Silage from tropical cereals and forage crops

G. Ashbell and Z.G.Weinberg

Forage Preservation and By-Products Research Unit,
Agricultural Research Organization (ARO).
The Volcani Center, Bet Dagan 50250 Israel
E-mail: gashbell@netvision.net.il

1. Introduction

The preservation of forages by ensiling has been a well known technology for many years and is popular in North America and Europe. This technology requires high investment in facilities, accurate timing in the several stages of the ensiling process, and better understanding of the whole process than hay making demands. In addition to these demands, silage making and management in tropical conditions needs special attention and care with regard to the following points:

- Maturation – depends on the climatic conditions. In warm areas, the lengths of maturation stages might be shorter and changes are faster than in a temperate climate. In such cases, it is more difficult to control the correct stage for harvesting, and this is especially crucial with cereal crops in the latest stages of maturity.

- DM content – the correct DM content in the plant before ensiling is an important factor for the fermentation success. Unexpected weather (dry, wet or hot) can damage the crop and increase losses.

- Aerobic stability – rapid deterioration of silage, especially during the feeding-out phase is a real problem in a hot climate: it reduces quality and results in losses. High temperatures enhance mold and yeast activities all year round, therefore, special attention should be taken in silage making to eliminate air penetration into the bunker (fine chopping, good compaction and sealing). The feeding-out of the silage should be done in such a way as to avoid destruction of the structure of the face and to leave it smooth. Aerobic stability should become a routine test in hot areas Ashbell *et al.* (1991).

This paper will discuss silage making of three main cereal-fodder crops in the tropics, viz.sorghum, maize and wheat.

2. Sorghum (Sorghum bicolor L. Moench)

2.1 Introduction

Sorghum was cultivated in Egypt as early as 2000 B.C. Usually it is grown in areas with inadequate rainfall for satisfactory maize cropping. Several qualities in which it differs from maize (an alternative forage crop) have made this a summer crop worldwide. The sorghum plant is not fastidious in moisture and irrigation requirements and it can be sustained on 300 mm of water (rain or irrigation), or grow on dry land relying on winter rain. Its demand for fertilizers is modest too. Sorghum can grow in a relatively saline environment (soil and water). In a hot and long summer it can re-grow during the same summer after cutting. Of course, yield is affected by growth conditions.

Poisoning by hydrocyanic acid occurs mainly through grazing of young sorghum. Therefore it is recommended to graze sorghum only when the plants are taller then 60 cm.

There are many varieties of sorghum; most of them were developed to provide grain for human and animal consumption.

2.2 Whole plant sorghum – qualities and ensiling

In the last few decades forage sorghum has become progressively more popular. Genetic work has been done to improve and adjust the sorghum qualities for forage too, and get a "whole plant sorghum forage". Much work on sorghum silage has been done in the USA (Dickerson 1986; Smith 1986; Dost 1989,).

Sorghum is a seasonal crop; the only way to preserve the whole plant for cattle feeding is by ensiling. Several characteristics of the plant have to be taken into account to succeed with the ensiling technology and to obtain high quality silage:

2.2.1 Digestibility: poorly digestible parts of the plant reduce its total nutritional value. Most of these parts are connected with the cell wall structure, especially lignin, which is dominant in the stem. Therefore, reducing the proportion of stem in the plant will increase its digestibility. i.e., in practice shorter hybrids are preferable.

2.3 Important properties determining the value of sorghum silage.

2.3.1 High energy. From a cereal crop we can expect mainly energy supply, and less protein. Water-soluble carbohydrates (WSC), structural carbohydrates and starch are the main energy resources in cereal crops. Starch is mainly accumulated in the grain, the amount of which greatly affects the total energy content. The higher the proportion of grain in the plant, the more the total energy. The positive effect of the presence of starch is especially important for dairy cows. Therefore, we are looking for a high-grain sorghum hybrid.

2.3.2 Dry matter content. Ensiling technology requires at least 30% of DM in the forage. With less than 30% of DM undesirable fermentation takes place and results in effluent, which creates an environmental pollution problem and increases losses. Such wet material encourages the activity of clostridial bacteria, enhances the production of butyric acid, increases losses, and reduces silage quality. Most of the water content in the sorghum plant is in the stem, therefore, wilting should be avoided because the stem will spoil before drying. A solution is needed that will enable us to harvest directly a whole sorghum plant that contains at least 30% dry. In the later stages of maturation (milk and dough), the grains are the driest part of the plant. High yield of grains, harvested between the milk and dough maturation stages will increase the total DM content to a level suitable to avoid effluent and clostridia fermentation. In this stage of maturity the DM content of the grain is around 50%. In other words, to increase the DM content of whole-crop sorghum for silage, the recommended maturation stage for harvesting is between the milk and dough stages. Harvesting at the late-dough maturity or later will increase the undigested amount of the grains and reduce the nutritional value. Processing the grain in the silage will increase its digestibility. Such a solution should be applied only if it is economic. A close ratio between the grain and the rest of the plant (stem and leaves) will help to reach the goal of increasing the DM content. Reducing the moisture content or an excessive WSC in forage sorghum hybrid for silage can be done by mixing it with a grain sorghum hybrid while ensiling (Ashbell *et al.* 1999)

Table 1 gives the changes in whole plant forage sorghum during maturation, and the resulting silages. DM increased, whilst WSC and NDF (neutral detergent fiber) contents decreased mainly between the milk and dough stages; this is attributed to the grain filling with starch; *in vivo* DMD (dry matter digestibility) was not affected by stage of maturity; pH of the silages prepared from sorghum harvested at the dough stage were highest; however, all silages were stable upon aerobic exposure; acetic acid and ethanol were found in all silages at 10-20 g kg^{-1} (data are from Ashbell *et al.* 1999, unpublished results).

Table 1 Changes in sorghum composition during maturation (g kg^{-1})

Maturation stage	DM	WSC	NDF	DMD	Silage pH	Lactic acid
Flowering	274±1	120±21	512±7	604±11	3.7±0.3	58±12
Milk	288±8	149±20	489±1	607±9	3.9±0.2	45±12
Dough	340±14	69±10	425±3	617±8	4.2±0.1	30±10

2.3.3 Lodging. Sorghum plants are susceptible to lodging. Harvesting lodged plants is complicated, takes more time and field losses are higher. Tall sorghum plants usually do not have heavy heads, but have a strong and a thick stem; both of these are negative factors. Therefore, short hybrids will be more lodging resistant, and are preferable.

Two negative components can be found in sorghum plants, and it is important to be aware of them:

2.3.4 Tannins. The grains of some hybrids may contain tanniins that have a negative effect on the digestibility rate of the protein in the diet. Large amounts of tannins are mainly found in "bird-resistant hybrids".

In places where sorghum grains are used for human consumption, it is possible to ensile the vegetative parts of the plant, the stem and leaves for feeding animals. In this case the sorghum is dual-purpose. Some hybrids of sorghum can “stay young” even in the late maturation stages, and retain fair digestibility.

Adding lactic acid bacteria inoculant during ensiling sorghum improved the fermentation process, but reduced the aerobic stability of the silage (Meeske *et al.* 1993). The decision to use additives, especially bacteria has to be decided after performing experiment under the particular conditions.

3. Maize (Zea mays L.)

Maize, a summer forage crop, originated in Mexico or Central America, but today it is a worldwide crop for grain, and it is a perfect crop for silage. Requirements for water and temperature are relative high, and often it is an irrigated crop.

Much scientific research has been done on maize for silage, from the agronomic, ensiling and nutritional points of view. Harvesting at the correct maturation stage is a very important factor, especially in tropical areas where vegetation and maturation processes are rapid. The maturation stage for harvesting is between the milk and dough stages. This requires opening the cob, inspecting the grain, and determining the ratio between the solid (starch) part and the “milk” part inside the grain. When each of the two components reaches 50% is the time to start harvesting, and it should end when 75% of the grain is in the solid form. At that stage it is expected to reach maximum total harvesting yield. An earlier harvest will cause potential loss, and a later harvest will increase field losses and reduce the digestibility of the grains.

In a hot climate, the correct maturation stage for harvesting can be reached after around 115 days of growth. In places with a long summer it is possible to obtain two harvests in the same year, one in summer and one in autumn. There is a big difference in the quality and the yield between crops in the two harvesting seasons.

The first maize crop has better climatic conditions for growth, and can complete a cycle of the vegetation period. While the days are getting shorter and cooler towards the end of the growth period of the second crop, the yield is lower, and the plant does not have the correct conditions to produce a mature cob. When harvesting the first maize crop, grains form the dominant energy source: almost 50% of the total nutritional value, mainly starch, (which is important for dairy cows) comes from the grains. Grains strongly affect the total DM content by increasing it, and bring the total DM of the whole maize plant to suitable moisture content for ensiling. To increase the yield and improve the quality of the second harvesting of the maize, it is recommended to sow more densely (according to conditions), and to wilt if possible. Ashbell and Lisker (1988) studied the aerobic deterioration of maize silage stored in commercial bunker silos in Israel (su-btropical climate). Losses in dry matter were between 4-7.5% in well sealed sites, and up to 36% at locations where air penetrated (upper layer and along the walls).

4. Wheat (Triticum L.)

4.1 Agronomic considerations

Wheat has been grown since the beginning of civilization, mainly for its grains.

Nowadays, in some areas whole-crop wheat is used as a forage crop, which is preserved either as hay or as silage. Whole-crop wheat provides both digestible fibres and energy (9.0 MJ kg^{-1} DM) and its nutritional value may approach that of maize silage, so that it can serve as an excellent forage for high-lactating cows or beef cattle (Adamson and Reeve 1992). There are numerous varieties and cultivars that have been adapted for different climates and soils. In tropical and sub-tropical climates only spring wheat is grown, which is sown just before the rainy season. Wheat for silage is harvested at the milk-dough ripening stage with a DM content of 30-35%. DM yields of whole-crop wheat for silage are around 10 t ha^{-1}, depending on cultivar and on growing conditions.

The advantage of growing wheat for silage in tropical and subtropical climates is that the early harvesting enables the farmer to grow an additional summer crop such as maize, potatoes, peanuts, etc. This system, referred to as ‘double-cropping’, has the advantages of more efficient utilization of soil, water and fertilizers, and of crop rotation (Ashbell and Sklan1985). In Israel, with a sub-tropical climate, this system even enables farmers to squeeze in a third crop of autumn maize for silage; this is irrigated with treated sewage water and is harvested after 80 days of growth, before the cob develops.

Spring wheat cultivars can be early and late maturing, with a 2-3-week difference between them in the time needed to reach adequate ripening. Advantages attributed to late-maturing cultivars used for silage in sub-tropical climates include:

- a longer growth period in semi-arid areas facilitates more efficient use of moisture remaining in the soil from late rains, so that they provide higher yields at a given stage of maturity;

- the time window available for silage making is extended, relieving some of the logistical pressure on the operating system ;
- the harvest period of the late-maturing cultivars offers a greater possibility of avoiding rainfall during silage making.

It is possible to grow wheat along with annual legumes such as vetch, peas and sulla (*Hedysarum coronarium*) and to ensile them together. The advantages attributed to such systems are

- the wheat may alleviate the lodging problem of the legumes;
- improved soil ecology and reduced incidence of plant disease;
- improved silage quality and reduced preservation losses of the legumes.

The latter advantage arises from the fact that the carbohydrate-rich cereals are complementary to the moist, protein-rich legumes, with regard to ensiling properties, aerobic stability of the silage and nutritional aspects. For example, Ashbell *et al.* (1997) found that the best combination was obtained when the silages were prepared from wheat and vetch at 3:1 (wet-weight basis), with 31% DM in the mixture. The problems that might be associated with such systems include growth domination of one type over the other, problems with using herbicides, and that the cereal and the legume may not reach optimal maturity for harvest at the same time.

4.2 Changes during maturation

Changes that occur in the whole-wheat plant during maturation are very rapid in warm climates, and the intervals between the various maturation stages are short. These changes affect DM yields, chemical composition, ensiling characteristics and nutritional value. During the short period between flowering and the soft dough stages the wheat plant undergoes remarkable changes; although there is a certain variability in composition among years and among cultivars, some tendencies are apparent (Table 2): DM content increases with advancing maturity, whereas crude protein decreases, mainly between the flowering and milk-dough ripening stages; starch accumulates in the grains while soluble carbohydrates decrease; fibre contents (both NDF and ADF, expressed as percentages of DM) peak at the flowering stage. The latter affects the nutritional value of this forage. Based on these facts, and considering yields, ensiling characteristics and nutritional properties, we believe that it is optimal to harvest wheat for silage at the milk ripening stage (Ashbell *et al.* 1997; Weinberg *et al.* 1991).

Table 2 Changes in wheat composition during maturation (g kg^{-1})

Maturation stage	DM	WSC	Ash	Crude protein	NDF	ADF	ADL
Shooting	170-190	-	108	133	562	360	57
Flowering	200-246	62-110	81-111	96-132	585-640	366-405	59-90
Milk	279-388	51-136	62-110	77-104	510-598	251-408	49-108
Dough	355-466	30-32	57-91	81-90	481-509	239-278	57-67

ADF, acid detergent fiber;ADL, acid detergent lignin.

4.3 Ensiling of wheat

Although yields are somewhat lower at the milk ripening stage, as compared with the dough ripening stage, it is preferable to harvest at the earlier stage because the wheat at the dough stage may be too dry and its fibres less digestible. On the other hand, wheat at flowering is too moist and requires prolonged wilting, and its ensiling properties are inferior.

Before ensiling, the wheat is usually subjected to a short wilting period in order to reach a DM content of 33-38%. It is difficult to control the DM content of the wheat at harvest because of the rapid changes mentioned above. In addition, in subtropical climates, the wheat for silage is harvested in spring when the weather is unstable and changes rapidly from cool to hot and dry. This affects maturation and drying rates during wilting.

Compaction of the chopped wheat in the silo is affected by its DM content and chopping length: the drier it is the more elastic it is and, therefore, more difficult to compact. Because wheat stems are hollow, removal of air demands more intensive compaction. Therefore, a drier crop requires a shorter chopping length. The recommended chopping length in Israel is 10 mm; however, excessively short pieces are not desirable because they are more costly to produce, and they may escape quickly from the rumen, and lose their function as roughage for ruminants.

Ensiling rates of wheat in subtropical climates are variable and depend on DM content, carbohydrate availability and development of adequate lactic acid bacteria in the silage. There are not many data on microbiological dynamics during ensiling of wheat in warm climates. Weinberg *et al.* (1987) found that the number of lactobacilli in the fresh crop varied between 10^2 and 10^6 colony-forming units (CFU) per gram. After 2 days of ensiling in mini-silos the numbers increased to 10^8-10^9 CFU g^{-1} in all cases.

Ashbell and Kashanchi (1987) and Ashbell and Weinberg (1992) studied DM losses in commercial wheat bunker silos in Israel. In the center of the silo DM losses ranged from 3 to 16%, near the walls from 10 to 22%, and under the cover from 14 to 27%. The shoulders of the bunker (where the walls and plastic sheeting meet) are the most susceptible parts of the silage to air penetration, and their DM losses ranged from 54 to 76%.

The aerobic stability of wheat silage is variable. In warm climates detrimental microorganisms (yeasts, molds) proliferate more rapidly, resulting in enhanced aerobic spoilage. In general, many factors may affect aerobic stability, including the presence of weeds, the management of the silage in storage (compaction and sealing), composition of the silage, additives, and the method and rate of feeding-out. In bunker silos in a warm climates it is important to refresh the face frequently by feeding-out 30-40 cm every day, in order to minimize its exposure to air. Aerobic deterioration of wheat silage is associated with increased numbers of yeasts and molds, heating and, consequently, DM losses. The roles of DM content, residual soluble carbohydrates and lactic acid in destabilization of the silage is not clear as yet. As in other silages, volatile fatty acids (such as acetic, propionic and butyric) produced during the ensiling fermentation inhibit yeasts and molds.

Molds are of concern in wheat silages because of the risk of mycotoxins. Several mycotoxins at various levels have been detected in wheat silage in Israel; there are not yet enough data to correlate their presence with disease incidence in cattle.

4.4 Additives

Both chemical and biological additives have been tried in wheat silage. A sulfur-based chemical, which inhibits yeasts and molds, is applied commercially in Israel; reduced losses and improved aerobic stability are attributed to it. On some farms, coarse sodium chloride is applied to the top layer (at 3-4 kg m^{-2}) of the bunkers for the preservation of this susceptible part of the silage. Anhydrous ammonia has also been tried on corn, wheat and sorghum silages, it improvrd aerobic stability, increased the NPN content, but it is hazardous to use, and therfore, not used in practice (Ashbell and Weinberg 1993).

Bacterial inoculants comprising homofermentative lactic acid bacteria were not found suitable for wheat silage in Israel: silages treated with such inoculants tended to deteriorate faster than the respective controls, and to enhance yeast and mold development (Weinberg *et al.* 1993). It was hypothesized that not enough volatile fatty acids, which inhibit yeasts and molds, were present in such silages. Inclusion of special bacterial strains alleviated this problem. Heterofermentative *L. buchneri* are being tried in several research laboratories and results are promising (e.g, Weinberg *et al.* 1999).

Cell-wall-degrading enzymes (cellulases, hemicellulases and pectinases) have also been tried. The expected benefits to be derived from such enzymes are the release of fermentable sugars and improved rumen digestibility. The enzymes have been found to reduce fibre content and to increase fibre digestibility only in silages made from moist wheat at the flowering stage, but not in those from drier more mature wheat (Weinberg *et al.* 1993 ; Weinberg *et al.* 1995).

4.5 Nutritional properties

The nutritional value of wheat for silage is strongly affected by the stage of maturity at harvest, because that affects yields, the ratio between grains and the vegetative plant parts, and DM and cell-wall contents and quality. In Israel wheat silage forms the main roughage in the rations for high lactating cows and, therefore, its quality is of the utmost importance, it forms approximately one third of the ration, and is fed at about 7 kg DM per cow per day.

Ashbell *et al.* (1997) compared the ensiling properties and rumen degradability of wheat silage from early- and late-maturing cultivars, at four stages of maturity: shooting, flowering, milk and dough. Although NDF degradability at the young wheat silage (shooting and flowering) was higher than at the milk or dough stages, yields of degradable DM and NDF (in terms of t ha^{-1}, increased as the wheat matured. Ben-Ghedalia *et al.* (1995) found *in vitro* organic matter digestibility of 69.2 and 70.5% and NDF digestibility of 63.3 and 56.3%, at the flowering and soft-dough ripening stages, respectively, of whole-plant wheat.

4.6 Research needs

Wheat cultivars that are used for silage making, were mainly developed for increased grain yields, and are actually dual-purpose types. Research should focus on development of cultivars intended solely for ensiling. Such cultivars should be adapted to specific climate and soil conditions, with higher yields and improved quality. Another possibility involves plants with intrinsic antimycotic properties, the silage of which should be more stable under aerobic exposure.

Development of more suitable inoculants for wheat silage in warm climate warrants research. The requirements of such inoculants should include crop specificity, improved ensiling fermentation with reduced losses, improved aerobic stability, and a probiotic effect on the animal performance (Weinberg and Muck 1996). Genetic engineering might also play a role in the development of ideal inoculants.

5. References

Adamson, A.H. and Reeve, A. 1992. Nutritional evaluation of whole-crop wheat. P. 85-96. In; B.A. Stark and J.M. Wilkinson (eds.) *Whole-Crop Cereals.* Chalcombe Publications , Aberystwyth, UK.

Ashbell, G. and Kashantchi, Y. 1987. In silo losses from wheat ensiled in bunker silos in subtropical climate. *J. Sci. Food Agric.* **40,** 95-103.

Ashbell, G. and Lisker, N. 1988. Aerobic deterioration in maize silage stored in bunker silo under farm condition in subtropical climate. *J. Sci. Food Agric.* **45**, 307-315.

Ashbell, G. and Sklan, D.1985. Winter wheat for silage: a double-cropping system for use in subtropical climate. *Feedstuffs* **57**, 18-19.

Ashbell, G. and Weinberg, Z.G. 1992 Top silage losses in horizontal silos. *Can. Agric. Eng.* **34**, 171-175.

Ashbell, G. and Weinberg, Z.G. 1993. The effect of applying ammonia on maize wheat, and sorghum upon ensiling. *Can. Agric. Engin.* **35**, 113-117.

Ashbell, G., Weinberg, Z.G., Azrieli, A., Hen, Y. and Horev, B. 1991. A simple system to determine the aerobic determination of silages. *Can. Agric. Engin.* **33**, 391-395.

Ashbell, G**.,** Weinberg, Z.G., Bruckental, I. Tabori, K. and Sharet, N. 1997. Wheat silage: the effect of cultivar and stage of maturity on yield and degradability *in situ. J. Agric. Food Chem.* **45**, 709-712.

Ashbell, G., Weinberg, Z.G., Bolsen, K.K., Hen, Y. and Azrieli, A. 1999. The silage characteristics of two varieties of forage sorghum mixed in different proportions at two stages of maturity. *African J. Range Forage Sci.* ***15,*** 69-72.

Ashbell, G., Weinberg, Z.G. and Hen, Y. 1997. Interactions between wheat and vetch during co-ensiling. *Meshek Habakar Vehachalav* **272**, 20-22 (in Hebrew).

Ben-Ghedalia, D., Kabala, A. and Miron, J. 1995. Composition and in vitro digestibility of carbohydrates of wheat plants harvested at bloom and soft dough stages. *J. Sci. Food Agric.* **68**, 111-116.

Dickerson, J., T., 1986.Yield, composition, and nutritive value of forage sorghum silages: hybrid and stage of maturity. *M.Sc. thesis, Kansas State University, Manhattan, Kansas, USA.*

Dost, M., 1989. Grain yield, forage yield, and forage quality of different sorghum types under irrigated and dryland conditions. *Ph.D. thesis, Kansas State University, Manhattan, Kansas, USA.*

Meeske, R., Ashbell, G., Weinberg, Z.G. and Kipnis, T. 1993. Ensiling forage sorghum at two stages of maturity with the addition of lactic acid bacteria inoculant. *Anim. Feed Sci. Technol.* **43,** 165-175.

Smith, R., L., 1986. Yield, composition, and nutritive value of grain sorghum harvested as silage: stage of maturity and processing effect *M.Sc. thesis, Kansas State University, Manhattan, Kansas, USA.*

Weinberg, Z.G., Ashbell, G., Azrieli, A. and Brukental, I. 1993. Ensiling peas, ryegrass and wheat with additives of lactic acid bacteria (LAB) and cell wall degrading enzymes. *Grass Forage Sci.* **48**, 70-78.

Weinberg, Z.G., Ashbell, G., Hen, Y. and Harduff, Z. 1991. Ensiling whole wheat for ruminant feeding at different stages of maturity.*Anim. Feed Sci. Technol.* **32**, 313-320.

Weinberg, Z.G., Ashbell, G., Hen, Y. and Azrieli, A. 1993 The effect of applying lactic acid bacteria at ensiling on the aerobic stability of silages. *J. Appl. Bacteriol.* **75**, 512-518.

Weinberg, Z.G., Ashbell, G., Hen, Y. and Azrieli, A. 1995. The effect of cellulase and hemicellulase plus pectinase on the aerobic stability of peas and wheat silages. *Anim. Feed Sci. Technol.* **55**, 287-293.

Weinberg, Z.G., Ashbell, G. and Lisker, N. 1987. The effect of addition of lactic acid bacteria inoculum to wheat and maize silages in Israel. *Agronomie* **7**, 709-713.

Weinberg, Z.G. and Muck, R.E. 1996. New trends and opportunities in the use and development of inoculants for silage. *FEMS Microbiol. Rev.* **19**, 53-68.

Weinberg, Z.G., Szakacs, G., Ashbell, G. and Hen, Y. 1999. The effect of *Lactobacillus buchneri* and *L. plantarum*, applied at ensiling, on the ensiling fermentation and aerobic stability of wheat and sorghum silages. *J. Indust. Microbiol. Biotechnol.* (In press).