All Forages Are Not Created Equally (for Ensiling)

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Preserving forages as silage is common throughout the north-central U.S., but remember all forages are not created equally for this purpose. Aside from obvious differences, such as legumes vs. grasses, annuals vs. perennials, or long-stemmed (baled) vs. precision-chopped, there are internal differences that can profoundly affect the way forages ensile. Two of the most prominent characteristics are concentrations of water-soluble carbohydrates (WSC) or sugars, and buffering capacity (BC). During silage fermentation, WSC serve as the substrate for fermentation; they are converted by bacteria under anaerobic conditions to various fermentation products. Acetic and lactic acids are the most common. Accumulation of these volatile fatty acids drives down the pH of the silage mass, and imparts some stability to the silage. In contrast, BC can be defined in most simple terms as the inherent resistance within any forage to a pH change, and is principally affected by concentrations of various organic acids or their anion salts. A quick look at each of these can explain a great deal about forage fermentation characteristics.

Water-Soluble Carbohydrates

Table 1 provides an overview of expected WSC concentrations within a wide range of forages. Most noticeably, corn silage has very high WSC, which contributes to its well-known ease of ensiling. Forage sorghums and other similar forages (sudan, sorghum-sudan, and millet) also have an abundance of WSC. Most cereal grains have somewhat less WSC than corn, but still have more-than-adequate reservoirs to support good fermentation. Although perennial cool-season grasses are not shown in Table 1, recent work at the University of Wisconsin Marshfield Agricultural Research Station has shown fully headed meadow and tall fescues exhibited WSC concentrations of 9.8-10.7% of dry matter (DM), respectively, which is mostly consistent with the WSC in cool-season cereals noted in Table 1. Concentrations of WSC in alfalfa are relatively low (4-7%), which contributes to the well-documented difficulties in ensiling this popular forage. Warm-season perennial grasses, such as bermudagrass and bahiagrass, have very low WSC, but these forages are common only throughout the southern U.S. It is important to note that within each forage, a large number of factors can affect concentrations of WSC. Factors can include stage of growth, time of day, climate, drought, frost events, nitrogen (N) fertilization, rain damage (wilting), poor/extended wilting conditions, or diurnal variation in WSC (where WSC are greater in late afternoon compared to early morning).

Table 1. Concentrations of WSC within various forage types as compiled by the University of Florida.

Crop/Species	WSC, % of DM
Corn Silage	10-20
Forage Sorghum	10-20
Sudan, Sorghum-Sudan, Millet	10-15
Rye, Oat, Wheat, Triticale	8-12
Ryegrass	8-12
Alfalfa	4-7
Bermudagrass,Stargrass	2-4
Bahiagrass	<5
Limpograss	<5
Perennial Peanut	1-4

Adesogan and Newman, 2013.

Rain Damage. Generally, WSC losses in response to rainfall events during field-wilting become greater as forage dries, and can be quite severe as forages approach a moisture concentration suitable for preservation as dry hay. Losses of WSC are much less severe within normal moisture ranges for chopped silages since plant cells are still hydrated and can maintain some physiological integrity. Table 2 depicts three alfalfa harvests, one without rain damage and two damaged by natural rainfall. With 1.9" of rainfall, WSC concentrations were reduced by ~50% relative to WSC at mowing, which would severely affect silage fermentation. Starch concentrations are also provided because they suggest (at least circumstantially) that starch can be hydrolyzed during wilting to buoy or maintain WSC.

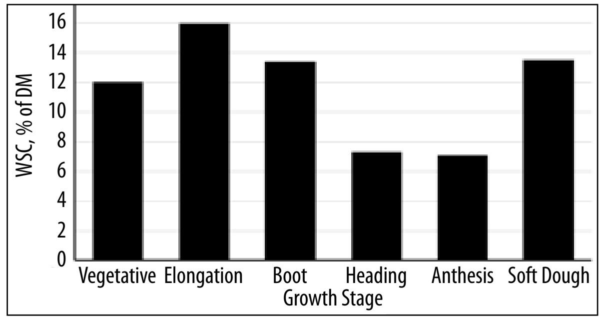
Table 2. Effects of natural rainfall on concentrations of WSC and starch in wilting alfalfa. Results from each rainfall amount are obtained from different alfalfa harvests.

Sampling Time	Rainfall inches	Moisture %	WSC %	Starch %
Initial	-	82.8	5.8	3.1
Final	0.0	54.4	6.1	0.7
Initial	-	78.1	6.4	3.3
Final	1.1	55.9	4.7	1.1
Initial	-	80.5	6.1	2.3
Final	1.9	56.2	3.0	0.6

Adapted from Coblentz and Muck, 2012.

Stage of Maturity/Frost Events. While it is impossible to cover energy dynamics of growing forages within a single paragraph, an example can be used for insight. Figure 1 illustrates WSC concentrations in triticale forages harvested during the spring of 2016 in Marshfield, WI. Before discussing trends observed during spring leading up to a silage harvest, brief mention should be made concerning WSC during the previous fall. Cereal grains managed as winter annuals, such as triticale, normally go through a winter hardening process as they approach winter. In response to frost events and cool temperatures, plants accumulate solubles within cells that increase osmotic pressure and prevent winterkill. One type of soluble compound accumulated in this process is WSC; therefore, it is common to observe increased WSC in response to frost events. In the spring, the energy status of these forages improves as they accumulate leaf area after emerging from winter. In Figure 1, this resulted in a peak WSC (16% DM) during stem elongation; however, WSC then declined rapidly during periods of rapid growth and development, reaching a minimum (7.1%) at anthesis (flowering). After flowering, WSC increased as the plant partitioned energy into the filling seedhead. It is important to note, WSC in all of these triticale forages is adequate to support good silage fermentation, and WSC at all growth stages exceeded those described in Table 2 for alfalfa at the time it was mowed.

Figure 1. Concentrations of WSC within triticale forages harvested at different stages of growth during 2016 at Marshfield, WI.



Adapted from Coblentz et al., 2018.

N Fertilization. Although it should not be considered a major factor in good silage management, many farmers do not realize N fertilization negatively effects WSC concentrations within forage plants. Recent work in Marshfield (Coblentz et al., 2014) has shown WSC declined by ~17% in a linear relationship with N fertilization rate for fall-grown oat fertilized with 0-90 lbs N/ac in the form of urea (46-0-0). For fall-grown oat harvested during 2011 and 2012, WSC did not decline to <10% DM, regardless of N fertilization rate, which is easily enough to support good silage fermentation. However, this relationship is observed consistently.

Buffering Capacity

Table 3 provides an overview of BC for many forages obtained from a wide variety of sources. The inherent resistance of forages to pH changes varies widely across forages, and contributes significantly to their ease of ensiling. As mentioned, BC is largely affected by concentrations of organic acids in plants, and is often associated more closely with the leaf rather than stem tissue. As a result, BC usually declines with any production or growth factor reducing leaf-to-stem ratio. Note specifically that white clover, which is essentially all leaf, has the highest reported BC. Normally, management factors reducing leaf–to-stem ratios would include maturation, rain damage, leaf loss associated with swath manipulation, etc. Generally, the highly-sugared warm-season annuals (corn) have low BC, which is desirable from a silage fermentation perspective. Cool-season annuals or perennials are typically intermediate, while legumes (alfalfa) are highly buffered, making them difficult to ensile. While factors affecting WSC and BC in forages are complex, a basic understanding can be helpful in managing good silage production.

Table 3. BC for selected forages compiled from various sources, and expressed as mEq/kg DM, where forages with lowest BC (least resistance to pH change) are the easiest to ensile.

Crop/Species	Buffering Capacity	
	Range	Mean
Corn Silage	149-225	185
Timothy	188-342	265
Fall Oat (Headed)	300-349	323
Orchardgrass	247-424	335
Red Clover	-	350
Fall Oat (Boot)	360-371	366
Italian Ryegrass	265-589	366
Alfalfa (mid-bloom)	313-482	370
Perennial Ryegrass	257-558	380
Alfalfa (1/10 bloom)	367-508	438
White Clover	-	512