Corn Silage

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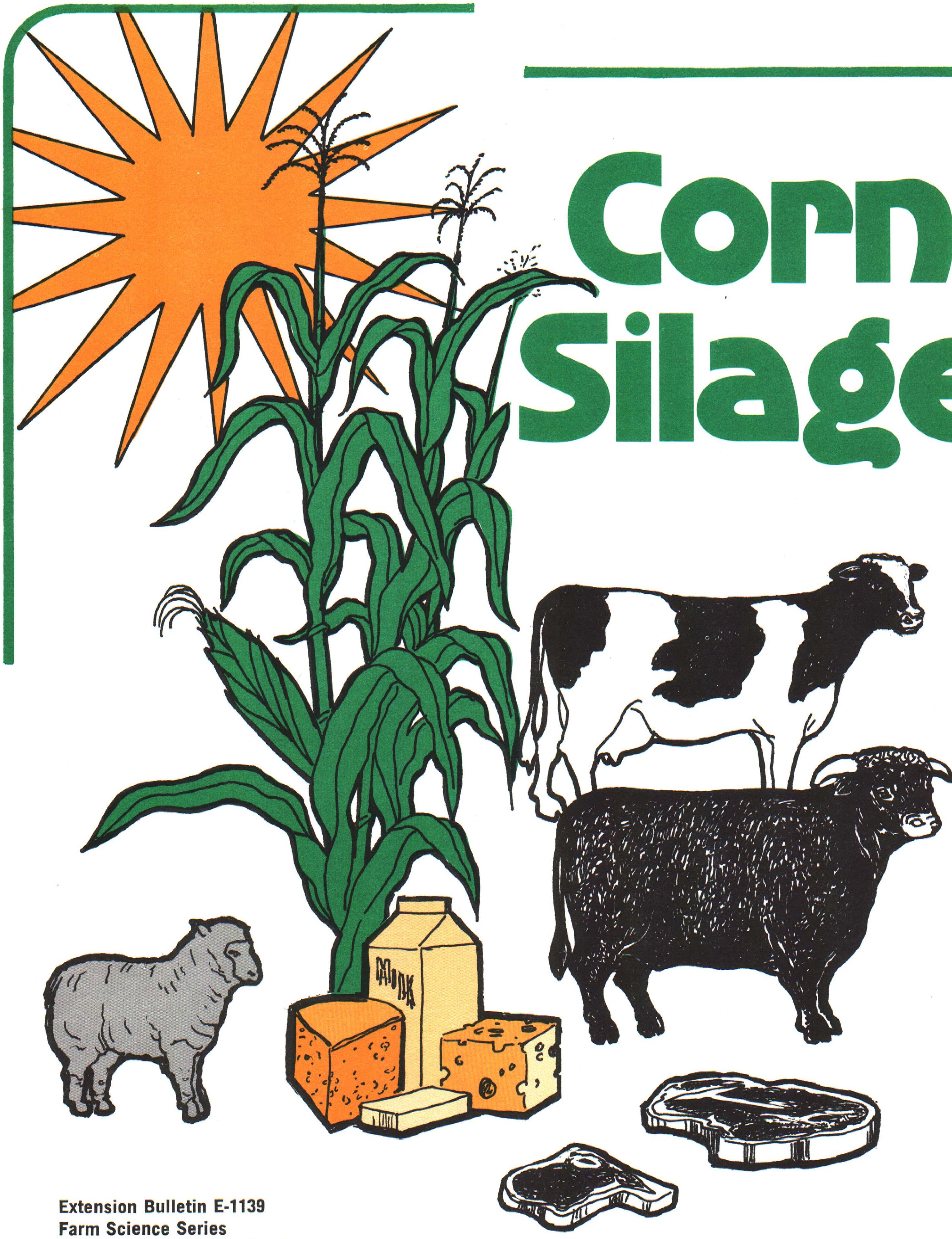

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foreword

This publication offers information on growing, harvesting, preserving and feeding corn silage for dairy and livestock producers whose soil and climatic conditions justify growing corn silage when economic conditions are favorable. Managers must control rations so as to utilize the high energy from corn silage while adjusting for the lower protein and other nutrient content of corn silage.

The following sections offer key points on:

—the nutrient content of corn silage;

—feeding corn silage to dairy cattle, feedlot beef cattle, beef cow herds and sheep;

—production of corn for silage;

—harvesting, handling, storage and feeding systems;

—silo structures and their selections; and

—investments for harvesting, storing and handling.

economics of corn silage

BY SHERRILL NOTT AND DON HILLMAN
Departments of Agricultural Economics and Dairy Science, respectively

CORN SILAGE will produce more megacalories[1] roughage feed energy than any other crop in Michigan where soil and climate are adapted. It is a major source of feed for ruminant livestock. Well over 4 million tons of silage are harvested annually from approximately 385,000 acres of corn in Michigan. Of the total corn acreage, some 17% is harvested as silage and stored for feeding later.

In normal, well-eared corn silage, approximately half the dry matter is shelled corn; the other half is equal to timothy hay in feed value. The estimated yield of hay-equivalent and shelled corn per acre for various yields of corn silage are given in Table 1. You can use these values to estimate the value of corn silage for livestock feed in terms of current prices for grass hay and shelled corn.

Corn silage and hay are the two main forage crops fed by Michigan livestock producers. In most rations they substitute each other. They often compete for land and labor on any given farm. Table 2 shows the cost differences between alfalfa hay and corn silage. Corn silage requires considerably more fertilizer each year than does hay; it does not fix its own nitrogen as alfalfa can. Corn growers meet these fertilizer needs through animal manures and purchased fertilizers.

An important management item with corn is weed control. This requires a larger annual expenditure on corn than on hay. The per-acre machinery costs are higher for corn silage because of the increased volume of material handled, the necessity of ground preparation, and planting a crop every year. Corn silage also requires a larger supply of capital than does hay because the variable costs are nearly double.

The average yield for corn silage in Michigan is about 12 tons per acre (4.0 tons hay-equivalent) and for hay it is about 3 tons for two cuttings, or 4 tons where 3 cuttings are possible. The machinery labor hours in Table 2 understate the total labor hours required for one acre of hay. Hay harvest usually requires manual labor in addition to the machine labor hours; corn silage usually does not. A total hay system typically requires 9 to 11 hr of labor per acre for manual and machine hours combined.

Some combination of alfalfa and corn is practical for most Michigan dairy farms. Optimum use of land, distribution of peak labor loads, minimizing risk of weather interference on yields, harvesting operations, forage quality and widely fluctuating prices of concentrates are the key aspects to consider. The high energy content of corn silage complements the higher protein content of alfalfa (and vice versa). A combination of 25 to 50% alfalfa with corn silage requires little supplementation when fed to growing young cattle, dry cows and milking cows in late lactation. Thus, dairy farmers on land capable of growing good

Table 1 — Estimated yield of hay-equivalent and shelled corn from corn silage.

Corn silage yield (33% dry matter) ton	Total DM yield ton	Estimated hay-equivalent (90% DM) ton	grain (85% DM) bu
18	6.0	3.3	125
16	5.3	2.9	110
12	4.0	2.2	78
10	3.3	1.8	64

Table 2 — Variable and fixed production cost estimates per acre (Michigan, 1975).

Item	Alfalfa for hay	Corn silage
Production costs:		
Seed	$ 7.01	$ 11.90
Fertilizer	13.57	31.52
Weed and insect control	1.51	9.24
Machinery operations	16.66	24.88
Machinery labor	11.75	17.56
Interest on operating capital	1.32	2.44
Total variable costs	$ 51.82	$ 97.54
Fixed costs	51.13	67.08
Total production cost	$102.95	$164.62
Tons harvested	3.00	12.55
Machinery labor hrs	4.76	7.11

Source: Input coefficients derived from the firm enterprise data system, ERS, USDA.

[1]*One million calories.*

corn and alfalfa generally find that some combination is desirable.

Corn silage is very different from hay in a livestock ration. Table 3 indicates that, when considered on an "as harvested" basis, hay is about 90% dry matter (DM), while Michigan corn silage averages 33% dry matter. Corn silage typically deviates little from the standard 8% protein, while alfalfa can vary from 12 to 24% protein and grass hay from 7 to 12%. In total, alfalfa hay crops yield more protein per acre than does corn silage.

In terms of megacalories of estimated net energy (M/cal of ENE), Table 3 shows corn silage has the advantage. There is more energy per pound of DM in corn silage. Given the yields in Table 3 and the total costs in Table 2, cost per M/Cal of ENE in alfalfa hay is 4.2¢, while it is only 2.9¢ for corn silage. The production of feed energy per labor hour is 791 M/Cal in corn silage as compared with 511 in hay.

Over the past two decades livestock farmers have tended to feed more corn silage and less hay. This has happened as farmers tried to keep more livestock on the same or fewer acres of land while doing the work with the same or fewer labor hours. Protein deficiencies in corn silage were corrected by feeding high-protein concentrates or by supplementing the silage with non-protein nitrogen sources. The historically low cost of these alternative protein sources and the high cost of land has made this kind of substitution economically feasible. These relative costs may change in the future.

Under certain soil and climatic conditions, alfalfa competes effectively with corn silage. Light soils are often defined as having a higher sand percentage and a smaller clay percentage. Light soils have less water-holding capacity and are often in more rolling terrain. On light, droughty soils, the deeper root system of alfalfa allows it to produce more energy and protein than does corn silage if irrigation is not used. In northern areas where there are not enough growing degree days or the growing season is too short, corn silage may not mature consistently and therefore may not be able to compete with grasses or legumes.

Table 3 — Protein and feed energy costs per acre (Michigan, 1975).

Description	Alfalfa for hay	Corn silage
Tons harvested	3.00	12.55
% dry matter	90.	32.
% protein, dry basis	15.	8.
Lb protein per acre	810.	643.
Total cost per lb of protein	$.127	$.256
Protein lb per labor hr	170.	90.
% ENE, dry basis	45.	70.
M/cal of ENE per acre	2,430.	5,622.
Total cost per M/cal of ENE	$.042	$.029
ENE M/cal per labor hr	511.	791.

nutrient content of corn silage

BY DON HILLMAN AND DAN G. FOX[2]
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NORMAL CORN SILAGE, harvested at the proper stage of maturity and well-preserved, is a high-energy source of forage for cattle and sheep. Corn silage dry matter is normally low in protein, calcium and sulfur, compared with legume forages. The average composition and variations in dry matter, protein and mineral contents of corn silages from Michigan farms are shown in Table 5 (page 5).

Considerable variation occurs in the nutrient content of corn silage from one source to another. Differences in maturity of the corn plant at harvest, types of hybrids or varieties, soil moisture and fertility, and storage conditions can influence the nutrient composition. In general, corn silage is less variable in energy and protein content than hay crop forages.

Energy Value

Normal corn silage that is well eared and well preserved is a high-energy source of forage for cattle,

[2]*Now at N.Y. State College of Agriculture, Cornell Univ., Ithaca, N.Y.*

Table 4 — Effect of grain content on energy value of silage.

No. 2 corn	TDN	NE_m§	NE_g
bu/ton	%	Mcal/lb DM	
6.7	75	.75	.48
5.4	70	.71	.45
3.5*	66	.65	.41
2.0†	56	.57	.36
0‡	49	.50	.32

*Assumed to be drought-damaged corn that came under heat and drought stress during pollination.
†Assumed to be drought-damaged corn that came under heat and drought stress during mid-summer and through pollination.
‡Assumed to be drought-damaged corn that came under heat and drought stress all summer.
§Net energy for maintenance value is used in formulating rations for dairy cattle.

sheep and other ruminants. The energy value of corn silage is influenced primarily by grain content and weather conditions (moisture and temperature).

Table 4 shows our estimate of the relationship between grain content and energy value, based on recent research at MSU and other Midwestern Agricultural Experiment Stations.

The net energy value reflects the calories available for growth fattening or milk production after deducting losses from digestion, metabolism and urine. Any factor affecting the quality of the ration, such as the amount and quality of protein or other nutrients, will influence the net energy value of the ration, the amount consumed above that required for maintenance of the animal, and the productive performance of the animal.

NE_m (net energy for maintenance) values as shown in Table 4 have been used successfully in formulating rations for dairy cattle. Both NE_m and NE_g (net energy for gain) are used in formulating rations for feedlot cattle.

These values, along with yield data on the variation in nutrient content for corn shown here, indicate that varieties selected for optimum grain yields are likely to give the highest silage net energy yield per acre. In general, varieties that give high grain yields will also have large forage yields per acre, due to leaf surface needed to convert solar energy into sugars which are then concentrated in the grain as starch.

Factors Affecting Sources of Energy

Maturity at harvest—Normal corn silage DM contains 45 to 55% shelled corn, which furnishes starch as a major source of energy, and the forage, which is composed of mostly cellulose and hemicellulose as the source of fiber. After ear formation has begun, the fiber fraction changes very little in digestibility, but the percentage of fiber tends to decline as the percentage of grain increases.

In contrast, immature corn plants (prior to grain formation) contain 20 to 35% soluble carbohydrates, mostly sugars and similar carbohydrates. If corn is ensiled at immature stages, the soluble carbohydrate is largely fermented to lactic acid as shown in Figure 1. Lactic acid is a concentrated source of energy and is efficiently utilized by ruminant microorganisms within certain undefined limits. However, when silage is fermented at the very immature stage, 75 to 80% of the lactic acid produced is the D(−) isomer (dextrorotary) and 20 to 25% L(+) lactic acid. At later stages of maturity 50 to 65% is D(−) lactate.

D− lactic acid is known to be toxic to cattle when consumed in large quantities or introduced into the diet too rapidly without sufficient adaptation period. Lactic acidosis can occur when cattle are fed large amounts of immature (high moisture) corn silage, particularly when accompanied by large amounts of grain without gradually changing the ration. Lactic acid is also rapidly produced by rumen microorganisms, causing an "off feed" condition and rumenitis under such conditions.

Immature corn silage is also high in moisture content (low DM). The soluble carbohydrate which constitutes a high proportion of the DM and the lactic acid of fermentation are dissolved in the moisture. This silage is very fluid, and an excessive amount of energy (and other soluble nutrients) can be lost in seepage when compressed under the weight of considerable height of forage.

Also, a large proportion of the protein in immature, and high-moisture silage is degraded to non-protein nitrogen and may be poorly utilized by the animal.

For these reasons, silage preserved at 30 to 35% DM (dough to glaze stage of maturity) is most desirable when fed as a major part of the ration.

Corn that is too mature may be too low in moisture content for good packing and thus difficult to preserve as silage. Aerobic fermentation (oxidation of carbohydrate to carbon dioxide and water) by yeasts and

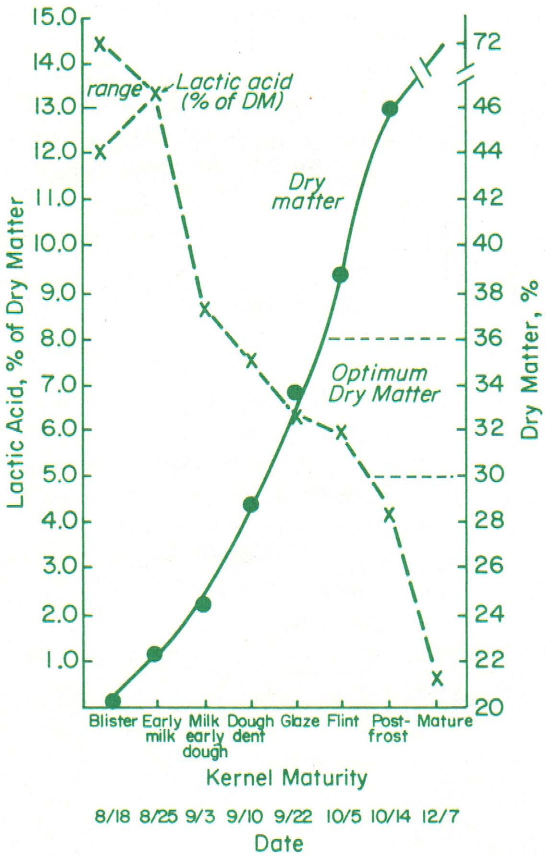

Figure 1—Relationship of stage of maturity at harvest to dry matter and lactic acid content of corn silage (untreated). (Source: Ohio data, Journal of Dairy Science 51:803, 1969.)

molds can be substantial in such silages. When carmelization and enzymatic browning occurs under such conditions, the availability of both energy and protein can be reduced. Fine chopping and firm packing are essential to prevent deterioration of high DM silage.

In practice, most producers plant some early maturing hybrids so that harvest can begin when the corn reaches the early dent stage (28 to 30% DM) in mid to late August. Then they harvest longer-season hybrids in September and plan to complete harvest before frost. This practice will result in the harvest of silage at an average 32 to 35% DM in most years, giving optimum silage quality and energy yields per acre.

After the corn plant reaches 40% dry matter, field losses of leaves and entire plants from lodging increase and packing becomes more difficult.

Protein Content

Corn silage (dry matter) from Michigan farms averages 8.3% crude protein when no non-protein nitrogen is added as shown in Table 5. Samples ranged from 6.1 to 14% crude protein. However, two-thirds of the samples contained within 2.2 percentage points of the average, as shown statistically by the standard deviation (s.d.).[3]

Corn silage treated with non-protein nitrogen (NPN) such as ammonia or urea averaged 12.1% crude protein (dry basis) and ranged from 8.0 to 17.6%. The standard deviation of 2.0% was similar to that for untreated samples, indicating that the variation was no greater than in untreated silages, and treatment was successful with few exceptions.

Immature silages tend to be higher in protein content as shown in Table 6. However, a larger portion of the protein is degraded to non-protein nitrogen during fermentation of immature high moisture silage (Table 6).

Mineral Content

The mineral content of corn silage dry matter from Michigan farms is shown in Table 5.

Corn silage is typically low in calcium and generally must be supplemented with calcium, particularly for lactating dairy cows.

The sulfur content is also low compared with legume forages. The sulfur deficiency will generally be corrected when silage is supplemented with natural protein from soybean meal or legumes. However, if NPN is used as the major source of protein, additional sulfur may be required. Apparently many of the silages treated with NPN also contained added sulfur (Table 5).

The potassium content of corn silage averaged 1.04% of the dry matter. This is adequate but low compared with hay crop forages. The large standard deviations indicate that potassium could be borderline or deficient in some dairy rations if corn silage and shelled corn (low in potassium) constitute most of the ration.

The average values of phosphorus (.29%), magnesium (.24%), manganese (33 ppm),[4] iron (214 ppm), copper (9.0 ppm) and zinc (37 ppm) are adequate. However, the standard deviations indicate silages from some farms were too low to meet the recommended nutrient requirements without supplementation.

Nutrient Content

Drought damaged corn — If the corn has been stressed all summer, has no ears and is short, the energy value will be about 70% of normal corn si-

[3]*Standard deviation (s.d.) is a statistical expression of the amount of variance among samples of data collected in scientific research.*

[4]*ppm: parts per million.*

Table 5 — Dry matter protein and mineral content of corn silage dry matter from Michigan farms.

	Dry matter	Crude protein	P	K	Ca	Mg	S*	Mn	Fe	Cu	Zn
	%	%	%	%	%	%	%	— ppm —			
Corn silage (no NPN added — 103 samples)											
Average	36.2	8.3	0.29	1.04	0.28	0.24	0.11	33	214	9.0	37
Sd_x	10.0	2.2	0.13	0.26	0.08	0.06	0.06	21	125	8.2	18
Min.	18.3	6.1	0.12	0.52	0.10	0.10	0.05	10	58	5.0	24
Max.	93.6	14.0	1.51†	2.21†	3.5†	0.45	0.19	98	643	14.0	186
Corn silage (NPN added — 93 samples)											
Average	34.7	12.1	0.24	1.03	0.40	0.23	0.14‡	31	280	9.8	46
Sd_x	6.0	2.0	0.08	0.17	0.27	0.10	0.10	18	156	6.9	27
Min.	25.5	8.0	0.11	0.67	0.17	0.10	0.03	10	69	7.0	22
Max.	60.7	17.6	0.40	1.38	2.15	0.97	0.48	110	699	17.0	200

*Sulfur-based on 50 samples. 1975-76.
†Sample apparently contained added minerals.
‡Sulfur-based on 51 samples. 1975-76.
§Sources of NPN include urea and ammonia and added minerals in some cases. Summary of feed analyses reports.

Table 6—Changes in nitrogen distribution in corn plant material with advancing maturity and effect of ensiling.

Date	Stage (grain)	Material	Dry matter	Crude protein	% total N in fractions		
					Protein N	Non-protein N	Ammonia urea
			%	% DM	%	%	%
8-17	Blister	Plant	20.9	12.0	62.9	30.2	
		Silage			48.3	52.3	5.6
8-25	Early milk	Plant	19.9	12.1	68.2	31.1	
		Silage			42.7	56.1	3.0
9-2	Milk-dough	Plant	21.9	10.8	73.8	28.9	
		Silage			46.9	55.4	5.0
9-9	Dough-dent	Plant	27.2	10.4	79.7	18.9	
		Silage			52.2	49.1	5.9
9-21	Glaze	Plant	33.5	9.4	81.4	20.4	
		Silage			57.0	44.0	8.1
10-6	Flint	Plant	45.4	9.0	83.1	19.3	
		Silage			68.0	38.4	3.7
10-15	Post-frost	Plant	49.2*	8.7	65.1	32.7	
		Silage			68.5	34.5	3.4

*5% water added at ensiling. Ohio Beef Cattle Research, Summary 7, 1966.

lage. This is an estimate based on experience, since no controlled research has been conducted under these conditions. Nebraska studies suggest corn which has not been as severely stresssed (perhaps 10 to 20 bu grain/acre) will have 80% of the energy of normal corn silage.

Michigan studies suggest corn which was stresssed by heat and drought during pollination (has normal stalk development, but relatively barren stalks and ears; approximate 3½ bu grain/ton silage or 40 to 60 bu/acre) has about 90 to 95% the energy value of normal corn silage.

Droughty silage typically has a higher protein content than normal silage. However, most of this protein is found in the plant rather than in the grain under these conditions, making it more easily degradable in the rumen. As a result, NPN supplementation does not appear to work as well as in normal silage, according to Nebraska studies. Thus it becomes especially important to supplement drought corn with a natural protein source for calves up to 600 to 700 lb and high-producing dairy cows in early lactation.

The DM content of droughty silage must be in the normal range (30 to 35%) to make good silage. If the corn did not set ears and is green, or if the ears are all brown and the stalk is green, the moisture content will be too high; but hot, dry weather can cause rapid moisture drop, so careful observation of changes in moisture content to determine when to harvest is essential.

Although nitrate levels in drought-stricken corn may be high, ensiling will reduce more than half the nitrates to ammonia, which can be utilized. For this reason, nitrate toxicity rarely occurs with feeding ensiled drought-damaged corn. However, if the drought damage is extreme, and high levels of nitrogen were applied to the soil, a nitrate test on the silage should be conducted.

High sugar corn—This type of corn concentrates sugars in the stalk rather than starch in the ear and will contain about the same amount of energy as average corn silage, even though it does not have ears. Thus, its use should be based on how it compares with other varieties in dry matter yield. Keep in mind that it has little alternative use other than silage and tends to remain high in moisture and water-soluble dry matter.

Brown midrib corn—This type of corn silage will have a somewhat lower grain content, but the stalk is more digestible due to a lower lignin content. It will have a somewhat higher net energy value than average corn silage. However, stalk breakage can be high if a high wind or an early snow occurs before harvest. In MSU studies, it was somewhat more difficult to harvest as grain, due to stalk breakage, and silage yield per acre was lower than normal corn.

Waxy corn—The protein in waxy corn is less degradable in the rumen, which should increase corn protein bypass to the small intestine. Also, the starch is in a form that is more easily degraded in the rumen. An average of experiments with waxy corn showed improvements of approximately 2% in average daily gains and feed efficiency from feeding waxy corn grain. An MSU study did not show any advantage for silage made from waxy corn compared with normal corn. It would appear that yields per acre of waxy corn need to be near that of normal corn to be considered.

Opaque-2 (high lysine) corn—This type of corn contains higher levels of the amino acid, lysine, which is low in normal corn. It has been shown to improve performance in swine; they must obtain all needed amino acids from the daily ration. However, results with cattle have been mixed. The likely reason is that cattle apparently can synthesize enough of this amino acid in the rumen; ½ to ¾ of the corn protein is degraded in the rumen and then re-synthesized into bacterial protein.

Fineness of Chop and Packing

Fine chopping (¼ to ⅜-in. cut) will increase packing. Tight packing will increase storage capacity and will reduce oxidation losses due to entrapped air or air entering silage that is not well packed.

Fine chopping silage will reduce sorting by cattle, and mixing of the total ration is facilitated. Some MSU studies indicate that fine chopping silage increases daily gain and feed efficiency. However, extremely fine silage may not be beneficial in high-grain beef cattle rations or in dairy cattle when displaced abomasum[5] is a problem.

Silage Additives

Several types of materials are being added to corn silage either to increase preservation of corn plant nutrients or to add sources of supplemental nutrients. This is a complex area, and only a brief summary of each will be given here.

Fermentable carbohydrates (molasses, ground grain, whey)—These may be beneficial under certain conditions with hay crop silage. However, corn silage normally contains a large quantity of sugars and starches, which allow rapid fermentation and production of the acids that preserve silage.

Biological additives—Research results with adding bacterial cultures to silage have been highly variable. Many factors likely influence the response to these types of products, including bacteria numbers and types on the crop at harvest, type and variability of cultures used, available fermentable carbohydrate in the forage and moisture content of the silage. Under some, as yet undefined, conditions, bacterial cultures may increase lactic acid content, which in turn may help preserve the silage. Nebraska studies with adding two of the most commonly used cultures, *aspergillus oxyzae* and *Bacillus subtilus*, to corn silage resulted in improved preservation in only one of three trials. In a feeding trial, however, the treated silage gave a 9.3% better feed efficiency.

Improvements in cattle performance by using these products have also been obtained by Georgia and Florida Experiment Stations.

Intensive, thorough experiments with these types of products are now underway at two midwestern experiment stations. These should result in definite recommendations on the use of these products in the near future.

Urea, ammonia and limestone addition—Research at several experiment stations indicates that the addition of these products have the common effect of buffering acids produced, resulting in a longer production of lactobacilli and a 40- to over 100%-increase in lactic acid production. Less energy is lost during fermentation when lactic acid, rather than acetic, propionic and butyric acids, is produced. Calculations by Oklahoma researchers indicate that fermentation in the silo can conserve more energy than a corresponding fermentation in the rumen. About 10% of the digestible energy is lost as methane during fermentation in the rumen. Less rumen methane is produced when the silage contains high levels of lactic acid. Theoretically, this means that pre-fermenting the carbohydrates to lactic acid in the silo can lower energy losses in the rumen, leaving more net energy for the animal. Thus, under ideal ensiling conditions, overall utilization of the corn plant energy can be improved if the silage is made at the proper moisture content (30 to 35% DM) and buffer is added.

The addition of ammonia to corn silage has also been shown to reduce mold growth; it is thought that decomposition of the original plant protein may be reduced by ammonia addition.

However, these benefits are often more than offset by high requirements of lightweight beef cattle or high-producing dairy cattle for protein, which cannot be met by entirely substituting NPN for a natural protein supplement. The whole corn plant is low in protein. Further, during fermentation, protein quality is reduced to 60 to 70% of that in the fresh corn plant. Thus, proper supplementation is critical to insure maximum utilization of the silage energy. NPN addition can greatly reduce the costs of providing supplemental protein, but the degree of substitution of NPN treatment for supplemental natural protein that can be done profitably will depend on the stage of growth or lactation and cost of natural supplemental protein. The proper use of NPN treatment of silage in various feeding programs will be discusssed in other sections.

Urea, ammonia or ammonia-mineral suspension can be used to add NPN to corn silage. The results with using these various products will be discussed in the sections on feeding corn silage.

[5] *The abomasum is a cow's fourth stomach.*

supplementing corn silage rations for dairy cattle

BY DON HILLMAN
Department of Dairy Science

NORMAL, GOOD QUALITY CORN SILAGE is an excellent forage for dairy cattle when the ration is properly balanced with energy, protein and minerals. Corn silage has been fed successfully for three lactations as the only source of forage for lactating cows in experiments at Michigan State and Purdue universities.

Feeding 5 to 8 lb of good quality hay (or haylage dry matter) may be desirable under farm conditions as a general practice because of variations in the nutrient composition of corn silage or where control over the ration composition is less precise than desirable.

Normal, well-eared, well-preserved corn silage contains 30 to 36% dry matter. The dry matter is high in energy value, 68 to 70% total digestible nutrient (TDN) content, or approximately 0.71 megacalories (M/cal) estimated net energy (ENE) per pound of dry matter. Corn silage is normally low in protein and calcium and requires supplementation.

Formulating Rations

Rations utilizing corn silage and other ingredients must be formulated to provide the nutrients required for maintenance, milk production, pregnancy and growth during the first year or two of lactation. The suggested nutrient concentrations for total rations are in Table 7.

The formulated rations in Table 8 are based on the normal composition of corn silage and other feedstuffs as described and should be adequate for those situations. However, the nutrient content of corn silage and hay crop forages varies considerably, and adjustments in the formulations, or amounts fed, may be necessary in specific situations.

Energy supplementation — Dry shelled corn was used as the source of grain in the formulated rations. Ground ear corn, high-moisture corn, oats, and other cereal grains can be substituted for shelled corn. Adjustments for differences in energy value, protein and moisture content should be made. Corn silage is higher in energy value than ordinary-quality hay crop forages. Therefore, somewhat less grain is required to provide the same total energy in the ration as shown in the illustration.

In general, for high-producing cows, 40 to 50% of the total ration dry matter will be composed of concentrates (grain and protein supplement) and the balance from corn silage or other forage.

Protein supplementation—Corn silage is low in protein content, averaging about 8.3% of the dry matter. Rations for cows in early lactation will require 15 to 16% protein. The amount and quality of other forages fed with corn silage will influence the amount of protein supplement required in the concentrate ration (grain mix) as shown in Table 8. During the second half of lactation, 13% protein may be adequate.

Commercial protein supplements may be substituted to provide the amounts of protein indicated in the illustrations. However, such supplements normally contain added minerals and vitamins. These must be taken into account to avoid double supplementation.

Non-protein nitrogen (NPN)—Most authorities agree that lactating dairy cattle can utilize about 0.4 lb non-protein nitrogen daily from all sources. This is equiv-

Table 7 — The approximate concentrations of major nutrients required in the dry matter of rations.*

Period	ENE*	Crude protein	Crude fiber	Ca	P	Mg	Salt	K	S
	Mcal/lb DM	%	%	%	%	%	%	%	%
Lactation									
5—150 days	.76	+15	+15	.5–.7	.35	.20	.45	.7	.18
150—300 days	.72	13	+15	.5	.30	.15	.45	.7	.18
Dry cow	.50	10	+25	.34	.26	.15	.25	.7	.18
Growing heifers									
200—750	.6–.7	12	+15	.34	.26	.10	.25	.7	.15
750—1,100	.6	10	+15	.34	.26	.10	.25	.7	.15

†ENE values are calculated from standard feed composition tables. Actual digestibility is believed to decline at high levels of intake, thus these values should be considered relative rather than actual.

*For further information on the nutrient requirements of dairy cattle and composition of feeds see Michigan State University Extension Bulletin E-702, "Basic Dairy Cattle Nutrition."

Table 8 — Corn silage plus hay or haylage rations.

Proportions of forage dry matter					
Corn silage %	100	80	68	55	42
Hay (or haylage DM) %	0	20	32	45	58
Estimated feed intake daily (1,400-lb cows, @ 60 lb milk)					
Corn silage (32% DM) lb	78	67	56	44	36
Hay or haylage, lb	0	5.0	10.0	15.0	20.0
I. Concentrate mix with medium-quality alfalfa (15.6% protein, DM basis)					
Shelled corn, % wt	55.8	57.9	66.1	75.3	83.6
Soybean meal (44%)	40.0	39.0	30.7	22.2	14.3
Dicalcium phosphate, % (defluorinated)	1.1	1.3	1.3	1.3	1.3
Limestone (feedgrade) %	2.5	2.0	1.1	0.4	0
TM salt, %	0.6	0.8	0.8	0.8	0.8
Vitamin A, IU/ton			2,000,000		
Vitamin D, IU/ton			500,000		
Protein, % (87% DM)	23.5	22.6	20.0	16.5	13.9
Concentrate daily, 60 lb milk	16.2	15.5	16.9	17.5	18.1
Lb milk/lb concentrate	3.7	3.8	3.5	3.4	3.3
Total ration protein (DM) %	16.5	15.3	15.0	14.2	13.7
II. Concentrate mix for corn silage and high quality alfalfa (18.4% protein)					
Proportions of forage dry matter					
Corn silage, %	100	80	68	55	42
Hay or haylage, %	—	20	32	45	58
Estimated feed intake daily (1,400-lb cow @ 60 lb milk)					
Corn silage, 32% DM, lb	—	70	60	50	41
Hay (or haylage DM) lb	—	5	10	15	20
Concentrate mix					
Shelled corn, % wt	—	56.6	66.4	77.0	88.2
Soybean meal, %	—	39.1	30.0	20.0	9.4
Dicalcium phosphate, % (defluorinated)	—	1.3	1.4	1.5	1.5
Limestone (feed grade), %	—	2.0	1.2	0.5	—
TM salt	—	1.0	1.0	1.0	1.0
Vitamin A, IU/ton			2,000,000		
Vitamin D, IU/ton			500,000		
Protein, %	—	22.6	19.1	15.7	12.2
Concentrate daily lb/60 lb milk	—	16.0	16.0	16.0	16.0
Lb milk/lb concentrate	—	3.75	3.75	3.75	3.75
III. Concentrate mix for corn silage and low protein (8.0%) grass hay					
Shelled corn	49.5				
Soybean meal	48.0				
Dicalcium phosphate (defluorinated)	1.0				
Limestone (feed grade)	1.5				
TM salt	1.0				
Concentrate, protein, %	22.6				
Conc/60 lb milk, lb	18.0				
Lb milk/lb conc.	3.3				

alent to 2.5 lb protein from NPN (0.4 × 6.25 = 2.5). In normal corn silage, about 45% of the protein (nitrogen) is in the form of NPN. If the silage dry matter contains 8.3% protein, and 45% is protein from NPN, then normal silage contains 3.75% protein from NPN.

Cows receiving corn silage as the only forage will consume about 25 lb dry matter from silage when balanced with adequate energy and protein. The silage contributes about 2.0 lb protein to the diet (25 lb DM × 0.083 = 2.0 lb protein). If 45% of the protein is NPN, then about 0.9 lb protein is from NPN in the silage (2.0 lb × 0.45 = 0.9 lb protein equivalent from NPN).

When urea is added to corn silage at the rate of 10 lb per ton or an equivalent amount of nitrogen from ammonia (fresh weight), the crude protein content is increased about 4 percentage points to 12.3% of the dry matter. Most of this increase is NPN. Thus, the silage then contains 7.75% protein from NPN.

At 25-lb dry matter intake, the total crude protein intake from urea-treated silage is 3.1 lb and the protein intake from NPN is 1.87 lb daily. This is below the suggested limit of 2.5 lb per day but should be considered the maximum since some NPN will be contained in the concentrate portion of the diet. Urea (or other NPN) should not be added to the concentrate ration of cows receiving corn silage treated with NPN as the major source of forage.

Some data indicate that part of the protein in high-moisture fermented corn grain is also degraded to NPN, particularly when stored at too high moisture content (greater than 32% moisture).

Also, when immature or drought-stricken corn silage is fermented, 60% or more of the protein may be NPN. The available data suggest that urea or ammonia should not be added to such silages for lactating cows. Likewise, dry grain may be more desirable, for at least part of the ration under such conditions. Substituting good quality legume hay for part of the silage will also reduce the NPN intake from silage. Normally, about 18% of the protein in dry hay is NPN. The protein in high-moisture grass silages is degraded to NPN similar to corn silage.

Change rations gradually—Abrupt changes in the ration should be avoided. Time is required for rumen microorganisms to adapt and establish a suitable population. This is apparently more important when NPN constitutes a significant portion of the dietary protein. Gradual changes over a period of 2 to 3 weeks are recommended.

Also, silage near the surface of newly opened silos is frequently inferior in quality. Such silages may cause serious digestive upset and "off feed" unless introduced into the ration in small quantities.

Mineral supplementation: calcium and phosphorus—Corn silage averages 0.29 ± 0.08% calcium and 0.28 ± 0.08% phosphorus. Cereal grains are also low in calcium (shelled corn less than 0.03% Ca) but contain about 0.3% phosphorus.

Rations for lactating cows should contain 0.6 to 0.7% calcium and 0.35 to 0.37% phosphorus. Since both the corn silage forage and the grain ration must be supplemented with calcium, a large amount of supplemental calcium is required, as shown in Table 8.

In general, mineral supplements for high-corn silage rations should contain 2.5 to 3 times as much calcium as phosphorus. Calcium carbonate (feed grade limestone) can be used to supply part of the additional calcium.

Legume forages contain more calcium than corn silage and require less supplemental calcium, but are similar in phosphorus content. Grass hay may be very low in calcium and require supplementation similar to corn silage.

Laboratory analysis of forages can provide a basis for more precise formulation of rations.

Potassium (K)—Corn silage is low in potassium, 1.04 ± 0.17% compared with hay crop forages (±2.0% K). While most silages contain adequate potassium, some rations can be too low (less than 0.7% K) when shelled corn or brewers grain is fed as the source of concentrate. Feeding 5 to 10 lb of hay crop forage may be helpful in such cases.

Sulfur (S)—Corn silage averages 0.11 ± 0.06% sulfur compared with 0.18 to 0.20% recommended in the diet of lactating cows. High-protein supplements such as soybean meal and brewers grains normally provide sufficient sulfur when included in the ration to provide adequate amounts of protein.

When non-protein nitrogen (urea or ammonia) are used to furnish part of the protein, additional sulfur may be required to balance corn silages that are below normal in sulfur content. Calcium sulfate ($CaSO_4$), magnesium sulfate ($MgSO_4$), and sodium sulfate (Na_2SO_4) have been shown to be of similar value as sources of sulfur. Excessive use of sulfate should be avoided.

Magnesium—Michigan corn silages average 0.24% magnesium and are typical of other hay crop forages. Because of the variation from farm to farm, magnesium supplementation may be required in some situations. Magnesium oxide (MgO) provides buffering activity in the rumen as well as a source of magnesium. The addition of 5 to 10 lb of magnesium oxide per ton of grain ration is desirable to supplement low-magnesium forages.

Salt (sodium chloride, NaCl) is required at a rate of approximately 0.5% of the total diet. Thus, about 1% salt in the grain ration is normally adequate.

Trace Minerals — Copper (Cu) Manganese (Mn), Zinc (Zn) and **Iron (Fe)** are contained in corn silage in concentrations similar to hay crop forages grown on the same soil. Because of the variation, supplementation with trace mineralized salt, or a mineral supplement containing trace minerals is recommended.

Cobalt may also be lacking but is normally contained in trace mineral salt and mineral mixtures.

Selenium in some corn silage is too low in content to meet animal requirements. Since the element is toxic at fairly low concentrations, it is not approved as a feed additive. Linseed meal and western wheat bran are fairly good sources of selenium and may be substituted for part of the soybean meal or other protein supplements when selenium is required.

Injectable selenium-Vitamin E is available through veterinarians and has been effective in reducing the incidence of retained placentas in some situations. The injected rate was 50 mg selenium and 600 IU vitamin E, 3 weeks before calving.

Rations for Dry Cows

Corn silage can be fed as a major part of the ration for dry cows when properly balanced with protein, minerals and vitamins. In general, a ration of 10 lb reasonably good quality alfalfa hay and 30 to 40 lb corn silage provides adequate energy, protein and minerals.

Dry cow rations should contain 10 to 12% protein, about 0.3 to 0.4% calcium and 0.3% phosphorus.

Trace-mineralized salt may be fed free-choice or limited to 1 or 2 oz per head daily.

If low-quality grass hay or cereal straw is fed as part of the ration, additional protein may be required.

Allowing free-choice corn silage may result in dry cows becoming excessively fat and increase problems at calving.

Rations for Growing Dairy Cattle

Good-quality corn silage is an excellent feed for growing young cattle when properly supplemented with protein, minerals and vitamins A and D.

Corn silage has been fed as the only source of forage from 2 months of age through calving with good results when properly balanced. Growth rates and daily gains are shown in Table 9. Concentrate mixes

Table 9—Feeding programs for dairy heifers fed all corn silage, or 60% corn silage and 40% alfalfa (dry basis).

Period	Forage program: Corn silage 100% / Alfalfa 0	Forage program: Corn silage 60% / Alfalfa 40%	Total feed: Corn silage (CS)	Total feed: CS & hay
Birth thru 4 months (90—250 lb body wt)			lb	lb
Milk (6—8 weeks)	8–10% body weight			200—300
Starter	Free choice up to 5 lb/head/day			300
Forage	------ free choice ------			100 (DM)
5th thru 8th month (250—490 lb body wt)				
Corn silage, 34% DM, lb	17.0	10.0	2,040	1,200
Corn silage DM, lb	5.6	3.4	—	—
Alfalfa DM, lb		2.7 (3 lb hay, 90% DM)	—	360
Concentrate mix #1	1.1	—	132	—
Concentrate mix #2	—	4.4	—	530
Shelled corn	3.3	—	400	—
9th thru 12th month (490—700 lb body wt)				
Corn silage, 34% DM, lb	35.0	21.0	4,200	2,520
Corn silage DM, lb	11.5	7.0		
Alfalfa DM, lb		4.5	—	600
Concentrate mix #1	1.1		132	—
Concentrate mix #2		3.3		
Shelled corn	—		—	400
13th thru 18th month (700—1,000 lb body wt)				
Corn silage, 34% DM, lb	45.0	28.0	8,100	5,040
Corn silage DM, lb	15.4	9.3	—	—
Alfalfa DM, lb	—	6.2	—	1,160
Concentrate mix #1, lb	1.1		200	—
Mineral-vitamin mix*		free choice		
19th thru 24th month (1,000—1,100 lb body wt)				
Corn silage, 34% DM, lb	50.0	30.0	9,000	5,400
Corn silage DM, lb	17.0	10.8		
Alfalfa	—	6.2	—	1,160
Concentrate mix #1	1.1		200	—
Mineral-vitamin mix	—	0.1	—	18

*Mineral-Vitamin Mix—50% defluorinated dicalcium phosphate, 45% TM, salt, 5% vitamin supplement (1 mill IU vitamin A, and 250,000 IU vitamin D per lb vitamin supplement).

Table 10—Concentrate mixes.

Content	Concentrate Mix #1 corn silage only forage	Concentrate Mix #2
	%	%
Soybean meal (50%)	89.5	17.0
Shelled corn		80.0
Dicalcium phosphate (defluorinated)	4.0	1.1
Limestone	1.5	—
Trace mineral salt	4.0	1.5
Vitamin A, D premix*	1.0	0.4

*Vitamin Premix provides 1 million IU vitamin A and 250,000 IU vitamin D per pound.

Table 11—Growth of dairy heifers fed all-corn silage vs. 40% hay silage or hay.*

	Corn silage	C.S.—60% H.S.—40%	C.S.—60% Hay—40%
Body weight (lb)			
Initial	94	87	91
4 mos	250	245	244
12 mos	734	710	711
18 mos	1,022	979	980
Heifer daily weight gains fed all silage or hay forage			
Daily gain (lb)			
0-4 mos	1.36	1.41	1.39
4-12 mos	1.89	1.85	1.83
12-18 mos	1.69	1.61	1.61

*No significant differences (Guelph, 1976).

given in Table 10, and heifer growth on all-corn compared with other rations is shown in Table 11.

Rations containing 12 to 13% crude protein (dry basis) are suggested for calves from 200- to 600-lb body weight (about 10 mo of age). Thereafter, a 10% protein ration is adequate. In general, 1 lb of 44% protein daily added to an all corn silage ration will provide adequate protein for young cattle of all ages.

A mineral supplement containing 2 parts calcium to 1 part phosphorus is suggested to cover those silages that are abnormally low in calcium and phosphorus content. A mixture of 2 parts limestone, 1 part defluorinated dicalcium phosphate, and 1 part trace-mineralized salt will usually be satisfactory.

Alfalfa (16% protein) substituted for 25 to 30% of the corn silage ration dry matter will provide sufficient energy, protein, calcium and phosphorus for growing young cattle over 10 months of age. Salt should be available at all times.

Green, immature corn silage is high in carotene and vitamin E, but deficient in vitamin D. Mature corn silage with some brown leaves and tassles is a fair source of vitamin D.

Insurance against vitamin A and D deficiency can be met by providing 1,500 to 3,000 IU vitamin A and 400 to 600 IU vitamin D per 100 lb of body weight daily.

Rations utilizing corn silage or combinations of 60% corn silage dry matter and 40% hay silage (HS) or hay, have been demonstrated to produce comparable growth of dairy heifers.

The amount of grain ration required to maintain normal growth of dairy heifers will vary with the energy value of the forages. With good quality forages, grain will not be required, other than the 1 lb of protein-mineral supplement for all corn silage, after the cattle reach 660 lb body weight, or about 10 months of age.

corn silage for feedlot cattle

BY DAN G. FOX[6]
Department of Animal Husbandry

A NUMBER OF FACTORS need to be considered in optimizing use of corn silage in beef cattle rations. These include the most profitable level, the expected performance and amounts required with various levels of grain feeding and silage qualities and protein supplementation.

The level of silage that will be the most profitable to feed will depend primarily on the price of corn, protein supplement prices, intensity of feedlot utilization and non-feed costs. A detailed discussion of the profitability of various levels of silage feeding can be obtained from AH-BC-7620, "Influence of Feeding System on the Energetic and Economic Efficiency of Grain in Growing and Finishing Cattle."[7]

Table 12 summarizes expected performance and feed requirements for various silage qualities and grain feeding. These values assume that the ration is properly balanced for protein and minerals at each stage of growth (see Fact Sheets 1204A and 1204B).[7] It is also assumed that a growth stimulant and rumensin are used and the cattle are fed in a stress-free environment. Shelled corn was assumed to contain 32% moisture, and corn silage is assumed to contain 68% moisture. Performance is given for average-frame cattle. Feed requirements per cwt gain will be similar for other frame sizes of cattle fed over similar stages of growth.

The pay-to-pay daily gains and feed requirements assume that 18 days are required to regain purchase weight, and tissue shrink at sale is 0.5%. The feed requirements include provision for a 2% death loss with calves and 1% with yearlings.

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[6]*Now at Cornell University, Ithaca, N.Y.*

[7]*This reference and Fact Sheets 1204C and 1097 are available from the Department of Animal Husbandry, 102 Anthony Hall, MSU, E. Lansing, MI. 48824.*

See the footnotes to Table 12 and Fact Sheet 1097 for details on adjusting for other conditions.

Protein Supplementation

Detailed recommendations of proper protein supplementation and NPN treatment are given in Fact Sheets 1204A, 1204B and 1204C. Due to the complexity of proper and least-cost protein supplementation of corn silage, these Fact Sheets should be carefully studied to determine the best system of providing supplemental protein and minerals to cattle fed corn silage.

Table 12 — Expected average payweight to payweight daily gain and feed requirements per 100 lb gain for corn-corn silage rations*

Gain and feed	Corn silage quality (bu #2 corn per ton 32% DM silage)								
	6.7			5.4			3.5		
	Added corn†			Added corn†			Added corn†		
	0	0.8	1.6	0	0.8	1.6	0	0.8	1.6
Steer calf									
Daily gain lb	1.90	2.19	2.49	1.75	2.06	2.43	1.46	1.85	2.27
Shelled corn lb	0	228	452	0	242	466	0	271	498
Corn silage tons	1.16	.757	.388	1.26	.802	.399	1.53	.899	.426
Soybean meal lb	39.3	29.3	21.0	42.1	31.0	21.7	50.3	34.0	22.8
Urea lb	6.50	7.17	7.17	7.17	7.67	7.33	8.67	8.50	7.83
Yearling steer									
Daily gain lb	2.09	2.38	2.68	1.95	2.25	2.62	1.65	2.04	2.46
Shelled corn lb	0	285	523	0	303	541	0	333	577
Corn silage tons	1.32	.860	.460	1.43	.912	.472	1.70	1.01	.503
Soybean meal lb	1.55	1.56	0	167	1.56	0	194	1.78	0
Urea lb	8.67	9.55	8.44	9.33	10.2	8.67	11.1	11.1	9.11
Heifer calf									
Daily gain lb	1.61	1.85	2.11	1.48	1.74	2.05	1.23	1.56	1.92
Shelled corn lb	0	239	464	0	254	478	0	285	512
Corn silage tons	1.20	.781	.400	1.30	.826	.412	1.58	.926	.422
Soybean meal lb	34.2	24.4	17.6	36.7	25.3	17.8	43.1	27.6	18.7
Urea lb	6.89	7.55	7.11	7.56	8.00	7.33	9.33	9.11	8.00
Yearling heifer									
Daily gain lb	1.78	2.03	2.29	1.65	1.92	2.24	1.40	1.74	2.10
Shelled corn lb	0	284	524	0	301	537	0	333	573
Corn silage tons	1.32	.856	.458	1.43	.909	.470	1.70	1.01	.501
Soybean meal lb	1.48	1.32	0	157	1.58	0	183	1.58	0
Urea lb	8.68	9.47	8.16	9.21	10.0	8.42	11.1	11.1	8.95

*The values given in this table assume the following conditions:

a. 18 days required to recover shipping shrink. Feed requirements include provisions for a 2% death loss in calves and 1% death loss in yearlings.

b. A growth stimulant was used. Decrease daily gain 12% if a growth stimulant not fed or an implant is not given every 100 days.

c. Rumensin was fed. Increase feed requirements 10% if rumensin not fed.

d. A stress-free environment was used. Decrease daily gain 5-8% and increase feed requirements 8-12% for cemented outside lots or well-drained outside dirt lots.

e. These cattle are assumed to be average-frame British breed. Increase daily gain 6% for British x Exotic cross and 12% for large-frame exotic breeds, but use same feed requirements per 100 lb gain. Increase daily gain 21% but also increase feed requirements 10% per lb gain for Holsteins fed to low choice grade.

†Lb 32% moisture shelled corn per 100 lb body weight daily.

corn silage for beef cow herds

BY HARLAN D. RITCHIE
Department of Animal Husbandry

CORN SILAGE AS A FEED for beef cow herds has the following general characteristics:

1. It is fed to cows primarily for its energy content, not for protein, minerals or vitamins.
2. Because of its relatively high energy value, it must usually be limit-fed to mature, dry beef cows. If not, they will become too fat, and the cost of wintering them will be too expensive.
3. The energy content of corn silage is ideal for developing young stock and for meeting the needs of lactating cows.
4. Crude protein content is considered marginal for the mature, dry cow and inadequate for other classes and ages of beef cattle.
5. Corn silage is variable in its content of calcium, phosphorus and certain other minerals. Therefore, it should not be considered a dependable source of mineral elements.
6. High-quality, properly stored corn silage is relatively high in vitamin A activity. However, low-quality, poorly fermented corn silage is not a dependable source of vitamin A for cow herds.

Abundant evidence shows that no other crop rivals corn silage in energy yield per acre on fertile land that is well adapted to corn production. Therefore, in southern lower Michigan and other Corn Belt states, corn silage is a viable option as a feed for beef cow herds if the machinery and facilities for growing, harvesting, storing and feeding it are already an integral part of the overall farm enterprise. However, starting from scratch and making an initial investment of this magnitude for the sole purpose of feeding silage to a beef cow herd is highly questionable unless part or all of the following conditions are met:

1. The cow herd should be well above average in size. In the United States, average herd size is under 50 cows.
2. The land and growing season should be adapted to generating high corn silage yields.
3. Cattle prices should be on the rising side of the beef cycle so that opportunity exists for recovering the initial investment in a reasonable period of time.
4. The genetic make-up of the herd should be of a kind that can make maximum use of a high-energy feed such as corn silage.
5. Feeding out the calf crop should be considered as a possible marketing alternative.
6. Purebred herds must usually be kept in better condition than commercial herds, which makes a corn silage program more feasible for them.
7. Treating the silage with an NPN compound should be considered as a means of reducing supplemental protein costs, especially in those years when soybean meal is high-priced.

In many areas of the country, beef cows are kept on less valuable land that is marginal in its ability to produce anything but grass for ruminants. Gearing up for corn silage production in such areas is either impossible, or impractical at best. In other regions, such as northern Michigan, the growing season is short, which makes corn production risky. However, recent development of higher-yielding, early-maturing hybrids may make corn silage more feasible in such areas.

The following paragraphs discuss the nutrient requirements of various classes of beef cattle and present corn silage-based rations to meet these requirements. In all cases, a salt-mineral mix should be provided on a free-choice basis so as to make up for the mineral deficiencies in corn silage. If silage quality is low, supplemental vitamin A should either be fed or injected. Vitamin A injections last for 90 to 100 days. From 1 to 3 million IU should be injected intramuscularly. If you are in doubt about the nutrient content of your silage, contact your county extension office about submitting a sample for analysis.

1,100-lb Mature Dry Pregnant Cow

Mid-Pregnancy

Most beef cows in the Northern states calve in late winter or spring, from approximately Feb. 15 to May 15, although a few herds drop their calves as early as January. This generally means that beef cows are bred in May, June and July. Their calves are weaned in the fall, and mid-pregnancy coincides with the early part of the winter feeding period—November, December, January. During this time, the nutrient requirements of the breeding herd reach their low point. The average mature cow in good condition simply needs to maintain her weight, and the fat cow can even lose some weight. The thin cow, however, should gain some weight. The following minimum daily allowances will maintain the weight of an 1,100-lb, mature, pregnant cow in average condition:

— TDN (total digestible nutrients): 8.6 lb

— Crude protein: 1.0 lb

— Calcium: 13 g

— Phosphorus: 13 g

— Vitamin A: 20,000 IU

A daily corn silage dry matter (DM) intake of 12.3 lb will provide approximately 8.6 lb of TDN (assuming a TDN value of 70% for high quality corn silage). If the silage averages 30% DM, daily allowance of fresh silage should be 41 lb; for 35% DM silage, 35 lb; for 40% DM silage, 31 lb.

If the 12.3 lb of corn silage DM averages 8% in crude protein (CP), daily intake of CP will be 0.98 lb, which barely meets the requirement. If the silage analyzes significantly lower than 8%, some form of supplemental CP should be provided.

Normally, 12.3 lb of corn silage DM will provide at least 15 g calcium and 13 g phosphorus, which meets the requirements listed above. However, as mentioned before, a calcium-phosphorus source such as bonemeal or dicalcium phosphate should be offered free-choice so as to be absolutely safe.

Unless the corn silage is of poor quality, it will meet the vitamin A requirement of 20,000 IU per day.

Late Pregnancy

During the last 60 to 90 days of pregnancy, the brood cow should be on a slightly rising plane of nutrition. The minimum daily requirements for the 1,100 lb cow in average condition during late pregnancy are:

— TDN: 10.0 lb

— Crude protein: 1.1 lb

— Calcium: 15 g

— Phosphorus: 15 g

— Vitamin A: 24,000 IU

To meet her energy requirements, 14.3 lb of corn silage DM should be fed. Fresh silage intake would be 48 lb for 30% DM silage, 41 lb for 35% DM, or 36 lb for 40% DM silage.

An allowance of 14.3 lb of corn silage DM would supply about 1.15 lb crude protein, 18 g calcium and 15 g phosphorus, which would barely meet the cow's requirements for these nutrients.

Coming 2-Year-Old Pregnant Heifers

The nutrition of the 2-year-old heifer is critical because she is still growing while developing a fetus and undergoing the stress of her first lactation. She should be fed to gain about 1.0 lb per day during the last 120 days of pregnancy. Her minimum daily nutrient requirements are as follows:

— TDN: 9.6 lb

— Crude protein: 1.6 lb

— Calcium: 17 g

— Phosphorus: 17 g

— Vitamin A: 23,000 IU

The following levels of corn silage will meet the pregnant heifer's minimum daily TDN requirement: 46 lb at 30% DM, 39 lb at 35% DM, or 35 lb at 40% DM. These silage levels will furnish approximately 13.7 lb of dry matter, which will in turn provide 9.6 lb of TDN, if one assumes a TDN level of 70% in the silage dry matter. This amount of silage dry matter will provide about 1.1 lb crude protein, 17 g calcium, and 14 g phosphorus. Therefore, 0.5 lb of supplemental crude protein must be fed daily. This would be equivalent to slightly over 1.0 lb of 44% CP soybean meal or 4 lb of 12% CP mixed legume-grass hay.

Weaned Heifer Calves

Heifer calves wintered for their first time should gain 1.0 to 1.5 lb per day from weaning in the fall until they go to the breeding pasture the following spring. An average of 1.25 lb per day is a reasonable goal. This rate of development should permit them to be bred at 14 to 15 mo so that they will calve for the first time at 2 years. Large-framed, later-maturing, exotic crossbred heifers should probably gain closer to 1.5 lb per day. The minimum daily requirements for wintering the heifer calf are as follows:

— TDN: 8.9 lb

— Crude protein: 1.5 lb

— Calcium: 15 g

— Phosphorus: 14 g

— Vitamin A: 14,000 IU

A level of 12.7 lb of corn silage dry matter will be needed to meet her TDN needs. This would be equivalent to the following daily allowances: 42 lb at 30% DM, 36 lb at 35% DM, or 32 lb at 40% DM. This level of corn silage dry matter will furnish approximately 1.0 lb crude protein, 16 g calcium and 13 g phosphorus. This falls 0.5 lb short of the crude protein requirement, which would be equivalent to about 1.1 lb of soybean meal. As with all other age groups of cattle, a salt-mineral mix should be offered free-choice and supplemental vitamin A provided if silage quality is questionable.

1,100-lb Lactating Cow

Average Milking Ability

After her calf is born, the cow's nutrient requirements are significantly increased. An average British cow (Angus, Hereford, etc.) will produce about 10 to 14 lb of milk in early lactation. In order for the average 1,100-lb cow to produce this level of milk and get back in shape for the breeding season, the following minimum daily requirements must be met:

— TDN: 12 lb

— Crude protein: 2.0 lb

— Calcium: 27 g

— Phosphorus: 27 g

— Vitamin A: 24,000 IU

To meet her TDN requirement, she will need 17.1 lb of corn silage dry matter. This can be provided by the following levels of intake: 57 lb at 30% DM, 49 lb at 35% DM, or 43 lb at 40% DM. This level of dry matter intake will furnish about 1.35 lb crude protein, 22 g calcium, and 18 g phosphorus. The crude protein level falls 0.65 lb short of her requirement, which is equivalent to about 1½ lb of soybean meal or 5½ lb of 12% CP mixed hay.

Heavy Milker

If the cow is an above average milker, she should receive the following minimum requirements:

— TDN: 15 lb

— Crude protein: 2.8 lb

— Calcium: 46 g

— Phosphorus: 43 g

— Vitamin A: 38,000 IU

This cow needs 21.4 lb of corn silage dry matter to meet her TDN requirement. This is provided by the following silage levels: 71 lb at 30% DM, 61 lb at 35% DM, or 54 lb at 40% DM. An intake of 21.4 lb silage DM will furnish approximately 1.7 crude protein, 27 g calcium, and 22 g phosphorus. This falls 1.1 lb short of her crude protein requirement, which could be met by supplementing with 2½ lb soybean meal equivalent or 9 lb 12% CP mixed hay. It is also very important to provide a salt-mineral mix at all times, because the lactating cow's mineral requirements are 2- to 3-fold those of the dry cow.

Herd Sires

Mature

In order to get back in shape for the coming breeding season, the mature herd sire requires the following:

— TDN: 15 lb

— Crude protein: 2.3 lb

— Calcium: 22 g

— Phosphorus: 22 g

— Vitamin A: 48,000 IU

His energy requirements are about the same as those of a heavy milking lactating cow, and can be met by feeding 17.1 lb of corn silage DM. The levels of fresh silage needed to provide this much dry matter were listed above for the lactating cow. A silage DM intake of 17.1 lb falls 0.6 lb short of the mature bull's crude protein requirement. This is equivalent to 1.4 lb syobean meal or 5 lb mixed hay.

Yearlings and 2-Year-Olds

Because he is still growing and developing, the young bull's nutrient requirements are higher than those of the mature bull even though he is smaller in body size. They are as follows:

— TDN: 17 lb

— Crude protein: 2.8 lb

— Calcium: 23 g

— Phosphorus: 23 g

— Vitamin A: 50,000 IU

A corn silage DM intake of 24.3 lb is needed to meet the young bull's TDN requirement. The levels of fresh corn silage that will provide this much dry matter are: 81 lb at 30% DM, 69 lb at 35% DM, or 61 lb at 40% DM. A silage dry matter intake of 24.3 lb will provide 1.9 lb crude protein, 30 g calcium, and 25 g phosphorus. Therefore, 0.9 lb supplemental crude protein is needed. This would be equivalent to about 2.0 lb soybean meal or 7½ lb mixed hay. However, it is not possible to meet the young sire's protein deficiency with this level of hay because his maximum daily dry matter intake capacity is normally about 28 lb.

Corn Silage Budget for a 100-Cow Beef Herd

Table 13 is an estimated feed budget for wintering a 100-cow beef herd on a corn silage-based diet. In developing this budget, the following assumptions are made: (1) a total winter feeding period of 180 days; (2) the herd is lactating during the last 60 days of the winter feeding period; (3) half of the cows are average milkers, half are heavy milkers; (4) 25 open yearlings are kept as herd replacements; (5) the pregnant herd consists of 80 mature cows and 20 coming 2-year-olds; (6) average consumption of a free-choice salt-mineral mix is assumed to be 0.15 lb per head per day.

As shown in Table 13, it takes about 5.8 tons of corn silage per cow unit to winter a herd of 100 producing cows, 25 yearling replacement heifters and 4 herd sires for 180 days. In addition, it takes about 200 lb of soybean meal equivalent and 35 lb of a salt-mineral mix. Assuming the herd goes to pasture for

Table 13 — Winter feed budget for a 100-cow beef herd using corn silage as the energy source.

			30% DM corn silage			Soybean meal equivalent			Salt-mineral mix	
Class of cattle	Head	Days	Per head per day	Herd total for winter	Total per cow unit	Per head per day	Herd total for winter	Total per cow unit	Herd total for winter	Total per cow unit
	No.	No.	lb	ton	ton	lb	lb	lb	lb	lb
Pregnant mature cows	80	120	45	216.0	2.16	—	—	—	1,440	14.4
Lactating mature cows	80	60	65	156.0	1.56	2.0	9,600	96.0	720	7.2
Pregnant 2-yr old heifers	20	120	45	54.0	0.54	1.1	2,640	26.4	360	3.6
Lactating 2-yr old heifers	20	60	65	39.0	0.39	2.0	2,400	24.0	180	1.8
Open yrlg. heifers	25	180	40	90.0	0.90	1.1	4,950	49.5	675	6.8
Mature herd sires	3	180	70	18.9	0.19	1.4	756	7.6	81	0.8
Young herd sire	1	180	80	7.2	0.07	2.0	360	3.6	27	0.3
TOTAL	—	—	—	581.1	5.81	—	20,706	207.1	3,483	34.9

the remaining months, it would take an additional 3,580 lb of salt-mineral mix or about 36 lb per producing cow to maintain the entire herd for one year.

NPN as Supplemental Crude Protein

Non-protein nitrogen (NPN) compounds such as urea, ammonia, etc., are usually more economical sources of crude protein than natural sources such as soybean meal. NPN is particularly well utilized on corn silage-based diets. Therefore, treating the silage with NPN or feeding a supplement formulated with NPN as the major contributor of crude protein is often recommended.

When treating silage with NPN, be sure to apply the correct amount. If in doubt, submit several representative samples of treated silage for crude protein analysis to be certain that the desired level of treatment was attained. Generally, the silage should be treated so that the dry matter contains at least 10.5% crude protein.

Free-choice lick tank supplements are a convenient and popular means of supplementing cow herds. However, overconsumption is sometimes a problem, which can result in undue expense. Therefore, watch lick tanks closely for signs of overconsumption. Place them well away from the water source.

Effect of Cold Stress

The nutrient requirements and feed allowances presented above are valid for environmental temperatures that fall within the normal comfort zone for cattle of 30° to 80° F. When the wind chill factor falls below 30°F, energy requirements increase accordingly. Extremely low temperatures combined with wind can increase winter feed requirements by 20 to 60%. As a rule of thumb, every 10° drop in wind chill factor below 30° F increases the daily TDN requirement by about 13%. One or two days of cold stress are little cause for concern, but during extended periods of cold winter weather, the corn silage allowances listed previously should be increased by at least 20%. Thin cattle and those with sparse haircoats require even more energy than fleshy cattle to maintain their body weight in cold weather.

Other Considerations

How to Feed Silage

Although some producers feed corn silage on the ground, it is generally not advisable because of the wastage and because it is difficult for the cattle to avoid consuming manure and other filth, especially if the silage is limit-fed. Ideally, silage should be fed in bunks or through a feeding fence placed at the end of a bunker silo. A feeding fence has the advantage of saving labor but the disadvantage of being difficult to effectively control consumption. A 14-foot portable bunk may be constructed from 2-inch lumber at a cost of approximately $125. A 100-cow herd would require approximately 10 of these bunks in order to have enough feeding space for all cows, heifers and bulls. Mature cattle need about 30 in.; yearlings, 24 in.; and calves, 18 in. of linear bunk space per head if they are to eat all at one time. For plans on constructing bunks, consult the Beef Housing and Equipment Handbook (MWPS-6), which may be purchased through your county extension office.

For good nutritional management, divide the herd into the following groups: (1) open yearling heifers; (2) 2-year-olds, thin 3-year-olds and old thin cows; (3) the remainder of the pregnant herd; (4) herd sires.

Problems in Feeding Corn Silage

Overfeeding is often encountered when corn silage is fed to mature dry cows. A level of 40 to 50 lb does not fill them up. Consequently, they tend to act restless and dissatisfied, and there is a natural tendency on the part of producers to feed them more than is needed. As a result, the cows may become too fat, which is not only wasteful of feed but can also lead to calving difficulty and fertility problems.

Some cattlemen believe that feeding corn silage lowers the fertility of a cow herd. There is no research evidence to support this belief when the silage is fed at proper levels. However, overfeeding can be detrimental, as mentioned above.

Corn Residue Silage

In recent years, there has been considerable interest in making silage out of corn residue, which consists of the stalks, leaves, husks, cobs, etc. after the grain has been harvested. The ensiled material is often referred to as "stalklage" or "stover silage." For best results, the following harvesting and storage procedures should be adhered to:

1. Harvest as soon as possible after grain harvest; within 2 to 3 days if possible.
2. Harvest early in season to maximize nutrient recovery.
3. Maintain moisture above 60%. Add water if necessary.
4. Chop fine. Equip forage harvester with a recutter screen or put a recutter attachment on the blower.
5. Pack well and cover silo to reduce storage losses.

Expected dry matter yields per acre may vary from 2.0 to 3.0 tons in a good corn year and from 0.5 to 2.0 tons per acre in a poor year. Over several years' time, you can expect to average about 2 tons of dry matter per acre. At 65% moisture, this would be 5.7 tons of "as fed" stalklage per acre.

There are three primary ways to harvest corn residue silage: (1) forage harvester with a flail pickup; (2) the "Foster" attachment for collecting husklage from the rear of a corn combine, leaving the stalks *per se* in the field; (3) the "John Deere Stalker," a row-crop attachment for forage harvesters, designed to follow after grain harvest and more efficiently gather the remaining residue.

If stover silage is properly harvested immediately following grain harvest, dry matter intake, dry matter digestibility, crude protein, calcium and phosphorus are usually higher than is the case with dry stover stacks. Daily dry matter intake for a mature cow will generally average at least 15 lb per day and may go as high as 20 lb, depending upon the palatability of the stover silage. Estimated TDN will range from 45 to 50% on a dry matter basis. Percent of crude protein, calcium and phosphorus are approximately 5.3%, 0.44% and 0.14%, respectively, on a dry matter basis.

Because of its relatively low energy content, use of residue silage should normally be restricted to the mature dry pregnant cow. It is not recommended as the primary feedstuff for young cattle or for lactating cows unless it is fed in combination with corn or other grain. Systems for supplementing corn stover silage are presented in Table 14 which assumes a daily dry matter consumption of 15 lb for an 1,100-lb dry cow. At this level of consumption, there is need for supplemental TDN, protein, phosphorus and Vitamin A. Lick tank supplements based on urea, molasses and minerals are also a possibility; however, they should be monitored to make certain that there is neither under nor overconsumption.

Table 14 — Supplementing corn stover silage for 1,100-lb dry cow.

Ration requirement	TDN lb	CP lb	Ca g	P g	Vit A IU
Required by cow daily	8.6	1.0	13	13	20,000
Supplied by 15 lb silage DM*	7.5	0.8	30	9.5	0
Daily deficit	1.1	0.2	—	3.5	20,000
Possible supplements:†					
(1) 2 lb mixed hay	1.0	0.22	7	2.2	10,000
(2) 1.5 lb corn + .25 lb soy	1.3	0.23	1	3.0	1,000
(3) 1 lb hay + 1 lb corn	1.3	0.20	3	2.6	5,700

*Assuming 45% TDN, 5.3% CP, 0.44% Ca, and 0.14% P in dry matter.
†Phosphorus and vitamin A should be furnished when supplements are inadequate.

supplemented corn silage for sheep

BY STEVE BAERTSCHE
Department of Animal Husbandry

THE USE OF CORN SILAGE in the diet of pregnant and lactating ewes has proven to be very successful. Corn silage can be harvested and fed, using labor-saving equipment, and it can provide more digestible energy per acre of land than any other Michigan grain crop.

Both past and present research by Dr. Charles Parker at the Ohio Agricultural Research Center demonstrates that ewes fed properly supplemented corn silage will perform as well as those fed mixed legume hay and grain.

The Ohio work shows that **fine-chopped** corn silage, when supplemented correctly, will provide ewes in late gestation and lactation with all of the nutrients required.

Best results were shown from supplementing **1 ton of fine-chopped** silage with:

20 lb urea
10 lb limestone
4 lb dicalcium phosphate
1 lb sulfur (which can be provided by adding 5 lb per ton of *Dyna-Mate*, 22%, at time of ensiling or 5 lb per ton of sodium sulfate at feeding time)

You can expect ewes to consume 12 to 15 lb silage on an as-fed basis.

Finishing Lambs

In most previous studies at several midwestern universities, all corn silage diets have not produced desirable gains in finishing lambs. It has been recently shown in lamb feeding trials at the Ohio Research Center, that with supplemental protein added, increased gains and feed efficiency have been obtained from corn silage.

However, another problem in feeding a high percent of corn silage in the lamb finishing ration has been the fact that lambs do not consume sufficient dry matter to meet their daily requirement. Current research is studying various calcium and protein supplementation levels to both maximize intake and digestibility of the ration.

Ohio researchers have found that lambs consuming 73% corn silage DM in their diet gained 0.42 lb per head daily compared with 0.59 lb per head daily for those consuming 39% of corn silage DM in their diet. In this study, they found gains and feed efficiency of the lambs have been improved over previous corn silage feeding experiments. Their results indicate that further studies should be carried out to look at various levels of corn silage feeding and their supplementation with both protein and minerals.

Listeriosis — No Problem

Experience at the Ohio Research Center and by sheep producers with **treated** corn silage has been satisfactory with no significant problems of listeriosis. Research data and experience in Ohio suggest that the additive package affects the fermentation process in such a way that the live *Listeria monacytogenes* organism does not survive in sufficient numbers to cause the disease. Problems of listeriosis are observed more often in sheep flocks being fed **untreated** corn silage. Because of this effect upon the listeria organisms, the silage additive package (20 lb urea, 10 lb limestone, 4 lb dicalcium phosphate, and 1 lb sulfur) should be placed into the silo at *filling time* rather than at feeding time.

production of corn for silage

BY M. H. ERDMANN AND S. C. HILDEBRAND[8]
Department of Crop and Soil Sciences

SEVERAL PRODUCTION PRACTICES, in combination, contribute to high yields of high-quality silage corn. These include: selection of high-yielding hybrids of proper maturity, good soil fertility, proper plant population, planting at the right time, effective weed control and control of damaging insects. Failure to consider any of these practices will result in less than optimum yield.

Soil Fertility and Fertilization

Because almost all the plant is removed from the field in corn silage production, fertilizer requirements for silage are different from those for grain corn. Under a continuous corn-for-grain program, the stalks and leaves return nutrients to the soil, serve to maintain soil tilth and water-holding capacity and furnish food for soil organisms. When corn for silage is grown continuously, the benefits above are not attained.

If corn for silage is grown continuously, heavy applications of manure should be applied and a rye or ryegrass winter cover crop grown in order to help maintain soil productivity.

Heavy manure applications serve to reduce nitrogen, phosphorus and potassium needs from commercial fertilizer, as well as help maintain soil organic matter.

Because silage corn is grown on many different soils and in many different cropping systems, the fertilization program will vary considerably from field to field and farm to farm. Commercial fertilizer applications should be based on soil test, crop history, manuring program, and yield goal. More potassium is required for silage corn than for corn grown for grain. Consult MSU Extension Bulletin 550, "Fertilizer Recommenda-

[8]*Senior author of the original 1969 edition, deceased Aug. 18, 1975.*

tions for Vegetable and Field Crops in Michigan," for specific information.

Types of Hybrids

The best **single cross** and **3-way hybrids** have the genetic potential for higher grain yields when fertility, weather, moisture and management factors are at the optimum.

The best **double cross hybrids** may do as well as other hybrids if maximum dry weight is the major objective.

A **silage blend** is usually a mixture of leftover grades and hybrids and may not be the same mixture each year. Blends usually do not yield as well as the best hybrid in the blend.

Sweet dent and **high-sugar hybrids** have been compared with normal dent hybrids in several studies. The normal dent produced 10 to 15% more total digestible nutrients (TDN) per acre.

Feeding trials with **brown midrib high lysine** and waxy corns have given inconsistent results.

Hybrid Selection

High dry-weight production per acre—rather than tons of green weight—should be the criterion for selecting hybrids for silage. Another important factor to consider in selecting hybrids for silage is the grain yield, as the best quality silage contains a high percentage of grain.

Corn hybrids vary considerably in their yielding ability. In silage yields at six locations in Michigan in 1975, the various hybrids differed markedly in dry weight, green weight and grain yield. The following summary (Table 15) was taken from the 1975 Ingham County Silage trial, which included 108 hybrids.

In terms of grain yield, 330 hybrids were tested at 17 locations in 1975. The average grain yield for all hybrids was 129.9 bu per acre; the highest yielding group of hybrids averaged 160.1 bu per acre; the lowest group averaged 93.9 bu per acre.

In most instances, hybrids that produce high yields of grain also produce high yields of high-quality silage. For a particular locality, hybrids of similar maturity should be chosen for both grain and silage use.

A hybrid adapted for silage production must be ready for silage harvest some time prior to the average time of the first killing frost. For highest quality silage and maximum tonnage, the corn should reach physiological maturity, or nearly so (about hard dent stage), and be harvested before a killing frost. The period of time needed to allow for silage-making before this frost depends on the acreage of corn, equipment available for harvest and operating crews. See section on harvesting equipment for details.

One can forecast silage harvest time by noting the silking date of each field. On a calendar, note the dates your fields of corn are 50% in silk. Corn will be physiologically mature (maximum dry weight) 50 to 55 days after silking. This period is reasonably uniform for all hybrids and does not vary much from one year to another. Therefore, one should be ready to harvest silage 50 days after silking.

Current information comparing yield and maturity of corn hybrids for grain and silage is published annually in MSU Extension Bulletin 431, *Corn Hybrids Compared*. Well-managed, unbiased tests (as reported in Bulletin 431) are the best basis for selecting hybrids.

Planting Date

Early planting is important whether corn is harvested for silage or grain. Research at Michigan State University shows that for each day of delay in corn planting in southern Michigan, after May 1 to 10, there is an average loss of one bushel of grain per acre. In silage trials, early-planted corn gave the highest silage yields as well as higher quality silage (percent grain in the silage). With early planting, two factors contributed to the higher percentage of grain in the silage: higher grain yields as well as slightly shorter corn plants. Table 16 shows the effect of planting date on both silage yield and quality.

Calendarizing Hybrids

Livestock producers growing large acreages of corn for silage find it difficult to make quality silage from the entire acreage when it is all planted to hybrids of the same maturity. The harvest season is not long enough; some silage is too wet and some too dry for optimum storage and highest quality. One solution

Table 15 — Silage and grain yields, 1975 Ingham County hybrid test.

Factor	Average for all hybrids	Low producers	High producers
Green weight, tons/acre	21.5	11.9	30.9
Dry weight, tons/acre	7.0	5.0	8.5
Grain yield, bu/acre	140.8	101.3	174.5

Table 16 — Effect of time of planting on the yield and quality of corn silage.

Planting date	Lb per acre (dry weight)			Grain (%) in silage
	Grain	Stalk	Total	
May 9	7,600	6,600	14,200	54
May 22	6,200	7,000	13,200	47
June 2	5,500	7,400	12,900	43

is to use several hybrids that differ slightly in maturity in order to spread out the harvest season and to enable harvest at the proper stage for silage. Three different hybrids, plus the normal spread in date of planting, will prove adequate for most situations. The difference in relative maturity between each hybrid might be 3 to 4 days. Plant the earliest-maturing hybrid first and the latest maturing hybrid last to provide optimum maturity range at silage harvest.

Plant Population, Row Width

Tests involving plant population have been conducted at 12 to 17 MSU Hybrid Corn Trial locations in Michigan for each of the past 7 years. A population of 19,000 plants per acre has given the highest yields, but very often only a few bushels more per acre than the 23,000 plant population. There have been only minor differences in yield from the 15,000 plants per acre population and 27,000 to 28,000 plant population, but these yields have been considerably lower than those from 19,000 plants per acre. (See Table 17.)

Rainfall generally is a limiting factor in corn production in Michigan. In irrigated trials in Cass and Montcalm countes over a period of years, a harvest population of 23,000 plants per acre has out-yielded 19,000 plants per acre by a substantial margin. The 27,000 plant-per-acre population did not yield as well in most years as the 19,000 plant population. See Table 18, for the average yields from 5 years of testing at the Montcalm Experiment Farm.

Most of the seed corn sold today is of excellent quality. However, no seed lot is perfect. In order to arrive at a desired plant population, plant extra kernels to allow for some seed mortality and loss of plants from other causes. Table 19 gives the number of seeds per acre obtained with varying spacings in the row and with different row widths. When corn is planted in late April or May 1 to 10 in southern Michigan, the number of seeds per acre should be increased by 15 to 20% in order to obtain a desired plant population. After May 15, ten percent extra seed per acre will usually give the desired plant population.

Plant population usually has a greater effect on corn yield than does row width. In a three-year trial at East Lansing with 33 hybrids at a standard population of 19,500 plants per acre, both 30-in rows and 18-in rows yielded 125 bu per acre; 36-in rows yielded 115 bu per acre.

Table 17 — Average yield in bushels per acre from four plant populations at 16 locations.

Year	Harvest population			
1975	15,400	19,200	23,200	27,500
	134.1	152.3	149.7	138.5
1976 (dry year)	15,100	19,000	23,100	27,300
	95.4	107.9	104.2	96.2

Table 18 — Yield of corn in bushels per acre at four plant populations, Montcalm Experiment Farm 1968-72.

15,000		19,200		23,100		27,200	
Irrig.	Not irrig.	Irrig.	Not irrig.	Irrig.	Not irrig.	Irrig.	Not irrig.
143	93	169	109	181	93	164	83

Table 19 — Approximate number of seeds per acre at varying row widths and spacings in the row.

Seed spacing in the row (in.)	Row width (in.) 28	30	32	36	38	40
5	44,900	41,800	39,200	34,800	33,000	31,400
6	37,300	34,800	32,700	29,000	27,500	26,100
7	31,700	29,600	27,800	24,700	23,400	22,200
8	28,000	26,100	24,500	21,800	20,600	19,600
9	24,800	23,100	21,700	19,300	18,300	17,400
10	22,400	20,900	19,600	17,400	16,500	15,700
11	20,400	19,000	17,800	15,800	15,000	14,300
12	18,700	17,400	16,300	14,500	13,800	13,100

Weed and Insect Control

Effective weed and insect control in modern day corn production involve the use of herbicides and insecticides. Herbicides are used for control of both annual and perennial weeds. Insecticides are generally required for control of corn rootworm when corn is grown continuously on the same field. Seed treatment is used to protect the germinating seed from seed corn maggot.

For current herbicide recommendations for weed control in corn, consult Extension Bulletin E-434, "Weed Control Guide for Field Crops." Cultivation may be used to supplement weed control with herbicides, but care should be used so as not to prune the roots of the corn plants.

Consult MSU Extension Bulletin E-736, "Corn Rootworm," for current recommendations for control of corn rootworm.

When to Harvest

The following are some important factors in determining the best time and practices to use in harvesting corn silage:

— Maximum dry matter (DM) per acre.

— Maximum digestibility of nutrients in the silage.

— Maximum DM stored per cubic foot of silo capacity.

— Minimum of seepage loss from the silo.

To best meet these goals, start harvesting when the kernels are in the early dent to late dent stage of maturity, and complete harvest as soon as possible. At this time, the dry matter of the corn plant is from 30 to 40%. Dry matter in the kernels will vary from 50 to 65%. Calendarizing hybrids (discussed following hybrid selection and planting date), will help to meet these objectives.

If corn silage is harvested when the dry matter is 30% or less, extensive seepage will occur, especially with silos 60 ft or taller. This results in a loss of nutrients (seepage is about 8% DM) and severe erosion of the walls and hoops of tower silos. There is also danger of the silo collapsing due to extreme pressures generated from the added weight of the material. To eliminate excessive seepage in tower silos the DM content of the silage must be above 35%.

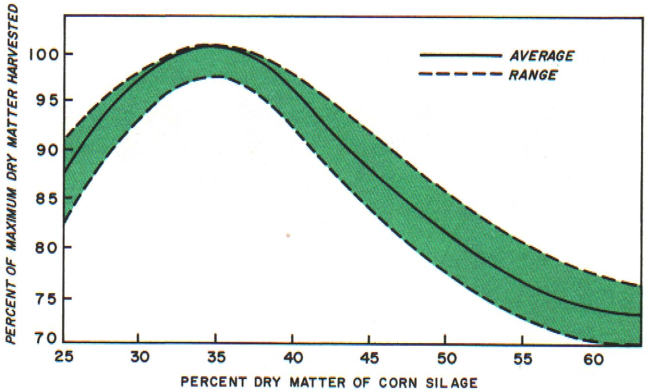

Figure 2—Effect of stage of maturity of corn silage on dry matter harvested per acre. (Summary of research conducted at Michigan, Indiana and U.S.D.A.)

In bunker silos seepage will not normally occur nor will extreme pressures be a problem with 30% DM silage. You may have to begin harvest silghtly earlier than the maximum yield stage because extra moisture in the silage is necessary to insure exclusion of air, good packing and proper fermentation.

If you wish to determine a more exact amount of dry matter or moisture in the silage before starting to ensile, a relatively accurate moisture tester to weigh, dry and reweigh the dried material is available. It requires about 30 min to run. The forage harvester must be run in the corn field to obtain a good sample of silage for the moisture test. An information sheet is available from the departments at MSU involved in the preparation of this bulletin.

Another method of telling when corn is ready for harvest is to shell kernels from several ears and take them to the elevator for a moisture test.

Effect of maturity on dry matter yield per acre — Research data from Michigan State University and other experiment stations relating stage of maturity of corn silage to dry matter yield per acre are summarized in Figure 2.

These data show that yield per acre increases until the plant reaches approximately 35% DM or until the first killing frost. It will then level off for 5 to 10 days (depending upon the extent of frost, wind and rain) and then begin declining at a rapid rate. This is due to the loss of leaves and tassels from standing stalks and the loss of the entire stalk from lodged plants.

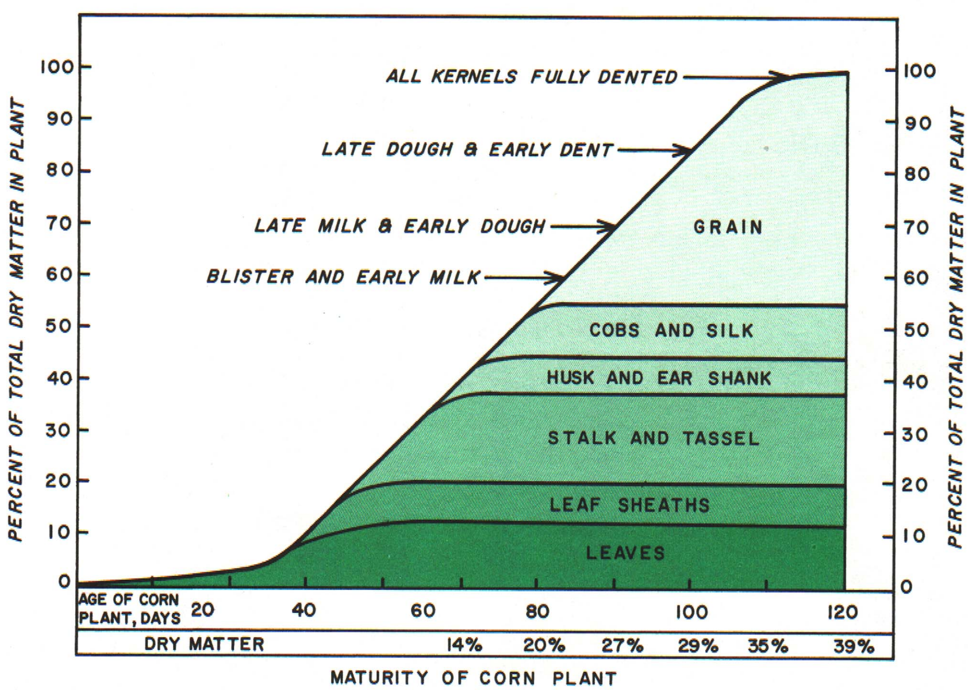

Figure 3—Effect of stage of maturity of corn silage on total dry matter accumulation. (Source: Iowa State University Special Report No. 48.)

Other aspects of harvesting corn for silage are discussed in the section on corn silage systems.

Figure 3 shows DM accumulation in the corn plant for typical 120-day corn, assuming no frost during the 120-day growing season and no loss of leaves, tassels and whole plants due to lodging.

Both Figures 2 and 3 show that there is an advantage in delaying corn silage harvest after it has reached 35% dry matter or after all kernels are in the hard dent stage of maturity.

corn silage systems-

harvesting, handling, storage, feeding

BY ROBERT L. MADDEX AND ROBERT G. WHITE
Department of Agricultural Engineering

A SYSTEM TO HANDLE SILAGE provides for the organized movement from harvest to utilization. It includes the machinery equipment, structures and methods required to move the silage from harvest to utilization.

A number of factors influence silage harvesting and handling, but the two factors that have the greatest impact on the selection of system components and methods are **total volume** and **silage flow rate.**

System Planning

While most farm operators do some planning before making a major purchase, often their purchases are made in a hurry. Time is not taken to do enough planning to insure a relative uniform silage flow of sufficient volume and with components that get the job done with reasonable labor, energy and silage loss.

Good planning takes some effort, as it requires digging out reliable information and utilizing a planning technique that relates silage flow to components of the system. Two planning tools that provide an organized planning approach are the **System Planning Guide** and the **flow diagram.** Much of the planning information needed to develop a system planning guide and a flow diagram is provided in this publication.

System Planning Guide

A system planning guide is shown in Figure 4. An example is worked out based on harvesting 1,500 tons of corn silage and information in Tables 20 and 21 using allowable harvest season of 3 weeks (21 days)

	Example	Your Farm
Harvesting		
Total tons to be harvested (estimated)	1,500	
Acres to be harvested (at 12 tons per hour)	125	
Harvest days per season (1 day out of 2)	11.5	
Hours of harvest per day	6	
Total harvest hours per season (Table 1)	63	
Flow Rate		
Tons per day	137	
Tons per hour	24	
Transport Vehicles		
Tons per vehicles	8	
Number of vehicles	3	
Unloading into Storage		
Minutes to unload transport vehicle	15	
Tons per minute	.5	
Tons per hour	30	
Unloading from Storage		
Total pounds or tons fed (50 lbs x 60 animal)	3,000	
Pounds per feeding	1,500	
Pounds or tons per minute removal from storage	200	
Removal time	7½	
Storage		
Tower silos required — size	24 ft x 60 ft 24 ft x 70 ft	
OR		
Horizontal silo (50 cu. ft per ton) — size	60 ft x 100 ft	

Figure 4—Silage system planning guide.

Table 20 — Corn silage harvesting time available in a three-week harvesting season, as affected by weather and hours per day the operator is available.

Harvesting conditions	Estimated frequency of Col. 1 harvesting conditions Yrs out of 10	Hr of corn silage harvesting time per 3-week season			
		6-hr work day	8-hr work day	10-hr work day	12-hr work day
Good weather Harvest 2 days out of 3	3 to 4	84	112	140	168
Moderate weather Harvest 1 day out of 2	5 to 6	83	84	105	126
Poor weather Harvest 1 day out of 3	7 to 8	42	56	70	84
Very poor weather Harvest 1 day out of 4	8 to 9	32	42	52	63

and moderate weather which would permit harvest 1 day out of 2. Acres required are based on an estimated yield of 12 tons per acre of 35% DM silage. Flow rates are determined by dividing the total tons by estimated harvesting days and hours. No allowance is made for Sunday's which could reduce the total possible harvest days by two or three for some farm operators. Three transport wagons are to be used in order to reduce lost field time for the harvesting unit. The size of the tower silo needed to store 1,500 tons of silage are selected from Tables 22 and 23.

The feeding rates are based on 50 dairy cows eating 60 lb of silage per day. With twice-a-day feeding, one half the silage would be unloaded for each feeding.

A planning guide is a good tool for estimating flow rates. Each farm operator must put in his own figures for total tons, working days and hours, transport vehicles and feeding rates. The more realistic the figures used in planning, the more accurate will be the results. This planning technique is applicable to any silage volume.

Flow Diagram

The flow diagram (Figure 5) lists the function or steps of a system to handle silage and provides a method of identifying the system components and manpower needed. The components and manpower are shown in Figure 5 for harvesting, transporting and moving into storage based on a total harvest of 1,500 tons of silage and the flow rates developed in the planning guide (Figure 4).

The components and labor required for the farmstead functions of the silage flow diagram are not identified as these would vary with the building layout and other feeds that might be mixed with the silage.

Length of Harvest Season

Timeliness of harvesting operations is of utmost importance, since it affects both the quantity and quality of the harvested crop. The optimum range of moisture

Table 21 — Capacity ranges for forage harvesters.*

Harvester size	Tons/silage harvested per hour	Tractor HP
Small	9 to 18	60 to 100
Medium	15 to 28	100 to 150
Large	20 to 40	125 to 200
Self-propelled	30 to 60	

*Based on a well-managed operation. Includes about 35 percent lost time for adjustments, repairs, changing wagons, etc. Under less favorable conditions, and/or with older machines, these figures should be discounted by 10 to 25 percent.

Table 22 — Capacity of tower silos.

Size (ft)	Tons		
	DM	40% DM	32% DM
14 x 50	62	148	195
16 x 50	81	190	252
18 x 50	103	245	320
18 x 60	124	296	392
20 x 50	125	300	394
20 x 60	155	370	483
20 x 70	184	456	574
24 x 50	182	435	570
24 x 60	223	530	697
24 x 70	265	628	827
30 x 60	348	673	886
30 x 70	413	825	1,087

Based on refill of silo with final silage level 3 to 5 ft below top of silo walls.

Table 23 — Amount of silage in inch layers for silos of different size (tower).

Silo diameter ft	Volume per ft depth cu. ft	Lb. silage in layer based on 50 lb per cu. ft		
		1 in.	2 in.	3 in.
12	113.1	470	940	1,410
14	153.9	640	1,280	1,920
16	201.1	840	1,675	2,510
18	254.5	1,060	2,120	3,180
20	314.2	1,308	2,615	3,924
22	380.1	1,583	3,165	4,749
24	452.4	1,885	3,770	5,655
26	530.9	2,215	4,430	6,645
28	615.8	2,565	5,130	7,695
30	706.9	2,945	5,890	8,835
36	1,017.4	4,240	8,480	12,720

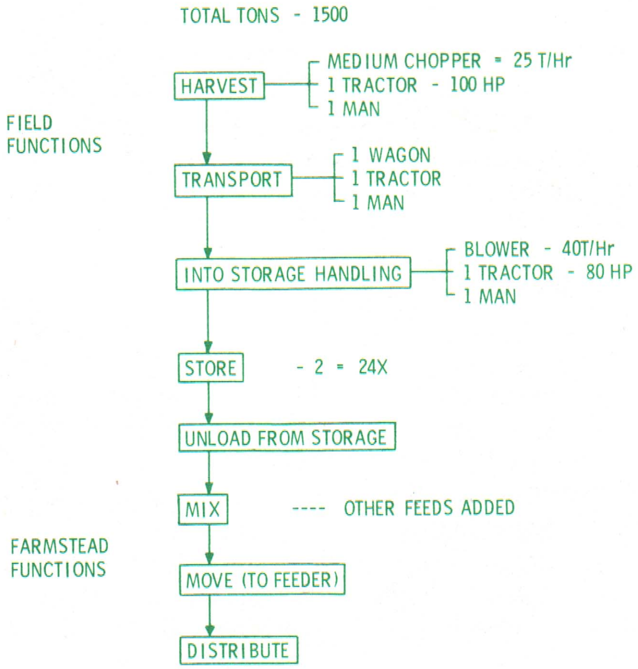

Figure 5—Silage flow diagram.

content of corn silage stored in tower silos is approximately 62 to 68% (32 to 38% DM). This sets some fairly specific limits on the length of time available for harvest. Harvesting operations should start when the corn is in the early to hard dent stage (see section on when to harvest) and should be completed as quickly as possible. Generally, there is a time span of 10 days to 2 weeks after corn is in the hard dent stage before a killing frost, assuming that hybrids of proper maturity are used. It is usually possible to continue silage harvesting operations after the first killing frost for 5 to 7 days before foliage losses become excessive. This gives a workable corn silage harvest season of about 3 weeks. Calendarizing hybrids, discussed in the section on production, could extend this period another 5 to 7 days.

Harvesting operations should be planned, and equipment and labor should be available, to permit completing silage harvesting operations with a 3-week period at least 6 years out of 10.

Weather Problems — Harvest Hours

Weather, an uncertain factor in all farming operations, is particularly critical for harvesting. Table 20 shows probabilities of having good, moderate, poor or very poor weather for harvesting corn silage.

An operator must select a harvesting system based on the extent to which he is willing to "gamble" on the weather. A logical solution is to mechanize sufficently to complete silage harvesting operations, 6 years out of 10, within a planned length of time.

The tonnage of silage that can be harvested within any set length of season is influenced by the capacity of the harvester, the weather probabilities and the number of hours per day the harvester can be operated. Many farms with limited labor supply and considerable chores can perform harvesting operations only a limited number of hours per day. Table 20, in addition to showing the weather probabilities, indicates the number of harvesting hours available per 3-week season, depending on whether the weather is good, moderate, poor, or very poor and how many hours per day the operator is available to perform harvesting operations. Some dairymen find they can harvest corn silage only 6 hr or less per day, while other farmers may assign full-time crews and operate equipment 8 hr or more per day. When larger volumes of silage are harvested, additional help is required on most farms to permit a 10- to 12-hr harvesting day.

Machine Capacity

Silage harvesting equipment is available either as pull-type or self-propelled units. Attachments are available for single or multi-row harvesting, with row spacing varying from 20 to 40 in. In addition, windrow pickup and direct cut attachments are available for most models, making the machines adaptable for harvesting a wide variety of crops.

Pull-type forage harvesters are available in a range of sizes, and will hereafter be referred to as "small," "medium" and "large" capacity machines. While not absolutely true in all cases, there is a general correlation between machine cost and capacity. Due to the increased maneuverability of the self-propelled machines, they are generally rated at a higher capacity in tons per hour than their pull-type counterparts.

Forage harvesters for which only a one-row corn head is available would generally be classified as "small" machines. Two-row harvesters with medium size tractors are classified as "medium." Two-row machines pulled with high hp tractors, three-row machines and self-propelled machines are classified as "large."

Machine capacity is important in planning a forage harvesting system. Most manufacturers rate their machines 100 percent theoretical capacity. This does not allow for time lost in turning at field ends, for changing wagons, or for making adjustments, repairs or lubrication. **From a practical point of view, one cannot normally figure on a forage harvester doing productive work more than two-thirds of the time.** The percentage of time the machine is doing productive work is known as the **field efficiency factor,** and this may vary considerably from farm to farm due to field topography, length of haul, age of machine, management ability of the operator, etc. Table 21 indicates typical capacity ranges for small, medium, large and self-propelled forage harvesters. This table is based on the expected average hourly production from these machines throughout the season, although many operators will obtain greater harvesting rates for short periods of time when things are going right. The use of trucks or wagons with tractors and drivers to catch silage from the harvester so that no time is lost in changing catch vehicles increases harvesting output but also increases the manpower needed.

Matching Components, Crew Size, Silage Flow

Silage flow is dependent upon the harvest and handling crew and organization as well as the size of the harvester. As volume and distance of hauling increase, crew size and organization become more important. A minimum crew for most operations would be three people. A fourth person might be needed for long hauls and additional people needed for high volume harvesting operations. Several combinations of crew size and components could be as follows:

Tower Silos

1. **Small harvester, 2 wagons, 2 men**—One man operates chopper; second man must move loaded wagon to blower, unload wagon and get it back to harvester by the time second wagon is full. If wagon capacity is 8 tons, and harvesting rate is approximately 15 tons per hour, second man would have approximately 30 minutes to move loaded wagon to silo, unload and get the wagon back to the harvester. Even with short hauls, it would be difficult to avoid some idle time for the harvester.

2. **Small or medium harvester, 3 wagons, 2 men**—One man operates the choppers, unhitches loaded wagon and hitches empty wagon to chopper. Second man takes empty wagon to field and positions as close as possible for harvester pick up, moves loaded wagon to silo, unloads, returns empty wagon to the field and picks up loaded wagon. With this method of operation, some additional downtime can be expected for the harvester as the operator must take time to pull out of the row to unhitch and hitch wagons. The time available to the second man to move loaded wagon to the silo, unload and return empty wagon to the field would be 20 to 30 min depending upon the capacity of the harvester.

3. **Medium or large harvester, 3 or 4 wagons, 3 men**—One man operates chopper, one man unloads at the silo and the third man moves wagons. The third man can trail harvester so that wagon can be exchanged by pulling harvester out of row at any location in the field to drop loaded wagon, and hitch empty wagon.

4. **Medium or large harvesters**—Long hauls or high volumes, additional drivers are needed for vehicles.

Horizontal Silos

1. **Small harvester, 3 wagons, 3 men**—A minimum crew requires three people, one person to drive chopper, one to pull wagons and one to place and pack silage in silo. Harvesting rate should be at least 100 tons per day to minimize spoilage in a horizontal silo.

2. **Medium and large harvesters, 3 or 4 wagons, 3 men**—Same operating procedures as for tower silos.

3. **Self-propelled and large harvesters with big tractors, 3 to 6 wagons or trucks, 5 to 8 men**—One man operates the chopper, one man places and packs silage at the silo, and other men drive vehicles and catch silage from chopper.

Harvesting Capacity

The range in capacity for the different size harvesters is shown in Table 21. Limited field observations of silage harvesting operations have supported the range shown:

Farm #1: One-row harvester, 80 hp tractor on harvester, 60 hp tractor blower, 2 men and part-time helper, three wagons—8 to 9 tons per hr.

Farm #2: One-row harvester with 100 hp tractor, blower with 60 hp tractor, long rows of good corn, 3 men, 3 wagons—18 to 20 tons per hr.

Farm #3: Three-row harvesters with 150 hp tractor, 3 wagons, 3 men, short haul—25 to 28 tons per hr.

Farm #4: Self-propelled harvester, two trucks, one man at silo, 4 men, short haul—60 tons per hr.

A major difference in the rate of harvesting was organization of the crew, operating practices that reduced or eliminated down time on the harvesting unit, long rows of corn and to some extent, the yield per acre.

Tractor size on Michigan farms has increased steadily. The increased horsepower available has resulted in increased capacity from all sizes of harvesters. While there is no hard and fast rule as to the size of tractor for harvesting units, suggestions from manufacturers generally are as shown in Table 21.

One characteristic of self-propelled harvesting units is the easier utilization of high-horsepower engines which results in greater harvesting capacity. Utilizing the potential capacity will depend on the organization, transport and unloading phases of the silage handling system.

One method of estimating harvesting system capacity is to estimate an average capacity from Table 21 for the size harvest, multiply by the number of hours per day, and then by the estimated harvest days. For example, the average harvest rate of a medium size unit (2 rows) would be 22 tons per hr $\left(\frac{15 + 28}{2}\right)$. Harvesting 6 hr per day for 12 days will result in a harvest of 1,684 tons, while harvesting 10 hr per day will harvest 2,640 tons in 12 days. If the tractor size is limited and the harvest rate was 16 tons per hr, the total tons harvested would be 1,152 tons for 12 days harvesting 6 hr per day or 1,720 tons harvesting 10 hr per day. Thus the output of a particular size harvesting unit can vary greatly. Realistic planning estimates plus organization during harvesting are important to satisfactory results.

Power Requirements

Adequate power for both the forage harvester and the blower are basic requirements for a successful forage harvesting operation. With forage harvesters the fineness of cut is particularly significant in determining power requirements.

A theoretical length of cut of ¼ to ⅜ in. is desirable in terms of utilization of silo space and exclusion of air in the silo. As the season advances and moisture in the plant lowers, fineness of cut becomes more important. With late-season operation, a recutter screen may be necessary in order to obtain the desired fineness of cut for adequate packing, exclusion of air and minimum of spoilage in the silo. A 2½ screen is usually adequate. A recutter screen also helps to crack corn kernels that might go into the silo as whole kernels. This screen will reduce harvester capacity, possibly by as much as 20%, or increase power requirements by about 20%, if the same production capacity is maintained.

Minimum power requirements for operating forage harvesters are shown in Figure 6. Note that power requirements increase as the length of cut is reduced. A ½-in. length of cut will not give adequate packing to control spoilage and provide maximum capacity for the silo. Power requirements shown are the maximum observed PTO tractor power and are minimum power requirements when operating under favorable conditions. Approximately 12 PTO horsepower are required to move the chopper and haul the forage wagon on level ground under favorable conditions. These requirements could more than double under adverse conditions. Figure 6 is not intended to imply that the capacity of any forage harvester will increase indefinitely if adequate additional power is supplied. Each harvester has a maximum design capacity level, and the application of additional power will not materially exceed this level.

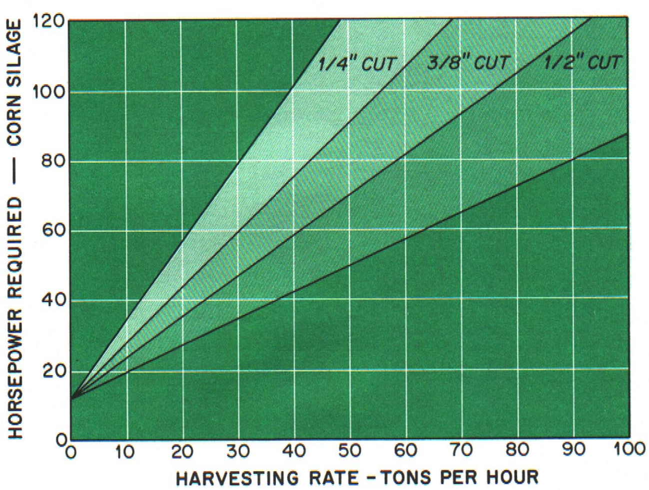

Figure 6—Tractor horsepower required for operating forage harvesters.

Forage Blowers

Forage blowers are an easy and convenient way for delivering silage to tower silos, but they are relatively low in power efficiency, generally not exceeding 10%. Their efficiency drops off rapidly with taller silos. Figure 7 shows the minimum power requirements for delivering corn silage to upright silos of various heights. Power requirements listed are maximum observed PTO horsepower. Maximum tonnage can be put through a blower only when the rate of feeding is fairly constant. Automatic self-unloading forage wagons tend to give the most uniform rate of unloading, and thereby result in maximum blower capacity.

Forage Wagons

Forage wagon sizes range from approximately 300 to 700 cu. feet, or a load capacity of 3 to 7 tons. Typical sizes are 7 × 14 or 7 × 16 ft. Running gears should have a rated capacity of the wagon. An 8-ton gear should be used with a wagon capacity of 5 to 8 tons. Use tires adequate to handle the load, and inflate to at least 36 lb.

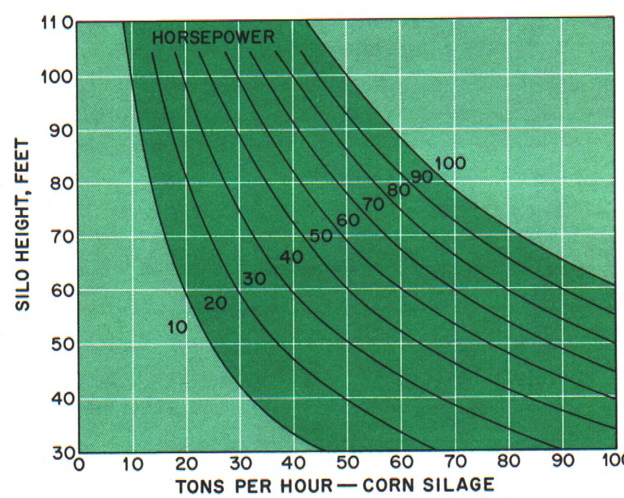

Figure 7—Tractor PTO horsepower required for operating forage blowers.

Rear unloading wagons cannot be used with hopper-type blowers but may be used with table-type blowers or for hauling to horizontal silos. Dump-type wagons or trucks may be used only for hauling to horizontal silos, unless the blower conveyor is below ground level and a dumping apron is provided from which the silage may be shoved into the conveyor by means of a tractor and blade.

Equipment Maintenance

Maximum production can be obtained only from equipment that is kept in excellent mechanical condition. Forage harvesters do their cutting by passing a knife past a shear bar:

1. Knives must be kept sharp.
2. The shear bar must have a good square edge, and the knife must pass very close to the shear bar to obtain good, uniform chopping with minimum power.
3. Dull knives and worn shear bars are usually the cause of ragged cutting and high power requirements.

Many forage harvesters have built-in knife sharpeners. These are excellent for touching up cutting edges but are not well adapted for major sharpening jobs. For best results:

— Use the built-in knife sharpeners several times each day to insure good, sharp cutting edges.

— Remember that the use of a knife sharpener automatically increases the clearance between the knife and shear bar. Periodic adjustment of the knife to the shear bar is necessary; and with most machines, the shear bar can be removed and turned to two or more positions to provide a new, sharp-cornered shearing edge.

With blowers, the clearance between the fan blades and the blower housing materially affects blowing efficiency. Clearance between the end of the blade and the fan housing should not exceed ⅛ in. Side clearances, should be within the ¼- to ½-in. range. Blower pipes should be straight, free of dents and have smooth, relatively tight joints. The condition of the blower pipe becomes much more critical with silo heights above 60 ft.

Where it is necessary for the blower to set away from the base of the silo, precautions should be taken to keep the pipe from sagging or bowing appreciably.

Daily maintenance on most harvesting units is required. A regularly scheduled maintenance period at the end of the day or the first thing in the morning before the crew assembles will reduce downtime during the day and a loss of crew hours. Refer to your owner's manuals for detailed information relative to service and maintenance for forage harvester or blower.

Silo Structures and Selection

High quality silage can be made in all types of structures. Quality will vary, depending on the condition of the silo, moisture level, stage of maturity when harvested, fineness of chop and other management factors. Because of the relatively low storage losses for corn silage, it is considered uneconomical to use sealed storage, especially when silos are filled only once. Important factors in selection of silos are: (1) size, (2) feeding arrangements, (3) materials other than corn silage that may be stored in silo and (4) investment required for total storage and feeding systems.

Losses in Storage

Tight structures, good distribution and packing and use of a plastic cover properly weighted down keep losses low. Losses in bunker silos are also influenced by depth and width of material stored. Less surface is exposed for the deeper silos. In well-managed operation, silage losses are estimated at 5 to 10% for concrete tower silos and 10 to 15% for bunker silos.

Tower Silo

The design of the tower silo is determined by the manufacturer. Silos sold in Michigan have proven satisfactory if reasonable silo maintenance practices are followed. Silage juice is the worst enemy of tower silos. A maximum silage moisture content of 68% is recommended. Continual seepage from silage high in moisture (70% or higher) will cause deterioration of all types of tower silos. An adequate foundation for silos, on well-drained soil, becomes increasingly important as silos increase in size and height. In addition, it is necessary to provide drainage for seepage away from the silos to protect the foundations.

The capacity of tower silos is shown in Table 22. The tonnage shown for the various size silos can vary by a plus or minus 10% for any tower silo. Density studies and actually weighing of silage into and out of on-farm silos have shown these results. Time of harvest, length of cut, rate of filling and unloading which influences oxidation losses in the silo and even varieties will contribute to variation of total tons in both tower and horizontal silos. The total dry matter tons in a silo remains relatively constant for a particular harvest operation even though the actual moisture content of the silage may vary considerably.

Table 24 is based on research data and has also checked out closely with some large farm silos where corn silage was weighed in and out.

Bunker Horizontal Silo

Bunker silos can be completely aboveground, partially in the ground or completely in a bank. The first consideration, however, is for drainage out of and away from the silo. Other considerations are access to the silo and orientation to prevent snow accumulation in the silo.

The density of the packed silage has a direct bearing on oxidation losses, which are not seen by the farm operator, as well as visible spoilages. The deeper the silage the less the loss in weight and quality. From a practical standpoint, 12 to 16 ft of settled silage is recommended. Putting the silage in at a slightly higher moisture (68% to 72%) and chopping it short will increase the density. Good packing of the silage is necessary. A wheel tractor will provide more packing pressure than a track-type tractor.

Several factors should be considered in the length and width of a horizontal silo. The best method of filling a bunker silo is to unload the silage on a concrete floor, then push it upon the silage silo with a front blade and tractor. A width of approximately 50 feet is needed to turn and manuever vehicles in the silo for unloading. Narrow silos require more backing of vehicles or unloading of silage on the front apron, resulting in a longer push to get materials in the back of the silo. With settled silage depth of 12 ft or more, the density of the silage is great enough to prevent any amount of spoilage on the face of the silage pile so that it isn't necessary to remove several inches per day. If silage depths are less than 10 ft, 2 to 4 in. should be removed daily from the face of the silage.

The capacity shown for bunker silos in Table 25 is based on 40 lb per cu. ft which is 50 cu. ft of storage space per ton of silage. A close estimate of the capacity for bunker silos can be made by determining the tons per foot of length, then multiplying by a given length. This also provides a method for determining the length of a silo. For example, a silo 60 ft wide with an average depth of 12 ft would have 720 cu.ft (60 × 12 ft) per foot of length. The capacity per foot of length would be 50 cu. ft/ton = 14.5 ton per ft of length.

If the silo was 100 ft long the total storage capacity would be 14.5 tons/ft × 100 ft = 1,450 tons, minus approximately 10 tons lost by the sloping front of the silage pile.

Table 25 also shows the amount of silage per slice of thickness for 1-in. and 12-in. slices. This information can also be used to determine the size of silos or the feeding days for a given length. For example, if 100 cows were fed 60 lb of silage per day it would require 6,000 pounds or 3 tons. Table 25 shows 1 ton

Table 24 — Number of animals fed per 2-in. silage layer for various size tower silos, and feeding rates.*

Silo diameter	Approximate lb silage in 2-in. layer	Lb of silage per day per animal: 20	30	40	50	60	70	80
ft	lb	Number animals to consume 2-in. silage layer at above rates						
16	1,675	84	56	42	34	28	24	21
18	2,120	106	71	53	42	35	30	28
20	2,615	131	87	65	52	43	37	33
22	3,165	158	105	79	63	53	45	39
24	3,770	188	126	94	75	63	54	47
26	4,430	222	144	111	88	74	63	56
28	5,130	256	171	128	103	86	73	64
30	5,890	295	196	147	118	98	84	74
36	8,480	424	283	212	169	141	121	106

*To determine height of silo, multiply 2 inches by feeding days and divide by 12.
Example: To feed 98 animals at a rate of 60 pounds per day would require a 30 foot diameter silo.
To feed 98 animals at this rate for 365 days =

$$\frac{2 \text{ inches} \times 365}{12 \text{ inches}} = 61 \text{ feet of silage}$$

Thus, 61 feet of silage plus 5 feet of unused silo from settling requires a 66-foot high silo.

Table 25 — Capacity of bunker silos (12-ft deep) and amount of silage per slice.

Length (ft): 60	80	100	120	140	160	200	Width	Amount silage per slice, Thickness: 1 in.	12 in.
			Tons				Feet	Tons	Tons
288	384	480	576	672	768	960	20	.4	4.8
432	576	720	864	1,008	1,152	1,440	30	.6	7.2
576	768	960	1,152	1,344	1,536	1,920	40	.8	9.6
720	960	1,200	1,440	1,680	1,920	2,400	50	1.0	12.0
864	1,152	1,440	1,728	2,016	2,304	2,880	60	1.2	14.4
1,152	1,536	1,944	2,292	2,688	3,072	3,840	80	1.6	19.2

Settled depth

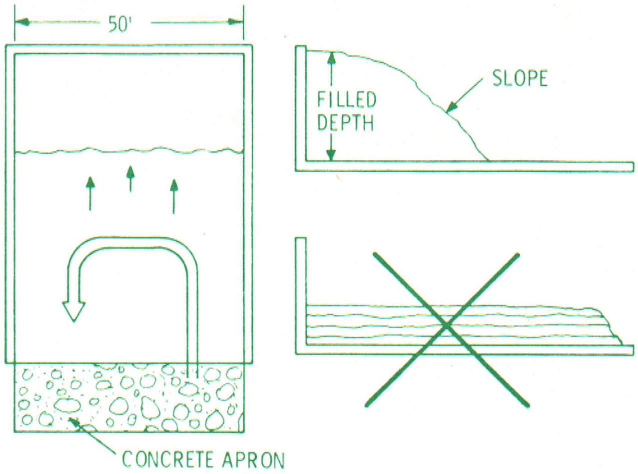

Figure 8—Placement of silage in a horizontal silo.

per inch for a 50-ft wide silo, 12 ft deep, so it would require approximately 3 in. per day to feed the 100 cows. The length required to feed 365 days from the 50-ft wide silo would be 3 in. per day × 365 days = 1,095 in. $\frac{1,095 \text{ in.}}{12 \text{ in./ft}} = 91$ ft

Filling Silos

Rapid filling is desirable for both tower and bunker silos to minimize oxidation losses and spoilage. Distribution of silage in silos is also desirable for all tower silos and necessary for large diameter silos. The ideal distribution of silage would maintain the silage along the side walls slightly higher than the center during filling with only a slight crowning at the center to top out the silo. Directing all silage at the center of the silo and letting it roll out can result in fluffy spots along the walls; this can result in the slipping of unloader drive wheels, the tipping of unloaders and sometimes pockets of spoilage.

The filling of horizontal silos will vary with the construction or location of the silo. Most permanent horizontal silos are constructed above ground. The best method of filling horizontal silos is to dump the silage on the concrete floor, then put it up on the pile to the maximum depth (Figure 8), keeping the slope on the pile as steep as possible. This reduces the exposure of the silage to the air and minimizes oxidation losses and spoilage. A 50-ft wide silo permits turning inside the silo and unloading silage close to the silage pile. Narrower silos may require unloading silage on the apron in front of the silo and pushing silage farther with tractor and blade. The least desirable method of filling an *above ground,* horizontal silo is by driving over the silage pile, because this results in layer filling, causing more silage loss and usually requires either light loading of the transport vehicles or a second tractor to pull the load onto the silage. Narrower silos and temporary silos partially below ground or in a bank may be filled by driving off a bank. A 50-ft wide by 80 ft long silo permits better manuevering of vehicles for unloading and thus easier filling than a 40 × 100-ft silo. If the silo is filled to a settled depth of 12 ft to 16 ft, the increased spoilage on the face of the silage in a wider silo is minimal.

investments for harvesting, storing and handling silage

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COMPLETE INVESTMENTS for machinery and equipment to harvest and handle, and facilities to store corn silage will vary greatly among farms. Investments per head fed are reduced with increased size of operation. Degree of mechanization, type of silo selected and the extent to which machines are also used to harvest alfalfa haylage or other silage crops affect economy of investments.

Harvesting

Initial investments for forage harvesters, chopper wagons and blowers are shown in Table 26. Since there is much variation in the capacity and costs of

Table 26—Investments in corn silage harvesting equipment.

Equipment	Range in cost	Economical for following tonnages
	dollars	tons
Forage harvester		
Pull type		
1 row	6,000— 8,000	400—1,800
2 row	8,000—10,000	800—2,600
3 row	10,000—12,000	1,000—3,600
Self-propelled	38,000—42,000	1,500—4,000
Chopper wagons	2,500— 4,000	
Silage blower	1,500— 2,000	

different makes of forage choppers, a range is shown for both investments and tonnages harvested seasonally for three sizes of pull-type and for self-propelled harvesters.

Silos and Unloading

Investments per ton of silage storage capacity will vary because of differences in size of structure, accessories furnished such as a roof, type of structure and difference in dealer prices.

Investments in silos and unloaders for some important sizes of concrete and sealed storage units sold in Michigan are shown in Table 27. Investments in tower silo and unloader ranged from $33.90 for the small diameter to $22.20 per ton of capacity for the 30-ft diameter concrete tower silos. Investments in sealed storage are higher per ton of storage capacity.

Investments in bunker silos vary with size of silo and material used. Initial cost per ton of storage capacity will range from $7 to $17. Bunker silos using tilt-up or poured concrete sides may cost the same or $2.00 more per ton storage capacity than silos built with 2-in. tongue-and-groove planks. The following are estimates of costs of material and labor:

Material	Cost/unit
Tongue-and-groove planks*	$3.20/ft height/linear ft
Concrete (poured or formed)†	$2.90/ft height/linear ft
Concrete (poured or tilt-up)‡	$5.10/ft height/linear ft
Concrete floor	$.85-$.95/sq ft(4 in thick)

On the basis of 40 lb per cu. ft for corn silage, a 40 × 160 ft bunker silo filled to an average depth of 12 ft would have a storage capacity of 1,536 tons.

2 sides × 160 ft + 40 ft = 360 linear ft of sides.

40 ft × 160 ft = 6,400 sq ft concrete floor.

Investment and Annual Cost

Investments and annual ownership and maintenance costs were calculated for complete corn silage systems using concrete tower and bunker silos. These were calculated for 500-, 1,000-, 2,000- and 4,000-ton capacity silos.

**Includes cost of poles, braces and labor.*
†Below ground structures needing limited supports.
‡Above ground includes cost of pilasters and labor.

Table 27 — Silo investments for corn silage by type and size North Central Region, 1976.

Silo type and size (ft)	Investment needed							
	Corn silage capacity*	Silo and roof	Foundation	Total silo	Total silo per ton	Unloader	Total silo and unloader	Total per ton
Concrete tower								
18 x 50	320	7,500	460	7,960	24.90	2,880	10,840	33.90
18 x 60	392	8,800	460	9,260	23.60	2,940	12,200	31.10
20 x 50	394	8,500	515	9,015	22.90	3,020	12,035	30.50
20 x 60	483	10,200	515	10,715	22.20	3,080	13.795	28.60
20 x 70	574	12,100	565	12,665	22.00	3,130	15,795	27.50
22 x 50	477	10,000	620	10,620	22.30	3,460	14,080	29.50
22 x 60	585	12,200	620	12,820	21.90	3,510	16,330	27.90
22 x 70	694	15,200	685	15,885	22.90	3,560	19,445	28.00
24 x 50	570	11,800	675	12,475	21.90	3,590	16,065	28.20
24 x 60	697	14,100	675	14,775	21.20	3,650	18,425	26.40
24 x 70	827	16,900	735	17,635	21.30	3,700	21,335	25.80
26 x 50	668	13,400	785	14,185	21.20	3,730	17,915	26.80
26 x 60	818	15,900	785	16,685	20.40	3,800	20,485	25.00
26 x 70	970	18,700	860	19,560	20.20	3,880	23,440	24.20
30 x 50	886	16,900	920	17,820	20.10	4,180	22,000	24.80
30 x 60	1,087	20,000	920	20,920	19.20	4,260	25,180	23.20
30 x 70	1,290	23,300	1,020	24,320	18.90	4,330	28,650	22.20
Sealed storage								
Steel								
20 x 50	375			20,500	54.70	8,300	28,800	76.80
25 x 90	1,350			49,000	36.30	8,900	57,900	42.90
Concrete								
20 x 67	588						30,300	51.50
24 x 77	830						37,600	45.30
Bunker†								
	500				13-17			
	1,000				11-13			
	2,000				9-11			
	4,000				7-9			

Source: "Dairy Systems Analysis Handbook" by C. R. Hoglund, Mich. St. Univ. Ag. Econ. Rept. No. 300.
*Based on settled capacity of 32% DM corn silage.
†Concrete floor and poured or tilt-up sides. Based on 6 ft high walls for 500 ton to 12 ft for 4,000-ton capacity silos.

Investments for field choppers, mechanical wagons or dump trucks and filling equipment are essentially the same for systems using tower and bunker silos (Table 28). Unit costs are less for the large operations.

Total investments for harvesting, storing and handling of corn silage ranged from $52.30 per ton for 500 tons to $33.40 per ton for 4,000 tons storage capacity using concrete tower silos. These investments were lower for the systems using bunker silos, ranging from $44.00 to $21.20 for these quantities.

Annual costs for complete silage systems include depreciation, maintenance, insurance and interest on the investments, plus value of estimated storage losses.

On the basis of one complete filling and a 20-yr depreciation period for both concrete and bunker silos, and 5 to 8 yr for harvesting equipment, annual costs per ton of silage preserved ranged from $12.02 to $7.53 for the systems with concrete silos and from $12.34 to $7.17 for the systems with bunker silos. The break-even point in costs per ton for the two systems was above the 1,000-ton capacity. With 500 tons, the tower silos are more economical; and when 2,000 or more tons of corn silage are harvested and fed, the bunker silo system is more economical.

Table 28 — Investments and annual ownership costs by silo type corn silage harvesting, filling and storage.

	Tons corn silage			
	500	1,000	2,000	4,000
CONCRETE TOWER SILOS		Dollars		
Investments				
Harvesting and filling	13,500	18,000	30,000	50,000
Storage	12,660	20,920	46,250	83,680
Totals	26,160	38,920	76,250	133,680
Per ton capacity	52.30	38.90	38.10	33.40
Annual costs				
Harvesting and filling	3,530	4,640	6,960	12,470
Silo	1,580	2,620	5,780	10,460
Silage loss	900	1,800	3,600	7,200
Total annual costs	6,010	9,060	16,360	30,130
Total per ton	12.02	9.06	8.18	7.53
BUNKER SILOS				
Investments				
Harvesting and filling	14,500	19,600	32,500	52,800
Storage	7,500	12,000	20,000	32,000
Totals	22,000	31,600	52,500	84,800
Per ton capacity	44.00	31.60	26.20	21.20
Annual costs				
Harvesting and filling	3,790	5,060	7,570	13,160
Silo	940	1,500	2,500	4,000
Silage loss	1,440	2,880	5,760	11,520
Total annual costs	6,170	9,440	15,830	28,680
Total per ton	12.34	9.44	7.92	7.17

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