Economical Value of Corn Silage

Normand St-Pierre[1]
Department of Animal Sciences
The Ohio State University

Abstract

There are a growing number of reasons why the economic value of corn silage must be frequently determined. Because of the absence of large and efficient corn silage markets, indirect methods must be used to estimate the economic value of corn silage. The first method is based entirely on the price of shelled corn. Assuming that corn grain represents 50% of the dry matter **(DM)** of the whole plant, and that corn silage contains 35% DM, multiplying the price of corn ($/bu) by 7 produces the corn-grain equivalent value of corn silage standing in the field. Harvesting, transportation, packing, DM losses, and various other costs must be added to this figure to determine the value of corn silage at feeding time. This first method essentially determines the floor price for corn silage from a corn grower standpoint. The second method values the silage based on the value of the nutrients that it contains. We have found that net energy for lactation, metabolizable protein, effective neutral detergent fiber **(NDF)**, and non-effective NDF explain over 98% of price variation across all major feedstuffs used for dairy production in the U.S. Unit prices for these 4 nutrients can be determined using *Sesame*. Nutritional content can be calculated using NRC (2001). The resulting economic value is sensitive to silage composition. It is almost always greater than the value calculated using the first method. In essence, this method determines a ceiling price for corn silage from a dairy farmer's point of view. Because silage DM digestibility and intake are depressed at low or high silage DM content, it is important to correctly adjust the economic value of silage based on its DM content. Multiplicative factors based on literature review are provided for DM ranging from 22 to 42%.

Introduction

Corn silage has become the dominant forage used in dairy diets across most major dairy producing regions of the United States. Whether the corn used for ensiling is home-grown or purchased from a crop grower, there is a real need to assess the economic value of the feed to be used in diet formulation (least-cost), as well as for ensuring optimal allocation of acreage across different crops. Unfortunately, there is very little corn silage sold as a fermented feed in an open market setting, such as what is frequent for hay and various other feedstuffs. Therefore, a direct assessment of the economic value of corn silage through market discovery would be ill advised if not impossible; the markets are generally way too thin to extract any meaningful information. In addition, not all corn silages are created equal; there are large differences in the nutritional value of individual silages due to a variety of factors, such as hybrid planted, weather conditions during growth, pre-storage processing, and fermentation characteristics.

Ultimately, corn silage is used as a source of nutrients. The nutritional content of specific silages varies depending on the species and class of animals

[1]Contact at: 221 Animal Science Building, 2029 Fyffe Ct., Columbus, OH 43210, (614) 292-6507, FAX: (614) 292-1515, Email: st-pierre.8@osu.edu

to which it is fed. In the balance of this paper, we will assume that the target animal is a lactating cow producing at 3 times (3X) maintenance. For a 1,500 lb Holstein, this equates to a milk production of approximately 70 lb/day at 3.5% fat, a production level that slightly exceeds the average daily production of U.S. dairy herds (~65 lb/day). Different methods that vary in complexity, depending on how much is known of the nutritional composition of the silage, can be used to assess the economic value of corn silage. In addition, the economic value will depend at what stage in the harvesting and storage process is the economic valuation desired.

Method 1: Corn Silage Value Based on the Price of Shelled Corn

Often, a crop of corn can be harvested either as silage or as shelled corn. From a corn grower standpoint, there should be a price for corn silage where the grower becomes indifferent as to whether the crop is harvested for silage or for grain. This point of indifference is when the net revenue per acre is the same regardless of the type of harvest (grain or silage). A bushel of corn contains 56 x 0.88 = 49.3 lb of DM. If at maturity the DM of the corn plant is 50% in the grain and 50% in the rest of the plant, then 49.3 ÷ 0.5 = 98.6 lb DM silage contains the equivalent of 1 bushel of corn. A ton (2000 lb) of corn silage at 35% DM contains 700 lb of DM. Thus, a ton of corn silage contains 700 ÷ 98.6 ≈ 7 bushels of corn. From a grower standpoint, multiplying the price of corn per bushel by 7 provides an estimate of the value of corn for silage standing in the field. The value of the corn silage at feeding time depends on who provides and pays for the various costs between harvest and feeding. Without getting into excruciating and unnecessary details, the following worksheet can be used to add the various costs along the harvesting/storage chain:

		Example
Corn price ($/bu) x 7	______	$4/bu x 7 = $28/ton
+ Harvesting costs ($/ton)	______	$5/ton
+ Transportation ($/ton)	______	$3/ton
+ Packing costs ($/ton)	______	$2/ton
+ Inoculant & cover ($/ton)	______	$2/ton
= Subtotal ($/ton)	______	$40/ton
+ Losses from fermentation ($/ton)	______	4/ton ($40 x 10%)
= Total ($/ton)	______	*$ 44/ton*

Although this worksheet will generally provide a good base point to the value of corn silage, one must be reminded that: (1) we assumed that grain represents 50% of the whole plant DM and that corn silage is at 35% DM, and (2) we didn't factor in any correction for the quality of the silage.

The standard bushel price multiplier (x7) can be easily adjusted depending on the grain content of the whole plant. Table 1 reports the multiplicative factor to be used for various percent contributions of kernel DM to whole plant DM. Of course, the average contribution of kernel DM to whole plant DM is seldom known and can easily vary between 40 and 60%. Table 1 exemplifies the range of error in pricing from using a constant multiplicative factor of 7, when the correct multiplicative factor could just as easily been anywhere between 5.7 and 8.5.

All of our calculations assumed a DM content of 35% for the silage. Obviously, the calculated value would have to be adjusted for the DM of the crop. The dilution effect can be easily accounted for. The value of a silage at X % DM is easily established from the value of the standard 35% DM silage as follow:

$$\text{Value at X \% DM (\$/ton)} = \text{Value at 35\% DM (\$/ton)} \times X \div 35 \qquad [1]$$

In the example above, the value of the whole plant standing in the field at 30% DM is $28 x 30¸ 35 =

$24/ton. Although the correction for the dilution effect is easily calculated, this correction is insufficient for silages below 30% DM or above 38% DM. This will be explained later on.

The prime advantage of this method is, of course, its simplicity. A simple agreement can be entered well ahead of the cropping season between a corn grower and a corn silage buyer as long as the source used for pricing corn grain is clearly identified ahead of time.

The prime disadvantage of this method is that it doesn't consider differences in feeding value. On an average, it will produce a floor value of the standing crop. But half the time, this value will be too high and half the time it will be too low. Nevertheless, the calculated value can be used as a floor price from a grower standpoint, anything less would make the grower an incoherent decision maker.

Method 2: Corn Silage Value Based on the Value of its Nutrients

Fundamentally, feedstuffs are used to supply nutrients to animals. If we knew (a) the unit costs of nutrients and (b) the amount of all nutrients in a ton of corn silage, then it would be relatively easy to calculate its value. But, there are no direct markets for nutrients, and we never know precisely the nutritional composition of a feed.

Although there are no direct markets for nutrients, there are relatively open and competitive markets for feeds, and these can be translated into indirect markets for nutrients. It is possible to estimate average unit costs of nutrients from market prices of all commodity feeds traded in a given market and the average nutritional composition of these feeds (St-Pierre, 2000; St-Pierre and Glamocic, 2000). The method has been programmed in the stand alone Windows-based software *Sesame*™. Version III was released a few years ago, and its prominent features were explained at this Conference (St-Pierre, 2005).

We have studied the "Sesame" approach across all major dairy markets over more than 20 years. Two models have consistently produced very high R^2. The first set includes net energy for lactation **(NE_L)**, rumen degradable protein **(RDP)**, digestible-rumen undegradable protein **(dRUP)**, effective neutral detergent fiber **(eNDF)**, and non-effective neutral detergent fiber **(ne-NDF)**. The second set includes NE_L, metabolizable protein **(MP)**, e-NDF, and ne-NDF. Although both sets are equally good, we have progressively moved towards using the second set because: (1) it has one fewer nutrient, and (2) animal requirements for MP are more straightforward than for RDP and dRUP. Solutions using these 4 nutrients (NE_L, MP, eNDF, and neNDF) generally produce an R^2 above 0.98, meaning that over 98% of the variation in prices of feedstuffs at a given moment is explained by their composition in these 4 nutrients. This is not to say that some other nutrients do not affect the price of a given feed (e.g., lysine in the case of blood meal), but that across all feeds, other nutrients have had little importance in setting market prices of feed commodities in the past.

The average unit costs for NE_L, MP, eNDF and neNDF, along with their standard deviations, for the Tri-State area from January 2005 through December 2008 are reported in Table 2. Over that time span, 1 Mcal of NE_L has cost ~ 10¢, 1 lb of MP ~ 20 ¢, 1 lb of eNDF ~ 3 ¢, and 1 lb of neNDF ~ negative 9¢. These are averages and have fluctuated widely over this time span (Figure 1). Unit costs for August 2008 and February 2009 are also reported in Table 1. In the absence of better information, the mean values can be used and should work on an average. But, one only has to look at the drastic changes that occurred between August 2008 and February 2009 (Table 1) to realize how wrong averages can be.

Estimation of the NE_L, MP, eNDF and neNDF content of a given silage according to the NRC (2001) system can truly only be made in the context of a diet. If one assumes that the corn silage will be used in a somewhat balanced diet, reasonable assumptions can be made to simplify the calculations. As in Table 15-1 and 15-2a of NRC (2001), we chose to make the following assumptions when calculating the nutritional content of feeds in *Sesame*: the diet contains 50% forage, dry matter intake **(DMI)** is at 4% of body weight, NE_L intake is at 3 times the energy requirements for maintenance, and the diet fed is at 74% total digestible nutrients **(TDN)**. The NRC (2001) software can always be used for special applications.

Table 3 reports the nutritional content of an average corn silage using data from NRC (1996, 2001). We will use this assumed composition in the rest of this paper, but it should be clearly understood that a corn silage with a different composition would necessarily have a different economic value.

Using the data from Tables 2 and 3, it is relatively easy to calculate the economic value of our standard corn silage. Table 4 shows the calculations using the 2005 to 2008 average nutrient unit costs of nutrients, as well as those calculated for August 2008 (peak of nutritional costs) and for the more recent February 2009. Over the 4-year span, a standard 35% DM corn silage has been worth about $47/ton compared to $76/ton last August and $58/ton in February ’09. Because feed prices used to calculate the costs of the nutrients in *Sesame* are on a farm delivered basis (i.e., at the mixer wagon), the economic value calculated using this second method is that of the silage at the time of feeding.

Comparing the Two Methods

Table 5 compares the calculated economic value of a standard corn silage according to the 2 methods just explained. The comparison is done using average prices over the 2005 to 2008 period, as well as for prices in effect in August ’08 and February ’09. The calculated value using method 2 was on average 27% greater than the value calculated using method 1 over the 4-year period. The same fractional difference was also observed last August, while the one in effect in February was not meaningfully different. Thus, it appears that one can get a rough approximation for method 2 valuation by simply multiplying the results of method 1 by 1.3.

Calculations using method 1 are exclusively based on the price of shelled corn. The approach basically attempts to determine a floor price from a corn grower’s standpoint. Method 2 estimates the economic value of the silage based on the value of its nutrients to a lactating dairy cow. In essence, method 2 establishes a ceiling price from a dairy farmer’s standpoint. The purchased price of corn for silage must fall between these two boundaries if both the corn grower and the dairy farmer are economically coherent individuals. The agreed price will be determined by how bad the grower wants to sell and how bad the dairy farmer wants to buy.

Factoring the Effect of DM Content

A ton of corn silage at 40% DM contains 33% more DM than a ton of corn silage at 30% DM. Thus, everything else being equal, a ton at 40% DM should be worth 33% more than a ton at 30% DM. This is a simple dilution effect which can be easily accounted for using equation [1]. But over a wide range of DM, this simple correction is insufficient. A review of published literature (St-Pierre et al., 1984, 1987) showed a curvilinear response in DM digestibility and intake to DM content of corn silage. Dry matter digestibility declines when silage is either below 28% or above 35% DM (Figure 2). Intake is depressed with DM under 30% (Figure 3). The intake depression associated with DM content greater than 36% is based predominantly on older data on non-mechanically processed silage. It is possible that mechanical processing reduces considerably the intake and digestibility depression of dryer silages, but published data are still too sketchy to allow a correct quantification of this effect.

Using average DM digestibility and intake depression presented in Figures 2 and 3, a feed efficiency of 1.5 lb of milk per lb of DMI, and a milk price of $14/cwt, Bill Weiss and I calculated correction factors to be used for calculating the economic value of corn silage at different DM (Table 6). For example, suppose that we have established a value of $45/ton for corn silage at 35% DM. The value of a similar silage at 28% DM would be calculated as $45/ton x 0.74 = $33.30/ton. The correction for DM content between 30 and 38% is solely based on a dilution effect (i.e., no DM digestibility and intake effect). Dry matter outside of that range results in more pronounced correction.

Conclusion

Two methods for calculating the economic value of corn silage were presented and explained. One establishes the floor price from a corn grower's standpoint. The other identifies the ceiling price from a dairy farmer's point of view. The resulting price should fall somewhere in between and be determined by who is the hungrier. Regardless, the value of silage with DM content substantially different than 35% should be adjusted to account for both the dilution effect, as well as the associated depression in DM digestibility and intake.

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Table 1. Multiplicative factor to the price ($) of corn per bushel to be used to calculate the value of corn for silage ($/ton) standing in the field with various proportions of the whole plant DM from corn kernels.

DM from kernels (%)	Multiplicative Factor
40	5.7
45	6.4
50	7.1
55	7.8
60	8.5

Table 2. Unit costs of nutrients from January 2005 through December 2008, and for August 2008 and February 2009. Costs were calculated using prevailing commodity prices in the IN-MI-OH markets.

	2005 – 2008		Aug 2008	Feb 2009
Nutrients	Mean	SD[1]		
	----------------------	¢/unit	------------------------	
Net energy lactation (cost/Mcal)	9.7	3.8	17.1	7.5
Metabolizable protein (cost/lb)	20.9	7.9	24.2	42.3
Effective NDF (cost/lb)	2.8	3.4	7.2	5.3
Non-effective NDF (cost/lb)	-8.6	4.7	-21.9	-5.7

[1]SD = Standard deviation.

Table 3. Nutritional composition of an average corn silage[1].

Nutrients	Abbr.	Value	Nutrients	Abbr.	Value
Dry matter (%)	DM	35	Rumen undegradable protein (% of CP)	RUP	35.3
Crude protein (% of DM)	CP	8.8	RUP digestibility (% of RUP)	RUPd	70
Ether extracts (% of DM)	EE	3.2	TDN (1X) (% of DM)	TDN1X	68.8
Ash (% of DM)	Ash	4.3	TDN (3X) (% of DM)	TDN3X	63.2
Neutral detergent fiber (% of DM)	NDF	45	NE_L (3X) (Mcal/ lb DM)	NE_L	0.657[2]
Lignin (% of DM)	Lig	2.6			
Neutral detergent insoluble crude protein (% of DM)	NDICP	1.3	NDF effectiveness (% of NDF)	NDFe	70
Acid detergent insoluble crude protein (% of DM)	ADICP	0.8	Metabolizable protein (g/kg of DM)	MP	74.3[3]

[1]Adapted from NRC (1996, 2001).
[2]NE_L assumes that the diet contains 74% total digestible nutrients (TDN) and is fed at 3X maintenance.
[3]MP assumes a 50% forage diet and DMI at 4% of body weight.

Table 4. Calculated value of corn silage based on the value of its nutrients.

Nutrients[1]	Composition (units/ton)		Cost (¢/unit)			Value($/ton) at 35% DM		
	100% DM	35% DM	2005-2008 Average	Aug 2008	Feb 2009	2005-2008 Average	Aug 2008	Feb 2009
NE_L	1134	397	9.7	17.1	7.5	38.51	67.89	29.78
MP	148.6	52.0	20.9	24.2	42.3	10.87	12.58	22.00
eNDF	630	221	2.8	7.2	5.3	6.19	15.91	11.71
neNDF	270	95	-8.6	-21.9	-5.7	-8.17	-20.81	-5.41
TOTAL						47.40	75.58	58.08

[1]NE_L = net energy for lactation (Mcal); MP = metabolizable protein (lb); eNDF = effective NDF (lb); and neNDF = non-effective NDF (lb).

Table 5. Comparison of two methods for estimating the economic value of corn silage.

	Periods		
	2005-2008	Aug 2008	Feb 2009
Corn price ($/bu)	$ 3.40	$ 6.00	$ 4.00
Value of corn silage ($/ton)[1]			
From Method 1	37.18	59.50	44.00
From Method 2	47.40	75.58	58.08
Ratio of Method 2 to Method 1	1.27	1.27	1.32

[1]Method 1 is based on the price of shelled corn. Method 2 is based on the value of the nutrients in the silage.

Table 6. Multiplicative factors to be used for correcting the value of corn silage based on DM content.

Dry Matter (%)	Dilution factor	Digestibility and DM intake depression factor	Combined factor[1]
24	0.69	0.78	0.53
26	0.74	0.85	0.63
28	0.80	0.93	0.74
30	0.86	1.00	0.86
32	0.91	1.00	0.91
34	0.97	1.00	0.97
36	1.03	1.00	1.03
38	1.09	1.00	1.09
40	1.14	0.91	1.04
42	1.20	0.85	1.02

[1]This factor is multiplied to the value of corn at 35% DM to establish the value at other DM.

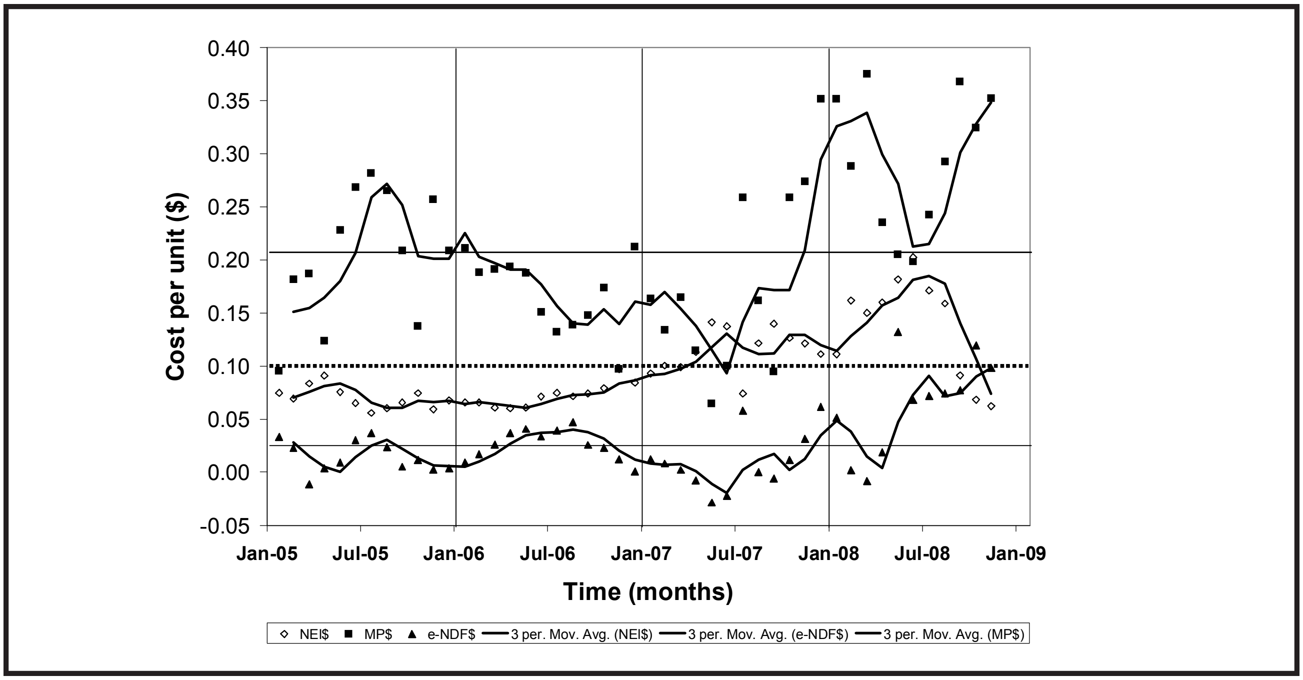

Figure 1. Costs of nutrients between January 2005 and December 2008; ■ = cost of metabolizable protein ($/lb), ◊ = cost of net energy for lactation ($/Mcal), and ▲= cost of effective NDF ($/lb). Results are from *Sesame*, using Mideast (OH-IN-MI) prices. Straight lines represent long-term averages, and solid, wavy lines represent the 3-month moving averages for the 3 nutrients.

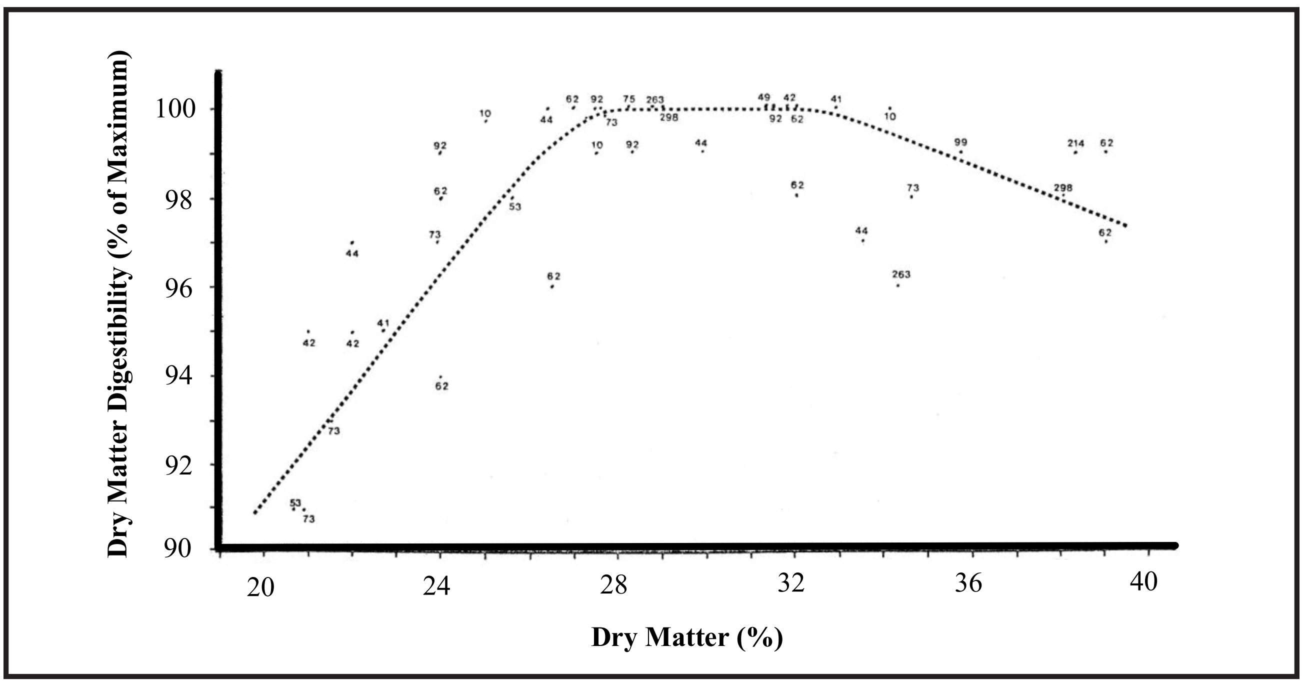

Figure 2. Dry matter digestibility (DMD) as a function of the dry matter in normal maturing corn silage. In this figure, DMD is expressed relative to the dry matter digestibility of silage between 32 and 34% DM. Observations are from many experiments (St-Pierre et al., 1984, 1987).

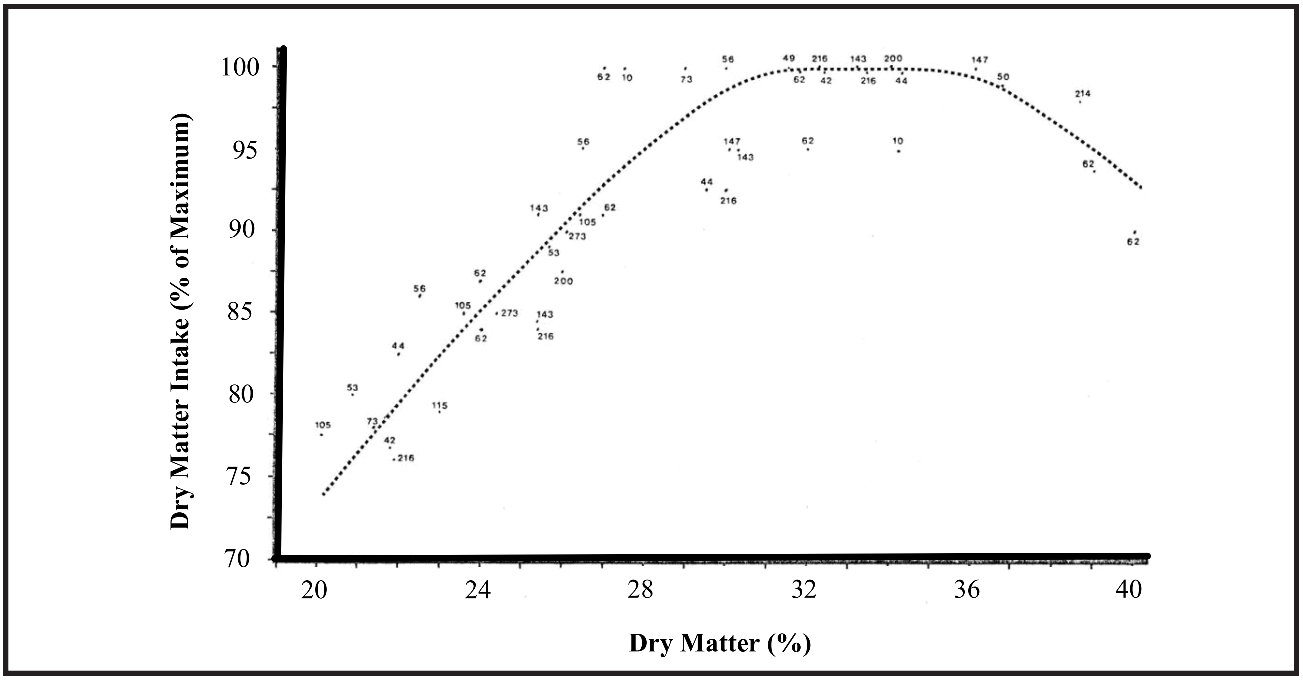

Figure 3. Dry matter intake (DMI) as a function of the dry matter in normal maturing corn silage. In this figure, DMI is expressed relative to the dry matter intake of silage between 32 and 34% DM. Observations are from many experiments (St-Pierre et al., 1984, 1987).