SILAGE FOR ANIMAL FEED

L. Mannetje
Wageningen University, The Netherlands

Keywords: silage, forage, water soluble carbohydrates, protein, buffering capacity, anaerobiosis, lactic acid bacteria, butyric acid bacteria, enterobacteria, Listeria, molds, pH, wilting, additives, maize, sorghum, crop residues, by-products

Contents

1. Introduction
2. History of Silage Making
3. The Ensiling Process
3.1 The Harvesting and Storage Phase
3.2 The Aerobic Phase
3.3 The Fermentation Phase
3.4 The Stable Phase
3.5 The Feed-out Phase
4. Silage Microflora
5. Silage Additives
6. Silage Quality
7. Properties of Common Forages and Crops for Ensilage
7.1 Grasses
7.2 Maize
7.3 Legumes
7.4 Whole Plant Silage
7.5 Sorghum
8. Silage from Crop Residues and By-products
Glossary
Bibliography
Biographical Sketch

Summary

Silage is made of forages, crop residues, or agricultural or industrial by-products that have been preserved by natural or artificial acidification, for use as animal feed in periods when feed supply is inadequate. Ensilation, being a natural process, was already used by farmers in ancient times.

Successful silage-making depends on anaerobic storage of material containing adequate levels of water soluble carbohydrates to be fermented by lactic acid bacteria into lactic acid, thus preserving it because of a rapid reduction in pH. Silage pH is not only determined by fermentation, but also by the buffering capacity of the forage. Maize and grasses have lower buffering capacities than legumes. Wilting the material before ensiling to between 30 and 50% DM decreases the buffering capacity and reduces the chances for butyric acid bacteria to spoil the silage. Chopping the material into small

particles and compaction in the silo improve the fermentation. The silage can be stored in pits in the ground, clamps above the ground, or bales covered with plastic.

There are desirable (lactic acid bacteria) microorganisms, and undesirable microorganisms that can cause anaerobic spoilage (yeasts, clostridia, enterobacteria) or aerobic spoilage (yeasts, bacilli, listeria, molds). Many of the undesirable organisms also have a detrimental effect on animal health and/or milk quality (e.g. listeria, clostridia, molds, bacilli).

Additives are used to compensate for limitations in the desirable silage microflora and/or the lack of water-soluble carbohydrates. Additives can be grouped into those that stimulate fermentation (lactic acid bacteria, enzymes, and sugars) or inhibit clostridia activity and aerobic deterioration (acids and salts), nutrients (urea, ammonia, and minerals) and absorbents.

Silage quality is judged by its feeding value (intake, digestibility, and crude protein concentration), pH value, its chemical composition, and the presence of harmful compounds.

The properties of the main forages that are commonly ensiled are briefly described.

1. Introduction

Silage is made of forages, crop residues, or of agricultural or industrial by-products that have been preserved by natural or artificial acidification, for use as animal feed.

The procedure to obtain silage is briefly as follows. Fresh forage is harvested, crop residues or by-products are collected, stems may be squashed (conditioned), the material wilted and/or chopped, and additives may be added before it is stored with the exclusion of air, so that facultative anaerobic lactic acid bacteria, present on the material, or added as inoculants, can rapidly convert WSC into acids. With appropriate fermentation, the resulting pH becomes so low that all life processes come to a halt; the material will be preserved for as long as it remains in airtight storage.

Silage is made in order to feed animals in periods when feed supply is inadequate, either in terms of quantity or quality. In northern temperate climates this is usually the winter period, but in other regions it may be an annual or incidental dry period. Silage may also be made of materials of a higher feeding value than the normally available forage (e.g. lucerne, maize, sorghum, or other cereals) and agricultural or industrial by-products, and then used as a feed supplement.

Silage making is an addition to hay making, which is simply drying green material in the sun. In climates with a low wet weather risk haymaking may be preferred, but where the weather is variable silage making has largely replaced haymaking. In modern animal husbandry the harvesting and storage techniques of both hay and silage making have been developed to improve efficiency for both and the fermentation process and the ensuing feeding value for silage making.

2. History of Silage Making

Ensilation being a natural process, it is not surprising that it was already used by farmers in ancient times. There is pictorial evidence on an Egyptian mural in the Museum at Naples dating from 1000 to 1500 BC, showing farmers filling a silo with a sorghum-like crop. Silos were also encountered in the ruins of Carthage dating to around 1200 BC. Also the Roman historian and agricultural writer Cato (100 AD) referred to the Teutons storing green fodder in pits covered with dung. The importance of anaerobic conditions (airtight storage) and the danger to health of entering a newly opened silo were already known in ancient times.

Silage making remained a technique extensively used in Mediterranean countries and it was not until the eighteenth century that silage making became common practice in other parts of Europe. First reports of silage making in northern Europe in the second half of the nineteenth century referred to Sweden and the northern provinces of Russia. The practice of simply throwing the fodder into an excavated pit and covering it with earth, which the early farmers used, has been maintained in Europe to well into the twentieth century.

Although grass was and still is the most common type of forage ensiled, maize was first ensiled in Hungary around 1860, and soon after in Germany. An early French book about silage making ("Manuel de la culture et de l'ensilage du mais") was written by Goffart in 1877 and soon afterwards translated into Dutch and English. This book was also published in the USA, where it led to a huge development of growing and ensiling maize. Goffart advocated maize to be cut into 1 cm lengths, a practice that aided compaction of the material in the silage, which was beneficial for the exclusion of air, to be ensiled in brick silos.

In the Netherlands silage was first made of a crop of spurrey (*Spergula sativa*) in 1845 on the Estate Hoekelum in Bennekom of Baron van Wassenaar. The crop was harvested as it began to set seed and put into a water tight circular pit in layers of about 10 cm, interspersed with thin layers of finely ground rock salt. It was reported that dairy cows relished the silage together with short chopped straw, despite the sour smell, "resulting in well colored butter".

A Danish agricultural extension officer (Pedersen) developed an artificial method of silage making during 1917 and 1918, by adding different acids (e.g. hydrochloric acid) to freshly harvested and stored grass. However, around 1925 the Finnish scientist A.I. Virtanen achieved fame by advocating the practical application of acidification with hydrochloric and sulfuric acid. He added only as much acid as was necessary to lower the pH to below 4, so that relatively low quantities of acid were needed. This way the losses due to respiration and protein breakdown were reduced, leading to a better product. However, the use of inorganic acids led to health problems in the animals, which developed "acid urine". Feeding of limestone was necessary to overcome this problem.

In the first half of the twentieth Century, two methods of silage making were distinguished:

- The “warm” method, developed by the English scientist Fry towards the end of the nineteenth century and further developed in Switzerland during the First World War, advised that forage, that was sometimes wilted to 30% dry matter (DM), should be heated in the silo to at least 50^{o}C, before the silo was closed airtight. However, this method led to large losses of DM and feeding value.
- The “cold” method developed in Germany was based on preventing heating up of the material by making an airtight closure immediately after filling the silo.

It was thought that the “warm” method was necessary to obtain “sweet”, in contrast to “sour” silage. Whereas the name referred to the sense of smell and not of taste, “sweet” silage had undergone a lactic acid fermentation and “sour” silage an acetic or butyric fermentation, the former being greatly preferred because of the higher feeding value and the absence of bacterial spores leading to spoilage of cheese. The prevention of butyric acid formation depends on the exclusion of air, not on allowing the grass to heat up.

Although ensiling of wilted grass has been practiced in Italy for over 700 years, even now farmers in some European countries still ensile freshly cut grass directly from the field. This leads to large effluent losses, which not only reduce feeding value but also contribute to serious environmental pollution.

However, it was not until the principles of the ensilation process became widely known that farmers were able to manipulate the process, including the use of additives (section 5), in order to obtain a better product.

3. The Ensiling Process

The key components of successful silage making are: adequate levels of WSC, exclusion of oxygen, rapid reduction in pH, low buffering capacity of the crop, wilting of green material, moderate temperatures, and high nutritive value of the material to be ensiled.

Silage pH is not only determined by the fermentation, but also by the buffering capacity of the forage. Buffering capacity of a crop is its ability to resist a change in pH upon the addition of an acid or base. In the case of silage making it is expressed as milli-equivalents of acid needed per kg of DM to decrease the pH from 6 to 4. The buffering capacity of forage depends mostly on its anion concentration (organic acids, orthophosphates, sulfates, nitrates, and chlorides) and to a lesser extent on CP concentration. Legumes have a higher buffering capacity than grasses, although that in grasses can vary fourfold between species. Wilting reduces buffering capacity.

The ensilage process can be divided into five phases.

3.1 The Harvesting and Storage Phase

Forage especially grown for silage or existing grassland is cut and can be directly collected and stored or first wilted to between 30 and 50% DM. As a result of photosynthetic and respiration processes (see *Cell Thermodynamics and Energy Metabolism*), the WSC concentration of forage varies during the day and is higher in the afternoon than in early morning. Therefore, cutting of forages for silage should be delayed until the afternoon to maximize the amount of WSC.

In order to exclude as much air as possible before the fermentation process starts, the material may be squashed (conditioned) and chopped before storage and must be compressed before an airtight seal is affected. The wetter the material before ensilation, the greater will be the risk of loss of WSC through respiration and for silage effluent to be formed. Wilting increases the relative WSC concentration and thus the fermentability of the forage, and it also eliminates effluent losses from the silo, and reduces slurry production by the cattle and the obnoxious odours of wet silage, which are all serious environmental problems.

Wilting of green forage was not adopted in northwestern Europe to any extent until the middle of the twentieth century, because agricultural advisors were of the opinion that the weather in these parts was not suitable for wilting. It is a fact that slowly wilted grass, particularly if rain occurs during the period between cutting and storing, is deleterious for the quality of silage as rotting processes lead to large field losses. Only rapid wilting (less than 24 hours) offers great benefits for reduced losses, improved intake, and animal performance.

Wilting can be improved by a cutting system developed in the UK by Vicon, which employs a mower conditioner consisting of a disc mower with a twin roller, the top half of metal and the bottom part a cylindrical nylon brush for squashing (conditioning) the grass. In addition, the cut grass is spread into a swath over the full cutting width.

Wilting above 50% DM is not recommended because it is difficult to compress very dry material and this may lead to poor fermentation and the development of mold. Compaction of the material is of the utmost importance. With long stemmy material, chopping into approximate 6mm lengths is advisable to enhance compaction.

Good silo filling techniques, particularly compaction, will help to minimize the amount of oxygen present between the plant particles in the silo. Good harvesting combined with good silo filling techniques will thus minimize WSC losses due to respiration in the field and in the silo, and in turn will leave more WSC available for lactic acid fermentation.

Silage can be stored in or above the ground in permanent or temporary silos that may be vertical or horizontal or in bales or small receptacles, such as plastic bags or barrels, depending on the size of operations. Modern large silos consist of a rectangular concrete floor and three concrete sides with a height of about 2 meters. The most modern methods of silage making entail wilted grass being compressed into rectangular or round bales covered with plastic, for which special machines have been developed, not only for large, but also for small bales.

Although the principles of silage making apply to all methods, baled silage generally has longer particle sizes and higher DM contents compared to forage ensiled in clamps, which may restrict fermentation to some extent.

-
-
-

Bibliography

McDonald P., Henderson A. R., and Heron S. J. E. (1991). *The Biochemistry of Silage*. 2nd edition. Marlow, Bucks, UK: Chalcombe Publications. [The most authoritative book on the subject.]

Catchpoole V. R. and Henzell E. F. (1971). Silage and silage making from tropical herbage species. *Herbage Abstracts* **41**, 213–21. [Excellent review of potential and problems of silage making in the tropics.]

Mahanna W. C. (1996). Silage Fermentation and Additive Use in North America**,** West Des Moines: Iowa Pioneer Hi-Bred International, Inc. http://www.pioneer.com/xweb/usa/nutrition/ferment1.htm [Extensive review of silage making theory and additive use in the USA.]

Mannetje, L.'t (Ed.) (2000). Silage making in the tropics with particular reference on smallholders. *Proceedings of the Electronic Conference on Silage Making in the Tropics* September 1 - November 30th 1999. FAO Plant Production and Protection Paper No 161, 180 pp. Food and Agriculture Organization of the United Nations, Rome. [Contains the full texts of 10 main papers and 26 posters on a wide range of topics related to silage making, particularly by smallholders.]

Merry R. J., Jones R. and Theodorou M. K. (2000). The conservation of grass. *Grass, its Production and Utilization.* (3rd Edition). (Ed. A. Hopkins) British Grassland Society. Oxford, UK: Blackwell Science pp. 196–228. [A practical treatise based on the principles of silage making.]

Wilkinson M. (1990). *Silage UK*, 6th edition. Marlow, UK: Chalcombe Publications. [A good overview of silage making practice in the United Kingdom.]

WEBSITE of FAO Electronic Conference on *Silage Making in the Tropics* held in 1999:

http://www.fao.org/waicent/faoinfo/agricult/agp/agpc/gp/silage/contents.htm.

(10 main papers and 26 posters on a wide range of topics related to silage making, particularly by smallholders, are presented and freely available.)

Biographical Sketch

Leendert "t Mannetje was born in The Netherlands, where he was educated (MSc) at the Wageningen Agricultural University. He obtained his PhD at Queensland University, Australia, in 1967. He was employed as a research scientist with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Divisions of Tropical Pastures, Tropical Crops and Pastures, and Tropical Agronomy from 1958 till 1982. During part of that period he was seconded to the Malaysian Agricultural Research and Development Institute (MARDI) at Serdang, Malaysia. In 1982 he was appointed Professor of Grassland Science at Wageningen Agricultural University, The Netherlands. Professor "t Mannetje has traveled, lectured, advised on and supervised research extensively in Southeast Asia, Africa, and Latin America.