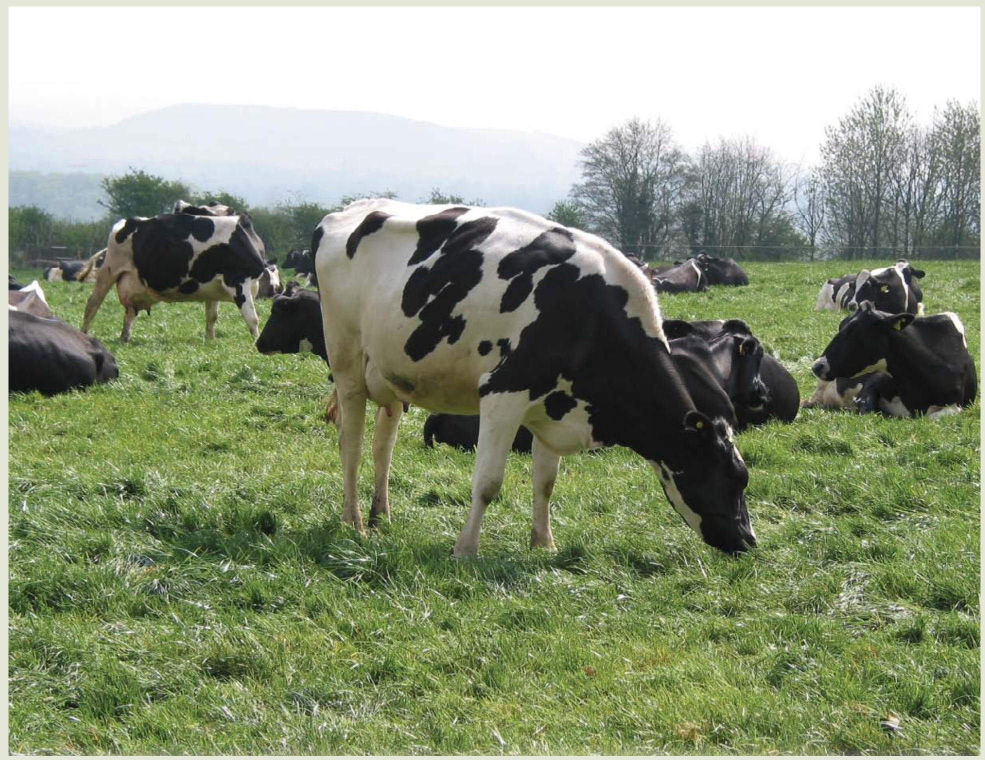
All Volac products are supported by our strong technical, marketing and sales teams, who aim to bring you timely husbandry and management information, to help you get the most from your livestock.

Reasons for Preserving Forage

Forage is a valuable resource as it provides the necessary fibrous component of the ruminant diet so essential for healthy rumen function.

It can also be the cheapest form of energy and protein available on the farm. Poorly produced forage either results in lower animal performance or an increase in the amount of purchased supplementary feeds, which can make the difference between a viable and a non-profitable unit.

To optimise livestock performance and maximise output from forage, it is essential to ensure that the potential nutritional value of the forage is successfully achieved. Therefore, good growing, preservation and storage techniques are extremely important, as well as making the correct choice of forage for your system.



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Forage - A Rethink

Forage preservation systems and crop varieties have developed dramatically over the last thirty years, with technology now allowing the preparation and feeding of high dry matter mixed forage diets.

During this period, grass silage dry matters have increased by approximately 5% per decade and alternative forages, such as whole crop and maize, have become significant constituents of the modern ruminant ration, now representing up to 20% of the forage diet on a national basis.

Can we afford not to rethink our forage management practices?

A summary of why we preserve forage

1) To conserve a stable and nutritious feed, with minimal loss of quality and quantity, to store for use when sufficient fresh forage is not available.
2) To maximise the use of cost-effective home grown forage to meet performance and profit targets.
3) To produce nutritionally balanced rations and support the healthy performance of livestock.

Forage options

There are many different options available and there is no universally right or wrong forage. The ideal forage, or mix of forages, for your farm will depend on a number of different factors, for example:

- What type of livestock you are feeding and what performance do you expect from them?
- What grows well on your farm and fits into your production systems?
- What storage facilities and labour do you have available?
- What feeding system do you use, e.g. Total Mixed Ration (TMR)?
- What straights or other by-product feed ingredients are available to you?

In this guide, we will give an overview of each of the main forage preservation options available and review the strengths and weaknesses of each.

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Forage Options

Dried forages Hay and straw have historically been the staple diet of livestock and still remain common sources of forage on many modern units. While low in nutrient density, they are an excellent source of long fibre, which is essential for healthy rumen function.

Hay

Fresh grass is cut at a mature stage and dried to stop respiration and enzyme activity from breaking down valuable nutrients, giving a dry stable forage for storage.

Although haymaking has declined over the last few decades, it is still a widespread operation around the UK and Ireland, and offers a saleable product that is easy to store and transport.

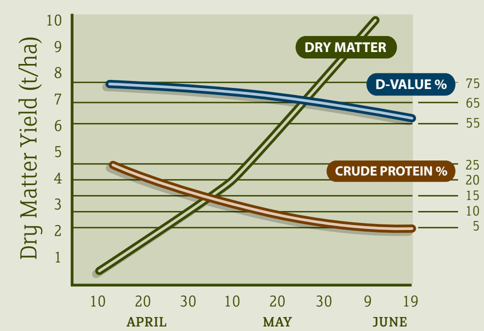
Method of preservation

Good quality hay is achieved by rapid drying of the grass crop to preserve the nutritive value. Nutrient losses can be excessive in anything other than fine weather, as plant and microbial enzymes use up the valuable protein and energy from the grass during the drying period. Ideally, the crop must be dried to at least 80% dry matter within 3 days to prevent yeast and mould proliferation. Mower-conditioners and tedders can be used to help dry the crop quicker, as can mobile field blowers and barn driers.

At dry matters below 75% there may be a great deal of spoilage, high levels of wastage, heating and potential fire risk.

The stage at which grass is cut is important; a more mature crop will dry more quickly and give the greatest yield, but the nutritive value and digestibility will be lower. Cutting time will inevitably be a compromise between weather, yield and nutritive value and always remember that you will never make good hay from poor quality grass!

Typical changes in nutritive value of grass



Source: Thomas, Reeve & Fisher (Eds), 1991

Advantages of Hay
Can be stored for long periods with little nutrient loss
Excellent source of long fibre
Easy to handle at feed-out
Does not require specialist storage or handling equipment
Excess can be sold as a cash crop

Disadvantages of Hay
Low in nutritive value, particularly protein
Limited intake potential
Very weather dependent / field losses can be high
Can be dusty and high in mould spores, increasing the risk of lung infections in livestock and handlers
Needs to be stored in dry conditions

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Straw

Straw is essentially a by-product of cereal production. It is the leftover stems and leaves after the grain has been harvested and makes good bedding material.

It is extremely high in fibre and low in nutrients, so it is not suitable for inclusion at high levels in diets for the high producing ruminant. Its main benefit as a feedstuff is the provision of fibre to encourage good rumen function. Barley and oat straw offer the best nutritional value and have an important place in feeds for young calves and lambs. They are valuable as bulky, but consistent, sources of fibre for growing heifers and store cattle.

Maize and legume straws have a higher nutritive value than barley or oat straw, but grain maize and forage legumes are not widely grown in the UK. Legumes contain high levels of protein, magnesium and calcium, but they are difficult to dry and prone to mould due to their thick stems.

Wheat straw has the lowest nutritive value.

Method of preservation

Crops harvested for grain tend to be around 80-85% dry matter, so the straw requires little drying when harvested and can be picked up and baled for storage immediately post-harvest. The use of a quality net (eg. Volac Topnet) helps to keep the bales in shape.

Most fungal problems occur in the leaf, so straw is far less susceptible to spoilage than hay, although quality will still be dependent on good weather from harvest up to the time the straw is baled and removed for storage.

Advantages of Straw
Can be stored for long periods with little nutrient loss
Excellent source of long fibre
Easy to handle at feed-out
Ideal feed for calves, lambs and dry cows
Does not require specialist storage or handling equipment
Can be sold for bedding

Disadvantages of Straw
Very low in nutritive value
Needs to be stored in dry conditions
Can be dusty
Limited intake due to high dry matter and low digestibility
Can be high in mould spores if harvested in wet weather

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Grass Silage

Through the 1970's and 1980's there was a dramatic shift from conserving grass as highly weather-dependent hay to the more flexible system of producing grass silage. The introduction of big bale silage in the 1980's gave the additional benefits of transportation, flexible storage and feeding.

Essentially grass silage is pickled grass. The aim is to retain as much feed value as possible by encouraging lactic acid bacteria to ferment grass sugar to produce lactic acid.

The acid lowers the pH and prevents the growth of spoilage micro-organisms, allowing stable preservation of grass as silage. In order to achieve this, there must be sufficient sugar available, the fermentation must occur as quickly as possible and air must be excluded throughout (anaerobic conditions).

This can be done in a silage clamp or in big bales, but both have the same objectives:

- Rapid removal of air (compaction).
- Rapid fermentation of grass sugars to lactic acid.
- Maintenance of anaerobic conditions in the clamp/bale during storage.

Method of preservation

The ensiling process is basically very simple.

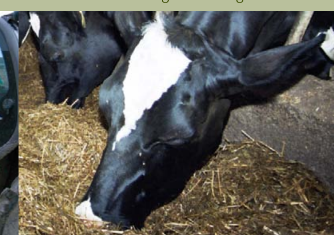
Grass is cut, left in rows or spread wide, and turned (tedded) to aid wilting.

The swaths are picked up, chopped, silage additive applied and carted to the clamp

The clamp is filled and rolled well to compact the forage. It is then covered with airtight sheeting

The grass is picked up and baled, then the bales are wrapped and stored

Fermentation takes place in the clamp or bale



6 weeks or so later, it can be opened and fed out

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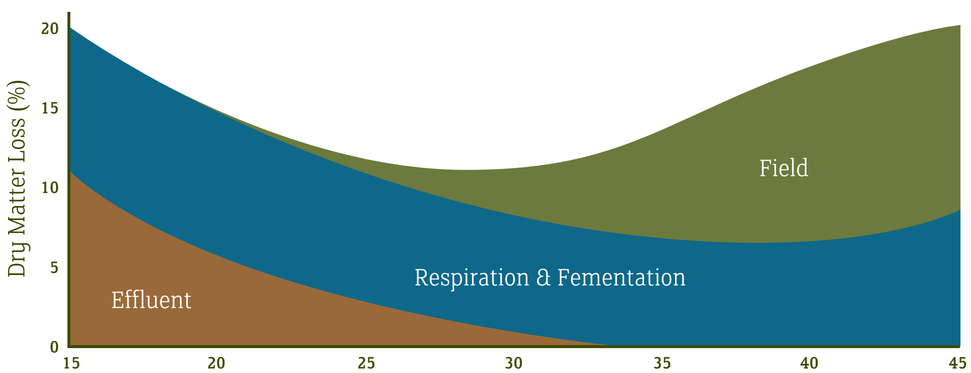
Typical clamp silage DM losses from original crop

Production Stage	Average DM Losses	Recommendations to reduce losses
Harvesting/field losses	2 - 12%	Rapid drying/wilting, cut in good weather, avoid soil contamination
Respiration & fermentation (including top & shoulder waste)	5 - 18%	Fill clamp rapidly with good compaction and air tight sealing. Use a silage inoculant to ensure an efficient fermentation is achieved. Seal the clamp effectively during breaks in harvest. Use side sheets
Silage effluent	0 - 8%	Wilt for 24 hours. Use a silage inoculant to overcome high populations of spoilage organisms
Feed-out losses	1 - 10%	Keep the clamp face smooth, remove 10 - 30cm of the whole face daily to keep material fresh and keep sheeting close to the face

Source: IGER2001

Good ensiling practices and the use of silage additives will help to control the process and minimise these losses as much as possible. Wilkinson (2005) suggests dry matter losses are minimised by ensiling at 25-30% DM.

Model of dry matter losses in well-managed grass silage systems



Source: Wilkinson, 2005

Total dry matter losses during ensiling can vary from as low as 10% to 40% or more when there are high aerobic spoilage losses. This represents a hidden increase in the cost per tonne of silage due to lost nutritive value and the need to buy in additional expensive supplements.

Assuming an average production cost of around £85 per tonne of dry matter (without losses) for grass silage, a 10% DM loss would increase this to over £94 while a 40% loss would increase it to nearly £142.

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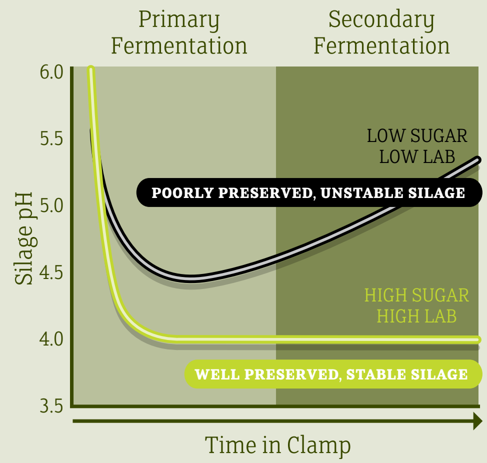
Grass Silage

Growing and harvesting factors influencing forage quality

Getting the right microbial population is essential to making good silage. Lactic acid bacteria (LAB) are the 'desirable' bacteria. Spoilage micro-organisms are 'undesirable' and make the fermentation less efficient as they convert sugars to weaker acids (e.g. acetic), which don't preserve the silage effectively and can lead to a secondary fermentation.

Fermentation of ensiled grass



Spoilage micro-organisms also use valuable grass nutrients and produce unwanted by-products. Even using good management techniques as much as 50% of the true grass protein can be broken down in the ensiling process.

'Desirable' micro-organisms

Lactic acid bacteria (LAB) - efficiently ferment the sugars in the grass, producing mainly lactic acid which pickles the grass by lowering pH to inhibit undesirable micro-organisms. LAB have a limited ability to ferment amino acids, unlike Enterobacteria and Clostridia, so more protein is retained in the final feed.

'Undesirable' micro-organisms

Enterobacteria – mainly coliforms from manure and soil; they ferment sugars to acetic acid and degrade protein to ammonia. Some are pathogenic (e.g. E. coli).

Clostridia – break down sugars, proteins and lactic acid producing toxic by-products and butyric acid.

Yeasts – ferment sugars to ethanol and CO_2 and oxidise preserving acids, resulting in less stable silage and heating.

Moulds – reduce feed value and palatability. Produce spores and mycotoxins which can cause severe health and production problems.

Listeria – potentially pathogenic. Contaminated silage can infect animals and may enter the food chain through milk and meat, posing a risk to human health.

Bacilli – less efficient fermenters, can increase aerobic spoilage at feed-out and can pass into milk causing health problems.

Most of the undesirable micro-organisms do not tolerate low pH and require oxygen to grow. Good ensiling techniques, fast efficient fermentation, the use of effective additives and continued exclusion of air, will help to avoid their presence.

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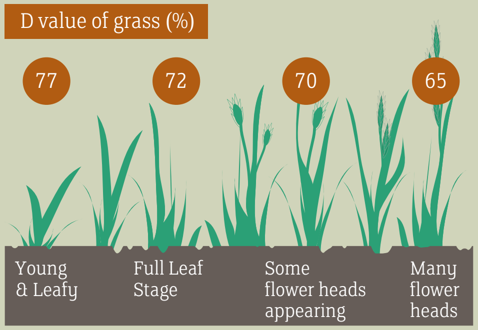
Pointers for Success

Growing

- Follow good crop management practices to encourage yields without reducing sugars.
- Avoid late application of fertiliser – apply nitrogen at least 8 weeks before mowing.
- Do not surface apply slurry within 10 weeks of mowing, and preferably not at all, because of the presence of undesirable micro-organisms.
- Buffering capacity reflects how readily a crop can be acidified, or fermented. Grass has a low buffering capacity and is easy to ferment, but residual fertiliser increases buffering, making fermentation more difficult.
- When reseeding, select the variety which meets your requirements relating to harvest date, yield, quality, soil type and climate.

Stage of growth and digestibility (% Perennial Ryegrass)



(see also graph on Pg. 3)

Harvesting

- Young leafy grass is more difficult to make into well preserved silage than more mature, stemmy grass, as it contains more moisture and less sugar. However, as the crop matures the digestibility (D value) falls.
- Expose as much surface area in the swath as possible by turning and spreading to dry the crop rapidly. Conditioners can also help improve the efficiency and rate of drying.
- Avoid contamination with soil when raking or tedding.
- Chopping results in a quicker and more efficient fermentation since the sugars are rapidly released and the chopped material is easier to compact, trapping less air.

IGER recommended chop lengths

DM (%)	Chop length (cm)
20% or less	2.5+
20-28%	2.0-2.5
28-35%	1.3-2.0

- Test for an absence of nitrate-N and a minimum of 2.5% grass sugar
- Maximise sugars by cutting in the afternoon on a sunny day, when dry matter and sugar content tend to be highest.
- Ensure adequate LAB are present by using an effective inoculant.

  (see Volac range in Forage Product booklet).

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Pointers for Success

Wilting

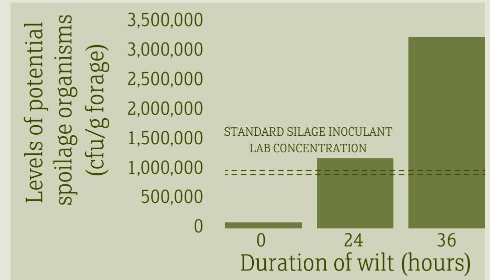
- Rapid wilt (24 hours maximum) to about 30% DM to reduce effluent and concentrate sugars if conditions permit.
- As a guideline, 1% of moisture is lost per hour of sunlight in bright conditions (greater with mower-conditioners and tedding).
- When wilting, remember that high DM grass (35%+) has a greater risk of mould.
- Wilting for 12 hours or more has become standard practice to reach the higher dry matter silage required by the modern dairy cow. However, longer wilting results in the proliferation of spoilage organisms, such as coliforms (see chart top right), leading to the loss of valuable nutrients.

Fermentation

The critical phase, but also the uncontrolled one if no additive is used.

- Other than ensuring good harvesting, wilting and clamping practices are followed, the only control factor is the application of an effective silage additive to ensure rapid production of lactic acid.
- Natural populations of LAB can be low and inefficient. Silage inoculants are designed to ensure that there are sufficient lactic acid bacteria present, of the right species, to achieve a fast and efficient fermentation.
- With high dry matter material, use an additive specifically formulated to inhibit spoilage micro-organisms. Aerobic spoilage from yeasts and moulds is common in high DM material as it is harder to compact, air gets trapped in pockets and localised spoilage can occur.
- Keep the clamp airtight, repair any rodent or bird damage.

Effect of wilting on levels of spoilage organisms



Guide to assessing grass dry matter

Grass swath grab sample	Approx dry matter
Juice drips from ball when squeezed	Less than 25%
Ball retains shape when released, no juices	25 - 35%
Ball unfolds slowly when released	35 - 45%
Ball unfolds quickly, grass breaks	Greater than 45%

Clamp filling

- Fill the clamp rapidly and evenly, and compact well to remove air (sheet at night).
- Ensure air-tight sheeting and use side sheets.

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Feed-out

Exposure to oxygen will cause deterioration - undesirable micro-organisms become active, break down the acids preserving the silage, and pH begins to rise. The clamp heats up, leading to spoilage. Nutritional value and palatability are reduced and the production of mycotoxins can have adverse effects on livestock health and performance.

- The more efficient the fermentation stage and the more stable the silage, the longer it will last once the clamp is opened.
- Use a shear grab to keep the clamp face smooth, reducing air penetration, and aim to remove 10cm from the face each day in cold weather and 30cm in warm.
- Move across the face as rapidly as possible.
- Never leave the sheet dangling over the face during feed-out; it will encourage spoilage. Roll it back or cut it and weight the front edge. Net if birds are a problem. Clear up any fallen material and dispose of any spoiled silage.

Additives and animal performance

The benefit of using a good quality silage additive is well documented. The table below shows the benefits found in research conducted at AFBI Hillsborough, where both silage fermentation characteristics and animal performance were improved when a silage inoculant was used.

Average of Hillsborough Trials

	Control	Formic Acid	Inoculant
Silage pH	3.9	3.8	3.8
Silage NH_3N (g/kg total N)	81	58	64
Butyric acid (g/kg DM)	0.34	0.01	0.30
Silage DM intake (kg/d)	9.44	9.70	10.39
Milk yield (kg/d)	22.9	22.2	24.4
Fat plus protein (kg/d)	1.48	1.53	1.59

Source: Gordon 1992

Advantages of Grass Silage
Easy to grow in UK conditions
Less weather dependent than hay
High protein
Well established system in place
Grazing balancer
2-3 cuts per year
Big bale system offers flexibility

Disadvantages of Grass Silage
Variable fermentation and quality
Can be low pH (pH < 4 = acid)
Wasteful - loss of dry matter and nutrients
Can be low dry matter
Labour intensive
Weather dependent
Second and third cuts may not be as cost effective

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Volac introduced the Big Bale Wrapping System to the UK and Ireland in 1984. Since then the practice of conserving grass in bales has revolutionised silage production giving increased flexibility of use and helping to improve animal performance.

Method of preservation

The principles of making big bale silage are the same as for clamp. Aerobic spoilage losses tend to be lower as each bale is individually sealed and the system reduces effluent production and nutrient losses to the environment. Bales can be readily stored and are easy to transport around the farm and feed out. Big bale silage can also be very economic compared to the cost of dedicated silage pits. Very low levels of wastage result in more efficient utilisation of the forage, with better returns from animal production.

Harvesting factors influencing forage quality

- Wilting for 24 hours to 25-50% DM is essential when making big bale silage to ensure effluent production is minimised.
- Present swaths well and use net wrap (e.g. Volac Topnet) to make even and well packed bales.
- Use a good quality film (e.g. Volac Topwrap) to ensure that the nutrients in your silage are fully protected.
- Typically, four layers of high quality film are sufficient to protect the silage.
- Six layers of film are recommended for; high dry matter (> 40%) round bales, all square bales, heavy chopped bales and bales for livestock sensitive to mould, i.e. horses, sheep or pregnant animals.
- Use Volac Topwrap Eco-green film to reduce spoilage and improve silage quality.
- Wrapping at the stack reduces potential bale damage.
- Good bale storage is essential, repair any damage straight away to avoid spoilage.

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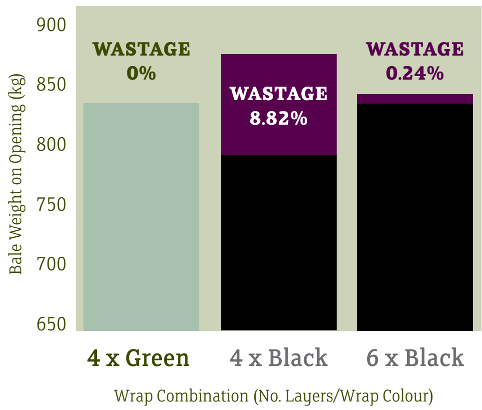
Film Colour

Variations in the surface temperature of a wrapped bale will affect the quality of the silage and the degree of spoilage. Higher temperatures make the plastic film more permeable to air, encouraging spoilage organisms, such as yeasts and moulds, leading to loss of valuable nutrients.

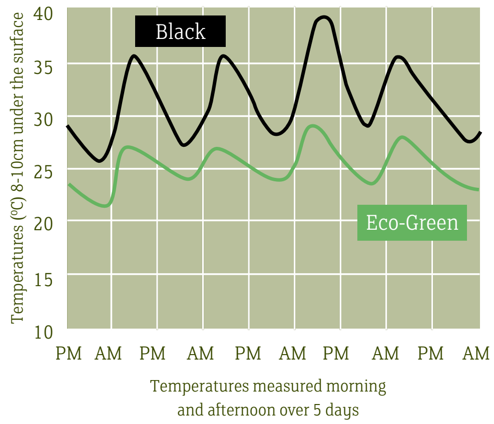
Research has shown that film colour can significantly influence the surface temperature of the bale, which can vary by up to 20°C. Volac Eco-Green film has been specifically designed to minimise temperature variations in all weathers, minimising the proliferation of spoilage organisms in the bale.

Average spoilage per bale for each combination of wrap



Source: DOW/CEDAR, 2002

Temperature variations in bales wrapped with different film colours



Source: Trioplast

Advantages of Big Bale Grass Silage
Low aerobic spoilage
Flexibility to cut at optimum cutting date for each field
Can target quality to livestock needs
Good for storing surplus grass, especially cuts taken in autumn
Low dry matter loss (<5-10%) during production and storage
Limited capital investment, low transport and storage costs

Disadvantages of Big Bale Grass Silage
Not suitable for very wet silage
Labour intensive at feeding out
Risk of variability between bales
Prone to damage - mechanical, birds, vermin
Plastic disposal; cost of compliance with waste regulations
High unit costs

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Haylage

Haylage is part-way between hay and silage. The grass is cut slightly earlier than for hay, between heading and flowering, but it is wilted and baled at 50% to 65% DM, instead of being left to dry to 80% DM as for hay.

It is then fermented like silage, but rather than undergoing the same extensive fermentation, a limited fermentation takes place because it is made using drier material. It is popular with horse owners as it does not contain the high levels of dust and mould often found in hay.

Method of preservation

A good lactic acid fermentation is still necessary so the same management practices as for silage apply. Choose an additive that will ensure a fast, efficient fermentation as well as inhibit the yeasts and moulds that cause heating and moulding. Due to the high dry matter, secondary clostridial fermentation should not be an issue but can occur in wetter pockets or if an animal carcass is present, leading to animal health problems (e.g. botulism in horses).

Spoiled or poorly fermented haylage will also increase the risk of Listeria, which can affect all livestock but is particularly serious for sheep. A pH of less than 5.6 will kill Listeria and good quality, well-fermented haylage should be pH 4.5-5.5.

Nutritional value

Although similar to hay, due to its higher moisture content, haylage should be fed at around 1.5 times the fresh weight you would normally feed hay. Good haylage will have a pleasant acidic odour, be uniform in colour and feel moist but not mushy. Good quality haylage will contain around 10-13% crude protein and have a dry matter digestibility of 65-70%. Less leaf loss occurs during harvesting than for hay because the material is more moist, resulting in a higher protein content. Haylage is also more palatable and digestible than hay, so there is very little wastage at feed-out.

Advantages of Haylage
Highly palatable
Produces less dust than hay
Fewer problems with moulds
Less weather dependent than hay
Totally mechanised production
Lower field losses than for hay
Higher nutritional value than hay

Disadvantages of Haylage
Can be labour intensive
Very sensitive to moisture variation
Risk of Listeriosis
Risk of aerobic spoilage and heating

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Maize Silage

Maize is now the most popular cereal crop conserved as silage. Though essentially a tropical plant, plant breeders have developed earlier maturing varieties, enabling northern areas to grow maize successfully.

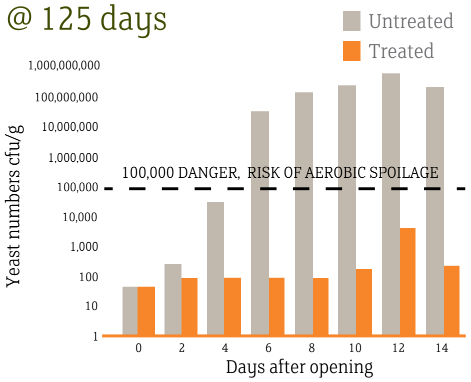
Method of preservation

The method of preservation for maize silage is basically the same as for grass. The crop is fermented to produce lactic acid, resulting in a lowering of pH which preserves the forage and prevents the growth of spoilage organisms.

Maize should be ensiled at 32 to 35% DM. The high DM and sugar contents, along with a low buffering capacity, make it easy to ferment, although a good inoculant can reduce fermentation losses and some can bring additional animal performance benefits.

The biggest issue with maize is its susceptibility to aerobic spoilage so it is worth applying an additive that can deal with this. This may contain chemical preservatives, specific bacteria or plant extracts, all designed to inhibit yeasts and moulds during ensiling and feed-out.

Maize Aerobic Stability @ 125 days



Advantages of Maize Silage
High DM and energy
Easily fermented
Potential to increase DM intake, milk yield and milk protein in dairy cows
One harvest per year
Direct cut – no wilting
Compliments grass silage

Disadvantages of Maize Silage
Not suitable for wet or very cold areas
Low in protein and fibre
High DM and starch levels means it is prone to aerobic spoilage (heating and moulding)
Variable quality - weather dependent
Can reduce milk fat if fed at high levels
Low in calcium, phosphorus and sodium

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Fermented Wholecrop Cereals

The popularity of ensiling wholecrop cereals has increased in recent years as they offer a good alternative or complement to traditional fermented forages.

Wholecrop provides a good source of starch and is generally cheaper to produce than grass silage, but it is low in protein. Cereals are a high yielding crop that can be grown in areas unsuitable for maize. They offer great flexibility as harvest takes place after first cut silage so a decision can be made on how much wholecrop is required and remaining areas can be left to produce mature grain for sale or crimping.

Method of preservation

Similar to grass silage, the crop is fermented in a clamp to produce lactic acid which preserves the crop and makes the grains more digestible.

Wheat is most commonly used due to its high yields, good grain to straw ratio and digestible grains, although any cereal crop can be ensiled.

The cereals are harvested at a range of dry matters.

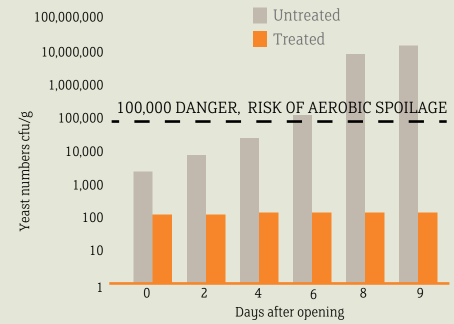
As the crop is relatively high in dry matter and it is difficult to maintain a good fermentation in wholecrop, an additive which combines an inoculant with an aerobic spoilage inhibitor is recommended to reduce heating.

Fermented wholecrop (35-45% DM)

The ideal range for fermenting wholecrop is 35-45% DM, preferably at 40% when the grain is at the soft cheddar stage.

The graph below, shows 40% DM wholecrop four months post harvest. Treatment of the crop with an additive at harvest ensures better aerobic stability when exposed to air.

40% Wholecrop aerobic stability @ 121 days



High DM wholecrop (56 - 65%DM)

Due to high grain maturity, wholecrop of this dry matter should be harvested using a primary processing mill to ensure maximum digestion when the forage is fed. Due to the high DM, fermentation will be limited but there is a high risk of aerobic spoilage, causing heating and nutrient loss.

Advantages of Wholecrop
Complement to grass and maize silage
Good starch and fibre levels
Flexible crop
Increases Dry Matter Intake (DMI)
Early harvesting

Disadvantages of Wholecrop
Low protein
Narrow harvest window
Wasteful fermentation – high DM losses
Animal performance does not always reflect increased DMI

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Nutritive Values

Forages: typical nutritive values

Forage	DM%	pH	Sugar	Starch	Protein	ME MJ/Kg DM
Fresh grass	18	6.5	high	none	high	12
Early cut grass silage	30	3.9	low	none	medium to high	11.5
Late cut grass silage	30	4.2	medium	none	medium	10.5
Maize	30	4.2	low	high	low	11.5
Fermented Wholecrop	45	4.3	low	medium	low	10.5
High DM Wholecrop (Fermented)	65	5.5	low	high	low	11.5

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Legumes

Legumes are the common term for plant species that have an association with bacteria known as rhizobia and include white and red clover, lucerne, sainfoin, bird's-foot trefoil or lotus, lupins, forage peas and beans.

Rhizobia live on the legumes root nodules and fix atmospheric nitrogen, making it available to the plant. This means there is little need for nitrogen fertiliser. Consequently, legumes are important crops for organic farmers.

The popularity of legumes has waned over the years as they are difficult crops to grow, but in recent years, more tolerant, disease resistant varieties have been developed and interest in these crops is increasing again.

Method of preservation

The principle of ensiling legumes is the same as for grass silage. However, legumes have a low sugar but a high protein content, resulting in a high buffering capacity.

This means that legumes are difficult to ferment, which can result in poor quality silage. Consequently, they need to be treated slightly differently. Rapid wilting (within 48hrs), assisted by the use of a mower-conditioner with rubber rollers, to at least 30% dry matter helps to make the crop easier to ferment using additives. IGER (2001) recommend that the dry matter must be over 45% if no additives are used.

Legume silage can be clamped or baled in the same way as grass and maize.

Advantages of Legumes
Environmental benefits due to fixation of atmospheric nitrogen
Reduction in the need for artificial fertilisers
High protein
High production per hectare
Reduction in concentrate feed costs

Disadvantages of Legumes
May increase nitrogen leaching from soil and excretion by livestock
Difficult to ensile
High input costs
Narrow harvest window

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Forage Analysis

Forage analysis is a valuable tool used to formulate balanced rations to ensure you get maximum animal performance at the lowest feed cost. It is also very useful in assessing how good your forage management has been and highlighting any areas that need improving for the next year's crop to help reduce the requirement for costly supplementation.

Many feed companies will offer the service for free, or a small fee. No-one should consider buying other feedstuffs without a forage analysis, but analysis results are only as good as the sample supplied so ensure that you collect a representative sample. Different laboratories may have varying requirements so it is best to check what they need first.

Interpreting the analysis

Routine silage testing is now done by Near Infrared Reflectance Spectroscopy (NIRS). Unusual silage mixtures will be analysed by wet chemistry methods. The key results to check are as follows:

Dry Matter (DM)

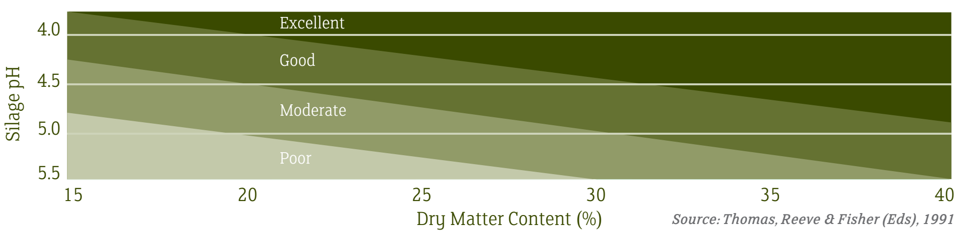
(% or g/kg)

Most analysis results are expressed as a " % of DM " so it is important to know the amount of dry matter in your silage. This will also affect the interpretation of other results, for example, wet silage needs a lower pH for good preservation than higher DM silages. If only one forage is being fed, then the DM will also have a significant influence on total diet intake.

pH

pH measures the acidity of the silage and is one of the best indicators of silage quality as it shows how effective the fermentation has been. As discussed, a good fermentation will produce mainly lactic acid, the strongest acid in silage. This will reduce the pH faster to a lower stable final pH. A pH of around 4.5 is required to halt the activity of most spoilage organisms and produce a stable silage, although this is linked to DM. Wetter silages need to be around pH 3.7-4.3 to prevent the activity of spoilage organisms (see graph below).

Silage pH & dry matter as indicators of fermentation quality



Source: Thomas, Reeve & Fisher (Eds), 1991

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Indicators of Fermentation Efficiency

Ammonia-N (NH_3-N)

(% or g/kg Total Nitrogen)

Ammonia-N is the other key indicator of fermented forage quality. A high ammonia-N level (>10% of TN) suggests that a lot of protein breakdown has occurred as a result of a poor fermentation, often due to high residual fertiliser. This can lead to reduced animal performance if the forage is not supplemented adequately. Good quality fermented forage will contain between 5 and 10% NH_3-N, less than 5% is very good and indicates that very little protein has been broken down.

Total fermentation acids

(% or g/kg DM)

Total fermentation acids (TFA) generally comprises mainly lactic and acetic acids and indicates how much carbohydrate has been converted into acids, all of which will help with acidification. A good fermentation usually results in a TFA of 8 to 12% DM.

Lactic acid

(% or g/kg DM)

As discussed previously, lactic acid is a key indicator of efficient primary fermentation. Typically, at a DM of 25-30%, a good lactic acid fermentation will result in a lactic acid content of around 7 -10% DM, with lactic acid as >80% of the total fermentation acids

Butyric acid

(% or g/kg DM)

The presence of butyric acid is indicative that secondary fermentation has taken place. It produces a putrid smell or taint, reduces palatability and results in poor quality silage. Ideally, silage should contain no butyric acid, although a maximum of 0.5% is acceptable.

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Indicators of Feeding Value

Metabolisable energy (ME)
(MJ/kg DM)

This estimates how much energy the silage will provide to the ruminant for maintenance and production. It is affected more by the quality of the grass at harvesting than by the efficiency of fermentation. We would normally expect the ME of a good silage to range between 11 and 12 MJ/kg DM.

Crude protein (CP)
(% or g/kg DM)

It is essential to know the CP when formulating and balancing rations. In silages this is primarily in the form of degradable protein which will be used by the rumen microbes. Very high protein levels indicate a high level of nitrogen in the harvested grass, commonly resulting from late fertiliser applications. This has a negative effect on fermentation and is best avoided. Average CP values for good quality grass silage vary between 12 and 16%.

Neutral detergent fibre (NDF)
(% or g/kg DM)

NDF is a measure of the fibre or plant cell wall material (cellulose, hemicellulose and lignin) in the silage and influences the rate of digestion by the ruminant and consequently the level of intake.

The higher the NDF, the lower the intake. It is, however, very important to supply ruminants with long fibre (>1cm) to keep the rumen functioning correctly, so there needs to be a balance between digestibility and fibre supply. A good silage will generally contain between 45 and 50% NDF.

Potential intake

Most analyses will give an estimate of intake based on the fermentation characteristics and feed value of the sample.

Maize and fermented wholecrop silage

Maize and fermented wholecrop silages can be highly variable and it is therefore essential to have them analysed to ensure that they can be balanced correctly into the diet to achieve yield and milk quality benefits. The best indicator of maize silage quality is starch content, which usually varies between 25-35%. For fermented wholecrop, a DM of 35-45% is critical to achieve 15-25% starch. Grains should not be too hard to prevent them passing undigested through the animal. If starch levels are high for maize or fermented wholecrop then diets should be carefully formulated to avoid acidosis.

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Typical Analysis Table

Typical analyses for the various forage options

	Dry Matter (%)	Digestibility D Value	pH	Crude Protein (% DM)	Starch (% DM)	ME MJ/kg DM
Hay	85	55	5.5 - 7	9	–	8.5
Straw (Barley)	86	39 - 46	6 - 7	2.4 - 3.4	–	5.6 - 6.7
Early cut Grass Silage	25 - 30	69 - 75	3.8 - 4.2	12 - 16	–	11 - 12
Late cut Grass Silage	25 - 35	62 - 69	4 - 4.5	9 - 13	–	10 - 11
Haylage	50 - 65	65 - 70	4.5 - 5.5	9 - 13	–	9 - 11
Maize Silage	30 - 35	65 - 71	3.8 - 4.3	8 - 10	25 - 30	11 - 12
Fermented Wholecrop (Wheat)	35 - 50	70 - 74	3.8 - 4.5	8 - 10	15 - 25	10 - 10.5
High DM Wholecrop (Fermented)	55 - 65	74	4.5 - 6.5	8 - 10	25 - 30	10.5 - 11.5
Legumes (Forage Pea Silage)	20 - 40	62 - 64	3.8 - 4.8	15 - 20	7 - 11	10.5 - 11.1

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Feeding Forage

Why do we feed forage to ruminants?

Two main reasons:

1. The rumen requires fibre in order to function effectively.
2. It is one of the cheapest forms of energy and protein available.

The Ruminant Digestive System – Functions of the four stomachs

		% of Total Stomach Tissue
Reticulum &	Small pouch-like structure at entrance to rumen. It is not actually a separate compartment, so the rumen and reticulum are usually considered as one (reticulo-rumen). Heavy, indigestible material and foreign objects (e.g. metal) drop in and are regurgitated and removed, or re-chewed (cudding), before entering the rumen.	64%
Rumen	Large fermentation vessel, with a capacity of around 150-250 litres, where rumen microbes break down feed particles.	
Omasum	Reduces the particle size of the digesta and removes excess water.	25%
Abomasum	The 'true stomach'. This is similar to our own stomach and is where digestive enzymes and acids are released to continue the digestion process.	11%

The partially digested material passes to the small intestine where the enzymes and bile carry out the final breakdown of fats, proteins and carbohydrates and the nutrients are absorbed for use by the animal for maintenance and production (growth, milk etc.).

Feeding the Rumen Microbes

When feeding a ruminant, it is important to remember that we are firstly feeding the rumen microbes. Microbes need nutrients in the form of energy, protein, water and minerals in order to multiply and grow.

The microbes ferment the carbohydrates in the feed to produce organic acids called volatile fatty acids (acetic, butyric and propionic). These provide energy to the animal and are mostly absorbed through the rumen wall.

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Feeding the Rumen Microbes

The Right Conditions

To ensure efficient fermentation, optimal conditions must be maintained in the rumen. These include an adequate nutrient supply, warmth (39°C), the correct microbial population, plenty of water, neutral to slightly acid pH (approx. pH 6.2-7.0), a large volume of digesta and regular mixing from contractions of the rumen wall.

Microbial Population

There are many different types of rumen microbes and they all have different functions; some will digest fibre, whereas others utilise sugars, starches or protein.

The composition of the diet being fed will have a significant impact on the microbial population. For example, if a high fibre diet is being fed then the number of fibre digesting microbes will be higher. However, when diets are changed it can take up to a month or more for the microbial population to adjust to deal with a new feedstuff effectively. Consequently, it is important not to make frequent and/or large changes to the diet, as the efficiency of digestion in the rumen will be temporarily reduced following each change.

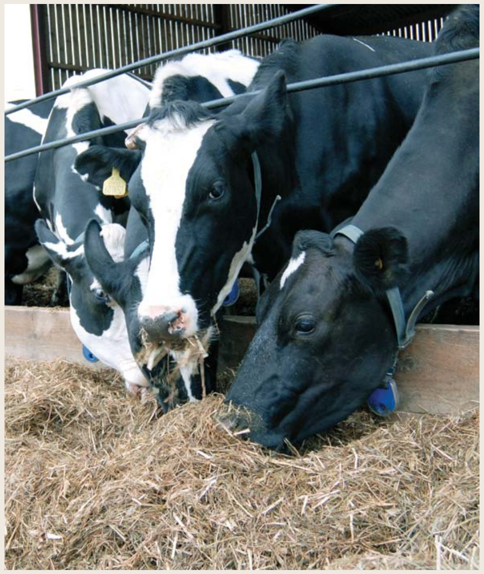
Nutrient requirements of microbes

Carbohydrates

Microbes need energy in the form of:

Fibre - which is slowly fermented and provides structure in the rumen.

Sugars & Starches - which are generally more rapidly fermented.



Protein

The microbes require a balanced supply of fermentable energy and rumen degradable protein (RDP). They break down the RDP into amino acids and some of these are further degraded into ammonia and carbon dioxide. In the presence of sufficient fermentable energy, the microbes use the amino acids and ammonia to synthesise microbial protein, supplying the ruminant with a high quality protein that has an amino acid profile very similar to milk. If there is insufficient fermentable energy, ammonia builds up and the excess is absorbed into the blood, contributing to high blood urea nitrogen (BUN) and milk urea nitrogen (MUN). Undegradable protein (UDP) passes through the rumen without being degraded and provides a by-pass supply of protein direct to the animal.

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pH

Ideally the rumen microbes require a pH of around 6.5. A low pH (<6.2) inhibits fibre digesting microbes, while a very low pH (<5.8) can cause damage to the rumen wall, leading to reduced absorption of nutrients.

Saliva contributes water to the rumen and is a very important rumen buffer as it contains sodium bicarbonate. The buffering action of saliva is essential, as it helps to prevent the acids produced during fermentation from making the rumen too acidic. Regurgitating and rechewing feed (cudding) promotes the production of saliva. The amount produced is directly related to the time the animal spends chewing and as forage encourages the cow to chew it is particularly beneficial in promoting salivation. Feeding too much concentrate or finely chopped material will reduce chewing and salivation, as will very lush pasture or high D value silage.

A healthy cow on a forage diet will produce around 170 litres of saliva per day and as a guideline, 50% of cows should be cudding at any one time.

Fibre - as a source of energy

The fermentation of dietary fibre is the primary function of the rumen, enabling the animal to utilise cheap sources of energy, such as forage. Fibrous feeds contain high levels of cellulose and hemicellulose and these can be degraded by the enzymes produced by rumen microbes in three main stages:

1. The microbes attach to the fibre particles and enzymes start to break the bonds between the cellulose that is not linked to lignin.
2. There is further enzyme breakdown of the celluloses into simple sugars.
3. The simple sugars are fermented by the rumen microbes into VFA's which are then absorbed to provide a source of energy to the animal.

As plants mature, the level of water soluble carbohydrate declines and lignin increases. Lignin is a material that acts like a glue, binding cellulose and hemicellulose together to give the maturing plant rigidity, but it is indigestible, even to rumen microbes. Consequently, mature plant material is of low energy value to the rumen microbes and to the animal.

Alkali or ammonia treatment processes can be used to break down some of the lignin, increasing the energy value.

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Fibre - to stabilise the rumen

The chemical analysis of fibre, often measured as neutral detergent fibre (NDF), is the same whether the fibre is finely ground or chopped in long pieces.

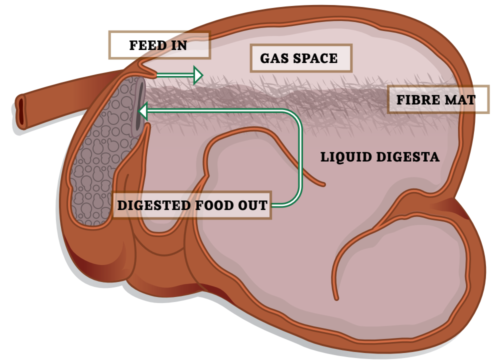
However, the physical effect on the rumen is very different and ground fibre will pass through the rumen rapidly, thereby reducing digestibility. It is essential to supply sufficient effective or structural fibre (over 2.5cm in length) in the diet for four main reasons:

1) To promote cudding and saliva production to buffer the acids in the rumen.

2) To provide the 'scratch factor' which stimulates rumen contractions, mixing the digesta, and forcing smaller particles out into the omasum.

3) To maintain a fibre mat which floats on the surface of the liquid in the rumen, helping to maintain the microbial population and sort feed particles.

4) To increase retention time in the rumen and improve the efficiency of degradation and digestion of all feedstuffs.



The long particles 'floating' at the top of the rumen are regurgitated for cudding. When they return to the rumen, wet and reduced in size, they will float below the larger drier particles. As the rumen contracts the liquid washes through the mat trapping very fine particles, slowing their rate of passage and enabling the microbes living on the mat to break them down.

Without a fibre mat, undigested feed particles would pass straight out of the rumen. The fibre mat also provides a 'home' or 'life raft' for the fibre digesting microbes.

When Things Go Wrong

If insufficient fibre is fed, particularly with a high concentrate (starch) diet, the rumen pH will decrease, leading to acidosis (see flowchart on p.27). pH is a good indicator of rumen function.

pH 6.5 OK

pH 6 CAREFUL!

DEAD! pH 4

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Assessing Rumen Health

Checking dung

Check the shape and consistency of dung pats - these should be round, moist and raised, with a dimple in the middle (right), not a thinly spread wet pool.

Take about a dozen faecal samples and sieve them under running water (use a standard kitchen sieve) - the fibre left in the sieve should be less than 1.25cm. If it is longer, this suggests that material is passing through the rumen before being effectively broken down, indicating a potential acidosis problem. Undigested grains in the dung can indicate acidosis, poor processing of the grain at harvest, or during feed preparation (below).

If fibrin casts (slimy membrane-like structures) are visible, these indicate that the intestinal wall has been damaged by the acidity of the digesta and are another indicator of rumen acidosis.

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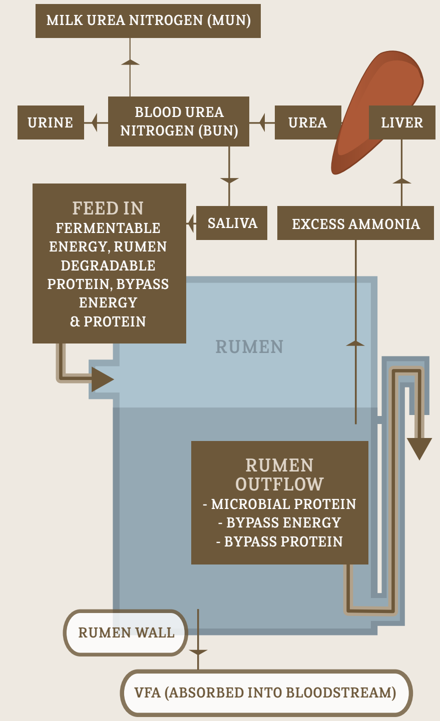
When Things Go Wrong

Sub-acute ruminal acidosis (SARA)

SARA is a common nutritional disorder in the modern dairy cow but is rarely diagnosed.

It often affects groups of cows and the most common signs of the condition are:

- Loose, soft faeces and variability - some cows affected
- Fibrin casts (intestinal lining) in dung
- Acidic dung and urine causes tail swishing and results in dirty rumps
- Reduced dry matter intake
- Cows dropping the cud
- Undigested grains in the dung
- Reduced production – milk yield & quality
- Increased occurrence of displaced abomasum
- Laminitis, ketosis and environmental mastitis
- Increased weight loss in early lactation



Recommendations for a healthy rumen

- Gradually introduce the animal to changes in the diet, giving the rumen microbes time to adapt. Do not make rapid or frequent changes to the diet.
- Ensure that a plentiful supply of fresh clean water is available.
- Ensure that the diet includes some long fibre (greater than 2.5cm in length). The amount required depends on diet and performance.
- Do not feed less than 40% forage.
- Check for sorting – cows will often sort out material longer than 5cm.
- A total mixed ration can help to avoid peaks of acid production and digestive upsets.
- Do not over-mix the TMR and consider the following, where required:

  - including 1-2kg straw, good quality hay (e.g. lucerne) or haylage in the ration

  - adding long fibre to the mixer last to avoid over-processing.
- Remember that NDF is a measure of total fibre content, but does not measure the level of the structural or 'physically effective' fibre present.
- Consider substituting some highly fermentable ingredients (eg. cereals) with rumen protected fat (eg. Volac Megalac).

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Forage and Performance - Dairy Cows

It is essential to match the quality of forage produced with the type of animal fed. Early lactation dairy cows, fast growing beef animals and pregnant ewes require the highest quality material to achieve their production potential.

Milk yield

It is well recognised that cows of high genetic merit are able to respond to high energy diets by increasing milk yield. However, increasing milk yield can result in a tendency to have reduced milk solids %. The nature of the additional energy supplied can influence dry matter intake and also modify the cow's performance response.

Milk fat

Butterfat levels in the UK have been declining over the last decade while milk yield per cow has increased. This is mainly due to the combined effect of improved genetics, which has increased milk production, and difficulties meeting the high nutrient demands of the modern dairy animal. Maintenance of normal milk fat percentage not only reflects effective rumen function and good cow health, but can also provide an economic advantage for producers, paid on milk fat %.

- Generally, increasing the forage to concentrate ratio will cause butterfat % to rise - do not feed less than 40% forage.
- Different forages have varying effects:
  - maize silage is highly fermentable and can cause reduced milk fat when it has a short chop length and is fed at high inclusion rates.
  - high levels of legumes can result in reduced milk fat %.
- Forage mixtures are recommended as no single forage provides the ideal balance of nutrient.
- Feeding good quality, digestible forages to dry cows to increase energy intake can help to improve butterfat in the next lactation.

It is well known that increasing digestible fibre intake helps to increase milk fat % as the fermentation of fibre in the rumen results in the production of acetic and butyric acid by the microbes. However, there is always a trade off between fibre and energy supply in early lactation. At this time, it is important to focus on maximising energy intake to reduce the energy gap which arises when appetite is low post-calving and energy demands for milk production are high, but it is difficult to achieve this without increasing the level of concentrates fed. Feeding a high quality forage can help to meet energy requirements without compromising the fibre supply to the rumen. When designing balanced diets for the high producing dairy cow, there are many aspects of forage feeding to consider, some of which are given opposite.

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Dairy Cows

Milk protein

The two main sources of amino acids for milk protein production are dietary protein and microbial protein. Microbial protein provides a balanced supply of amino acids to the cow at a low relative cost. The rumen microbes need a balanced supply of fermentable energy in order to make use of the rumen degradable protein and turn it into microbial protein.

So energy and protein supply are both very important.

Providing a balanced supply of energy and protein from a combination of mixed forages and concentrates will help to maximise dry matter intake, particularly in early lactation. This will help to ensure that sufficient energy and protein is available to the rumen microbes to optimise milk and milk protein production.

General guidelines for the use of forage to enhance milk protein production are given below:

- Feeding mixed forages helps to increase DMI and, consequently, energy supply - mixtures including maize, wholecrop or fodder beet help to increase milk protein %.
- Whilst maize silage reduces butterfat when fed at high levels, it tends to increase milk protein.
- High levels of legume silage can reduce milk protein as well as fat.
- Fresh grass helps to increase milk protein %.

Fertility

Fertility is a major problem in high yielding dairy cows. Whilst feeding forage does not have a direct effect on fertility, anything that can lead to an energy deficit, e.g. feeding poor quality forage, will increase the risk of fertility problems. Negative energy balance will delay the onset of oestrus and can result in decreased progesterone levels, causing problems with embryo implantation and survival.

Protein nutrition also plays a key role as excess BUN has been associated with impaired fertility (see also p.27). This can arise under the following circumstances.

- excess rumen degradable protein in the diet
- insufficient rumen fermentable energy, or
- excess rumen by-pass protein

Excess ammonia is detoxified in the liver by conversion to urea, which then circulates in the blood and milk. This can pass into the uterus, inhibit conception and reduce embryo survival. The conversion of ammonia to urea is also a very energy demanding process, thereby further increasing the cow's energy deficit. Hence, it is important to feed high quality forage along with an appropriate supplement to high yielding cows post-calving.

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Beef Cattle and Sheep

Beef finishing diets

Poor quality silage is not adequate when aiming for high performance from finishing cattle. Under these circumstances, high levels of concentrate supplementation become necessary and this can make the system less economically viable.

It is important to encourage microbial protein production, as this high quality protein drives animal growth. Good rumen health helps avoid the production of fat animals, resulting in improved grades.

Feed accounts for 75-85% of the variable costs of beef production, so feeding a high energy forage is a good option for reducing costs.

Sheep

Sheep have a predominantly forage-based diet with concentrate supplementation when nutrient demands are high for growth, pregnancy or lactation. Generally speaking, the cheapest way to feed forage to sheep is to take them to the crop and let them graze. However, preserved forage usually becomes necessary for winter feeding, or if grazing is short in the spring or autumn.

During pregnancy, energy demands are very high in the last couple of months when foetal growth is at its highest. At the same time rumen volume is reduced by the large size of the uterus. This means that the ewe is unable to cope with bulky forage diets and requires a very high quality forage with concentrate supplementation to meet her nutrient demands. Lucerne hay or high quality grass hay are ideal in this instance, although grass hay will require protein supplementation.

High DM grass silage can be fed and must be of good quality. Low DM silage is too bulky and intakes will be low.

Intensively finished lambs are commonly fed concentrates, with straw or hay to keep the rumen healthy, whereas store lambs are usually grazed to keep costs low.

Sheep are particularly sensitive to forage quality and will reject poorly fermented silage, leading to low intakes and performance.

Feeding tips:

- Precision chopping of forage can help to increase intakes.
- Listeriosis is a risk if silage becomes spoiled and mouldy forage and can lead to abortion.
- Match amount of silage offered with likely intake to avoid waste silage becoming spoiled.
- Clean any waste silage out of troughs as quickly as possible.

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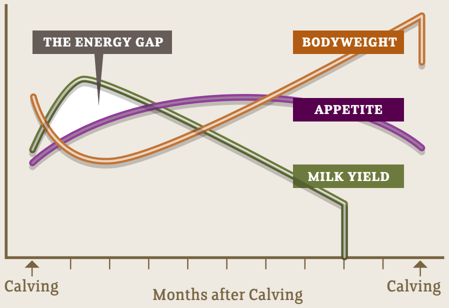
Maximising Dry Matter Intake

The factors affecting DMI are complex but if a good balanced ration is offered then a dairy cow will generally eat to satisfy her needs. However, in the high yielding cow, the lowest point of feed intake occurs post-calving and coincides with peak milk production (see chart below), so it is not always possible for her to eat enough to support high milk yields.

Changes in milk yield, bodyweight & appetite of dairy cows throughout the lactation period



As lactation is given higher priority for nutrient allocation than reproduction, cows that don't consume enough energy will lose excessive body weight, take longer to return to oestrus and may not get back in calf. A common cause of low intake and performance is poor quality forage.

Practical guidelines aimed at maximising DMI

- Including higher dry matter forages (50 - 75%) in a mix will generally encourage higher DMI.
- Total mixed diets containing less than 50% dry matter (e.g. high levels of fermented feeds) reduce intake because of their effect on rumen fill.
- Some ingredients are naturally more palatable than others.
- Feeding a Total Mixed Ration (TMR) will encourage increased DMI.
- Good quality, highly digestible forages will result in a higher daily DMI than forages of lower digestibility.
- Poorly fermented (e.g. butyric) or mouldy forages will be less palatable and will reduce overall nutrient intake and performance.
- Feeding unprotected fats can reduce rumen efficiency and result in decreased performance. If feeding supplementary fat, use a protected fat (e.g. Volac Megalac), which will help to satisfy energy demands without affecting rumen function.

Feeding mixed forages

No single forage provides everything that a ruminant needs and a balance of forages can therefore improve rumen function and animal performance.

Feeding a forage with a medium-high starch content (e.g. maize or wholecrop) alongside a forage containing high levels of rumen degradable protein (e.g. grass and legume silages) will provide the rumen microbes with a balance of fermentable energy and rumen degradable protein sources. This means that the rumen microbes can make good use of both the energy and protein supplied, enhancing the efficiency of the rumen and increasing the rumen microbial protein supply to the animal. So, ideally we should feed a mixture of these different forages to provide the ideal balance of nutrients required by the rumen microbes.

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Sustainability

The benefits of conserving forage

While many factors influence feed costs, grazed grass is recognised as the cheapest form of feed. Forage silages are considered the next most economical feed source, with concentrate supplements being most expensive.

No crop is ensiled and consumed with 100% efficiency – losses can occur during harvesting, storage and at feed-out, amounting to over 40% of the available grass DM (Teagasc). Management systems such as big baling and use of additives that reduce these losses will impact positively on the cost and efficiency.

On-farm produced feeds are the most sustainable in terms of efficiency of production as transport is minimised, and in addition, 'home-grown' silage gives traceability and security for farmers.

The ability to preserve forage in times of plenty, gives flexibility to cope with shortages when unpredictable weather patterns disrupt seasonal feeding strategies.

Fertiliser and cereal-based concentrates are becoming increasingly costly and will come under competitive pressure to be used for growing food for direct human consumption.

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Notes

Quoted references are available on request.

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