Keys to Producing High Quality Corn Silage in Western Canada

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Take Home Message

- Corn grown in western Canada has potential for high silage yield with high digestible energy content. However, the potential is not always achieved due to the limited growing season.
- Select a hybrid with a corn heat unit rating that matches the long-term rating of the growing location to maximize starch content before frost occurs.
- Corn should be harvested for silage when the whole plant contains 32 to 38% dry matter content. Later maturing hybrids may not reach this target before frost occurs.
- Kernel processing should be conducted at the time of harvest to maximize starch availability in the rumen.

Introduction

With the relatively recent availability of short-season corn hybrids that fit within the prairie maturity zone, corn silage acreages in western Canada continue to expand, reaching 16,200 seeded hectares in Alberta in 2015. Corn silage can be a good alternative to small grain silage for dairy cows because of its high dry matter (DM) yield and high digestible energy content. We believe that about 50% of dairy producers in Alberta are currently growing or have tried to grow corn for silage. However, corn grown in western Canada does not always achieve its potential due to the limited growing season. Many recommendations for producing high quality corn silage originate from studies conducted in the USA, with limited applicability in areas with shorter growing season. Thus, the purpose of our paper is to discuss results from recent studies conducted in western Canada that highlight important factors to consider when producing high quality corn silage for dairy cows in short season areas.

▪ Getting the Agronomics Right

Consult with seed companies and experienced growers to find out what works best in your area. Because corn makes use of the entire growing season, early seeding to take advantage of all available Corn Heat Units (CHU) is necessary despite the risk of spring frost. Usually, corn is seeded at a depth of 3.5 mm (1.5 in) or deeper. Recommended seeding rates are 64,000 to 89,000 seeds/ha (26,000 to 36,000 seeds/ac) with row spacing about 75 cm (30 in) apart. Planting density is greater relative to the cornbelt area of the USA because short season corn plants are smaller. Corn requires at least 500 mm of water per growing season; however, most of the corn grown on the prairies is not grown under irrigation. Corn grown in drier areas needs to be grown at plant densities as low as 45,000 to 50,000 plants/ha. Further, as plant densities increase, silking date, grain and silage maturity may be delayed, having subsequent effects on silage quality (Cusicanqui and Lauer, 1999; Baron et al., 2006).

Pests and diseases can cause large economic losses, with infections of Fusarium being the greatest threat. Specialized equipment requiring substantial investment is needed to seed and harvest corn. A kernel processor on the silage chopper is highly recommended because short season hybrids can have very hard kernels that resist degradation in the rumen unless processed.

▪ Corn Heat Unit (CHU) System

Corn hybrids marketed in Canada are rated for maturity using the CHU system (Brown and Bootsma, 1993). CHUs indicate the number of accumulated thermal units from planting to grain maturity. Hybrids used for silage can have grain maturity ratings 100 to 200 CHU less than those used for grain because they are harvested at a lower DM content before the grain is fully mature. CHU zones in Canada are mapped according to the growing season and long-term weather data. Hybrids are then selected such that their CHU rating fits within the CHU rating of the location in which they are grown. In the USA, the Minnesota relative maturity rating (RM) system is used, which provides a hybrid rating in days. A very early corn hybrid used in western Canada rated at 2000 CHU would have a RM of 52 days and one with 2600 CHU would have an RM of 78 days.

In contrast to barley silage, which can be planted at several dates and still mature within the growing season, there is much less flexibility for corn grown in short-season regions. Corn development, in particular kernel filling, will be limited if the CHU accumulation from planting to harvest is less than the CHU rating of the hybrid. In regions very suited to corn production grain fills rapidly and linearly over a 3 to 4 week period at a rate of 3 to 4% of maximum grain yield per day. Grain filling begins about 14 days after silking. In short season areas, frost can occur before the plant reaches the ideal maturity and as a result starch content will be low and kernel moisture will be above 50%.

■ The Research Study

Corn hybrids were grown for silage in 3 years (2013, 2014 and 2015) in 4 different locations (Lacombe, AB; Lethbridge, AB; Vauxhall, AB; Elm Creek, MB) representing various environmental conditions in western Canada. Long term average CHU received at these locations versus the CHU received during the study are shown in Table 1. At each location, 6 hybrids were planted in replicated plots. Given that each location has a different CHU rating, hybrids grown in each location differed and were selected such that the CHU rating of the hybrids overlapped with the rating of the zone. The CHU ratings of the hybrids used in the study were: Lacombe, 2000 to 2200; Lethbridge, 2000 to 2600; Vauxhall, 2175 to 2650; and Elm Creek, 2175 to 2650. The plants were harvested before and after frost. The results demonstrate the pre-ensiling potential of the forages as harvested.

Table 1. Seeding and harvest information for the corn hybrid study.

Location (long term CHU rating)	Year	Seeding date	Before Frost		After Frost		Water supply (mm)*
			Harvest date	CHU received	Harvest date	CHU received	
Lacombe, AB	2013	10/05	18/09	2113	01/10	2113	276
(CHU=1955)	2014	16/05	16/09	1780	22/09	1780	231
	2015	05/05	15/09	1837	23/09	1842	279
Lethbridge, AB	2013	08/05	22/09	2631	07/10	2692	572
(CHU=2448)	2014	22/05	22/09	2205	27/09	2293	480
	2015	06/05	18/09	2263	29/09	2418	284
Vauxhall, AB	2013	13/05	24/09	2458	01/10	2500	445
(CHU=2538)	2014	19/05	21/09	2168	27/09	2269	354
	2015	07/05	18/09	2182	29/09	2306	283
Elm Creek, MB	2013	17/05	17/09	2292	08/10	2521	313
(CHU=2463)	2014	29/05	08/09	2178	23/10	2178	317
	2015	03/06**	24/09	2308	06/10	2413	253

*Precipitation and irrigation; **Late seeding because of delayed spring.

■ Maximizing Silage Yield

Whole plant DM yield of the corn hybrids during the 3-year study are shown by growing location in Table 2. Yield was highly variable within location from year-to-year and among hybrids. These effects were especially evident in Lacombe in 2014 and 2015. In those years, less than 2100 CHUs were received from planting to harvest causing DM yield of all hybrids to be severely negatively affected. In addition, the 2015 May and June rainfall was 50% of normal. In contrast, in 2013, a good year for growing corn in Lacombe, the average yield was 14.5 t DM/ha. The operating cost of corn silage production is 50% greater than for barley (Baron et al., 2014). If the expected barley silage yield is 10 t DM/ha and the yield of corn silage is ≥14 t/ha, then corn would be an appropriate choice because the energy content of corn silage is about 10-15% greater than that of barley silage. However, in CHU zones less than 2200 the risk of not achieving adequate yield of corn is high.

Table 2. Whole plant dry matter (tonnes/ha) yield of corn hybrids grown in 4 locations in 3 years in western Canada. Only hybrids harvested with 28 to 40% DM content are shown (n = 288).

Location	Average	Minimum	Maximum
Lacombe, AB	9.4	3.5	17.6
Lethbridge, AB	15.4	4.8	23.4
Vauxhall, AB	12.5	6.3	22.4
Elm Creek, MB	19.2	12.1	24.2

▪ Hybrid Selection

Dry matter yield and nutritional value of corn silage is mainly determined by CHUs received from planting to harvest versus the CHU rating of the hybrid. While later maturing hybrids have the potential to maximize yield, kernel development can be challenged by the short growing season and the onset of frost at harvest. In all four locations, differences in yield among hybrids were significantly less than differences in yield from year-to-year caused by variability in weather. However, in general, later maturing corn hybrids had greater yields than earlier maturing hybrids. Thus, producers may be tempted to use a later maturing hybrid to maximize silage yield. However, later maturing hybrids may not reach the desired DM content before the first frost even though yield is high. It may be necessary to sacrifice yield to ensure quality by selecting a hybrid that is rated at or below the CHU zone of the growing location.

▪ Dry Matter Content

Corn should be harvested for silage when the whole plant is 32 to 38% DM. It is important to seed a hybrid that will reach the ideal DM content before frost. A recommendation from USA corn experts is to harvest corn silage when the milk line in the kernel is 1/2 to 2/3 down from the kernel crown; however, in western Canada that recommendation does not hold true because there is a poor relationship between whole plant DM content and kernel milk line. To monitor whole plant DM, cut 5 corn plants/row from 2 rows in different locations in the field. Put the material in a large plastic bag until it can be chopped through a yard or brush shredder. Take several representative samples and determine moisture content using a microwave or Koster moisture tester. Standing corn plants dry down at a rate of about 0.5 percentage units per day (faster in dry and hot weather and after frost), so it may be necessary to start the harvest at a lower DM and end at a higher DM. It is important to avoid silages that are too wet (< 28% DM), as these will cause seepage from the silo and excessive fermentation resulting in high concentrations of total silage acids that reduce dry matter intake (DMI) of cows. It is also important to avoid silages that are too dry (> 40% DM), as these are difficult to pack and are poorly fermented in the silo.

▪ Nutrient Content

The overall nutrient content of the hybrids harvested in our study is presented in Table 2. Chemical composition and digestibility were extremely variable, which would have large impact on expected milk production from cows. It is important to understand the factors affecting this variability.

Table 2. Nutritional composition of corn hybrids from a 3-year study conducted in western Canada (DM basis). Only samples harvested 28 to 40% DM content are shown (n=255).

	DM %	TDN %DM	DMD %DM	CP %DM	Starch %DM	NDF %DM	NDFD %NDF	ADF %DM	ADL %DM
Mean	34.1	65.1	66.5	7.9	24.0	54.0	54.3	28.6	3.1
Min	28.0	54.1	55.5	5.1	3.4	39.6	39.5	19.0	1.0
Max	39.9	73.4	74.4	10.0	47.3	75.1	69.6	39.8	10.4

DM, dry matter; TDN, calculated total digestible nutrient content (NRC, 2001); DMD, DM digestibility (48 h in vitro); CP, crude protein; NDF, neutral detergent fiber; NDFD, NDF digestibility (48 h in vitro); ADF, acid detergent fiber; ADL, acid detergent lignin.

▪ Maximizing Digestibility and Energy Content

Corn silage can be a major source of digestible energy in the diet of dairy cows. Average total digestible nutrient (TDN) content of hybrids in our study was 65% DM, ranging from 54% to 73%. The low TDN forages were those with very low starch content, which affected estimated milk yield (Fig. 2).

There are two distinct components to corn silage: forage (fiber) and grain (starch). As the corn plant matures, its digestible energy content increases, unlike legumes and grasses. Increased energy content with maturity is due to the increase in starch content in the grain portion, despite increased maturity of the fiber in the forage fraction. Starch is almost twice as digestible as fiber, so maximizing energy content of corn silage is mainly achieved by maximizing starch content. Generally speaking, starch content increases in concert with advancement in kernel maturity, which occurs at about 35% grain moisture, depending on location and expected CHU accumulation. Lower mature-kernel moisture percentages occur in regions with higher CHU accumulation.

Interestingly, DMD measured in vitro (48 h) gave a very similar estimate of digestible nutrients, as did TDN, which was calculated from the individual nutrient components. DMD was positively associated with starch content (r = 0.36), negatively associated with NDF content (r = -0.46), and positively associated (r = 0.43) with NDF digestibility (NDFD, measured at 48 h in vitro). Thus, in addition to maximizing starch content, hybrids with low NDF content and high NDFD are desirable. Because starch, NDF and NDFD contents are highly variable in short season hybrids, lab predictions of energy content (TDN or NE_L) from equations developed in eastern Canada or the USA may be highly inaccurate for western Canada, unless these three components are measured.

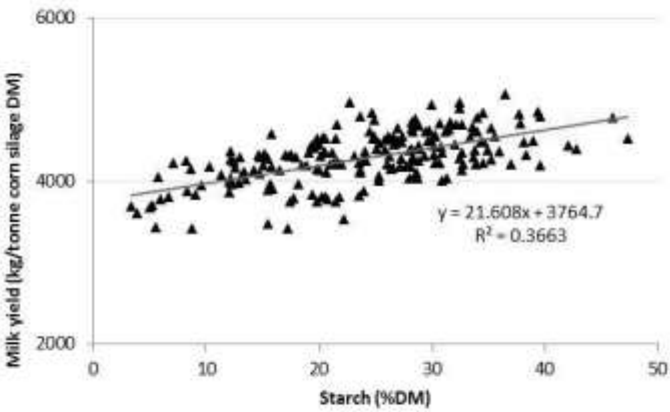

Fig. 2. Effects of starch content of corn hybrids on estimated milk yield using the Milk2006 model. Data from a 3-year study conducted in western Canada. Only samples harvested 28 to 40% DM content are shown (n = 255).

▪ Maximizing Starch Content

High starch content can be difficult to achieve in western Canada due to the short growing season. **Choosing a hybrid with a CHU rating that matches the long-term CHU average of the growing location will allow for adequate kernel development and high starch content in most years.** In the USA, starch content of corn silage almost always exceeds 30% DM. The mean (±SD) starch content of corn silage from 3 labs in the U.S. was 32.6% ± 6.95 (169,620 samples; NASEM, 2016). In our study starch content averaged 24% DM, but there was tremendous variability (range: 3 to 47% DM; Table 2). Starch content of the plant increases with maturity; as the cob is formed starch is laid into kernels. We observed a strong positive correlation between starch content and whole plant DM at harvest (r = 0.68; Fig. 3). Thus, if the hybrid CHU rating exceeds the CHU received in a given year, starch content will be low in the same way that DM content will be low.

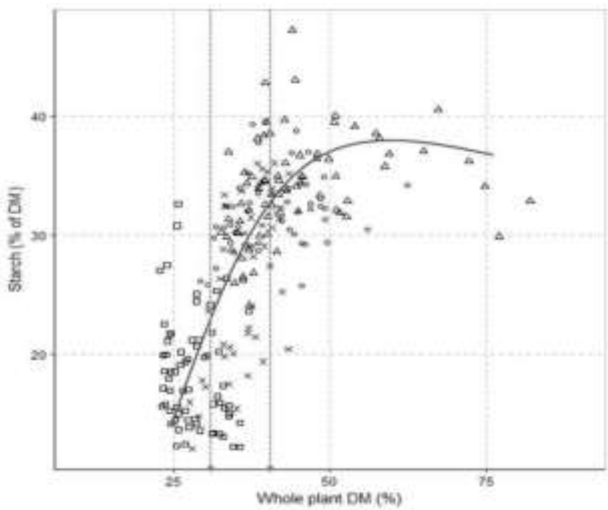

Fig. 3. Starch content as a function of whole plant dry matter (DM) content. Dotted lines with arrows indicate optimum range of DM content at ensiling.

For hybrids grown in Lacombe, characterized by a very short growing season, there was a strong negative relationship (r = -68) between starch content and CHU rating of the hybrids. When the growing season is short, hybrid selection becomes more critical for maximizing starch and consequently energy content of the silage. In the warmest location, Vauxhall, starch content was mainly a function of the CHU received, with smaller differences among hybrids.

To a certain extent starch content can be managed, but these practices may negatively impact silage or DM yield. Choosing an early corn hybrid for a lower CHU zone may sacrifice yield for kernel maturity, but result in more milk per tonne of silage produced. Growing corn at lower plant populations may increase grain yield and starch yield per plant, thereby increasing milk yield per tonne over milk yield per ha. Finally increasing cutting height should increase grain and starch content of silage, but the degree of impact depends on stage of maturity at cutting and hybrid type (Lewis et al., 2004). None of these practices have been thoroughly investigated in the Prairie environment.

■ Kernel Hardness

Hybrids differ in kernel hardness due to moisture content, starch content, and properties of the endosperm. As kernel DM content increases, so does kernel hardness. Short-season corn hybrids grown in western Canada are of both flint and dent origin. Use of genetic populations of flint heritage in short-season corn breeding programs can confer early silking dates, cool temperature and drought tolerance, and resistance to kernel damage during combining. Flint-endosperm hybrids contain a greater proportion of vitreous endosperm in the kernel making the starch harder to degrade because it is protected by a thick protein matrix. Hybrids with greater proportion of floury endosperm (dent hybrids) have more digestible starch because the granules are loosely packed and the surrounding protein matrix is thinner. Hybrids vary in their proportion of vitreous starch. To maximize digestibility of starch in the rumen and minimize the limitations of kernel hardness, **kernel processing should be conducted at the time of harvest**. This is especially needed when corn is harvested relatively dry, and for hybrids with low CHU ratings, as they tend to have more vitreous starch.

We conducted a study to determine whether kernel hardness of short season hybrids affects availability of starch in the rumen, and whether processing can overcome any potentially negative effects. We selected kernels from hybrids grown in Lacombe and subjected them to (median size): coarse (2.3 mm), medium (1.3 mm), and fine (0.7) processing. The processed kernels were incubated in the rumen over time. Examples of two hybrids with higher and lower ruminal starch degradabilities grown at Lacombe are shown in Fig. 4. Processing had a much greater impact on starch availability for the hybrid (39F44) with less degradable starch. However, fine processing did not overcome the limited starch availability, as the starch from the finely processed kernels was still only as degradable as the coarse material from the hybrid (PS226RR) with greater starch availability.

Starch digestibility will increase by about 5 percentage units during the first 60 days in the silo (Der Bedrosian et al., 2012), but even after fermentation in the silo, the starch may not be fully digestible. As a result, a significant fraction of the corn kernels will pass through the cow undigested. The calculation of TDN content of silage assumes starch digestibility in the rumen is 96.7% (NRC, 2001). With unprocessed corn and hybrids with high starch vitreousness, energy content of the silage will be highly overestimated. When fed these silages, cows may increase their intakes to meet energy demands; however, this may not be possible if intake is limited by rumen fill. Thus, milk production will be less than expected.

The bottom-line is that kernel processing is needed for short season hybrids to ensure the starch in the kernels is available for rumen digestion. Degree of kernel processing can be checked by separating kernels from forage in a bucket of water (L. Kung, University of Delaware; personal communication). The heavier kernel pieces will sink, while the lighter forage material will float. Remove the long particles, pour off the water and examine the remaining kernels. Adequate processing is when 90 to 95% of the kernels are cracked, with 65 to 75% equal to or smaller than 1/3 to 1/4 kernel size. Cobs should be more than quartered.

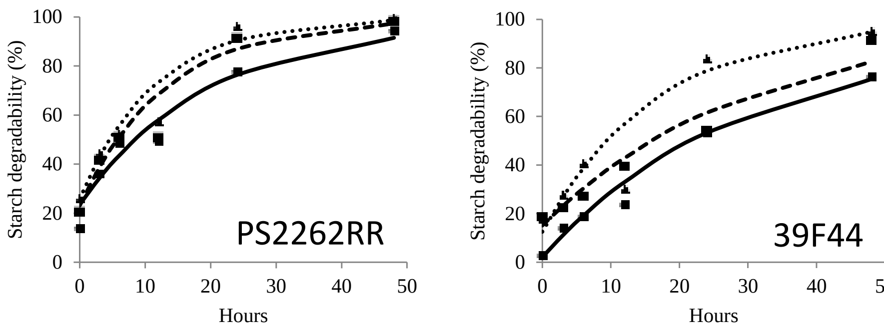

Fig. 4. Starch degradability in the rumen of 2 hybrids grown in Lacombe (39F44, CHU rating = 2000, Pioneer Hi-Bred, Johnson, IA; PS2262RR, CHU rating = 2175, Pickseed, Lindsay, ON). Kernels were processed – coarse, - - medium, and ⋯ fine.

▪ NDF and NDF Digestibility (NDFD)

The concentration of NDF and its digestibility determine the maximum amount of forage that a cow can consume. Increased NDFD of forage increases DMI and milk yield (Fig. 5). Summarizing a number of studies that used non brown mid-rib corn silage, Owens (2014) reported that daily DMI and milk production increased by 0.034 and 0.111 kg/d, respectively, for each one-percentage unit increase in NDFD of forage. Oba and Allen (1999) reported an even larger increase in intake and milk yield per unit increase in NDFD for a range of forages (0.168 and 0.245 kg/d, respectively; Oba and Allen, 1999).

As starch content increases, the NDF content in the stalk, leaves, husk and cobs is diluted out, and thus NDF content of the whole plant decreases. Overall, we observed a correlation between starch content and NDF content of -0.71 (for plants harvested before frost). The NDF content in our study averaged 54%, but ranged from 40 to 75% DM (Table 2). The NDFD (% of

NDF, 48 h) averaged 54% and ranged from 40 to 70%. The NDF content was poorly correlated to NDFD (r = 0.22) meaning that NDFD cannot be predicted from NDF content. Similarly, in a study of 32 corn hybrids grown in Michigan, NDFD-48h ranged from 25 to 60% (Allen et al., 2003), and NDFD was also not related to NDF content. Hybrids with higher NDFD may be more leafy with more husk, shank and cobs, as the NDFD of these portions is typically > 60% in contrast to stalk with NDFD < 38% (Owens, 2014).

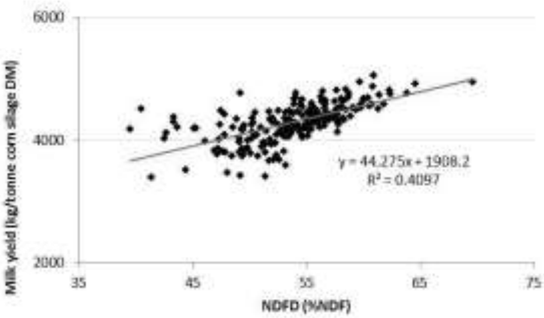

Fig. 5. Effect of variation in NDF digestibility (NDFD) of corn hybrids on estimated milk yield using Milk2006 model. Data from a 3-year study conducted in western Canada (DM basis). Only samples harvested 28 to 40% DM content are shown (n = 255).

■ Harvesting After Frost

If corn plants are immature at the time of frost (< 30% DM), they are often left standing in the field to extend the growing season. Subjecting the plant to frost increases its DM content, which can have beneficial effects for fermentation in the silo and DMI. However, standing corn subjected to frost will dry down very rapidly. Monitoring silage DM percentage is important because ensiling right after frost may be necessary. Kernel processing is a must for frozen corn silage because kernels can dry and harden more rapidly than expected when subjected to frost. After a hard frost, little moisture enters the kernel; husks dry and loosen, reducing the resistance to moisture evaporation from the kernel. Drying winds speed up the kernel dry-down rate.

■ Particle Size Recommendations

In addition to chemical composition, particle size affects fermentation in the silo and DMI of cows. It is recommended to use a theoretical length of cut of 3/8 to 1/2 inch for unprocessed corn silage and 3/4 inch for processed silage. It is important to check actual particle size during harvest because the feed roll speed determines actual particle length. Using a Penn State Forage Separator (3 sieves plus pan), 3 to 8% of the weight should be retained on the top screen to ensure optimum levels of physically effective fiber in the diet. More than 8% will increase sorting and will make packing of the silage difficult. The middle screen should have 45 to 65% of the particles, the lower screen should have 20 to 30% of the weight, and the pan should collect <10%.

■ Fermentation in the Silo

The keys to making good quality and palatable silage in western Canada are the same as elsewhere, and have been covered previously at this conference (Kung, 2009). It is critical to rapidly exclude air from the forage mass during ensiling by packing tightly to promote rapid production of lactic acid and reduction in silage pH. Silos should be sealed rapidly after filling and penetration of air into the silage during storage should be avoided. Use a proven inoculant with supportive research data for corn silage to help improve storage and feed-out.

■ Milk2006 Model

Milk 2006 is a software tool developed at the University of Wisconsin to help dairy producers predict the potential amount of milk that can be produced accounting for corn silage nutritive value (Schwab et al., 2003; https://shaverlab.dysci.wisc.edu/spreadsheets/). Inputs into the calculation include chemical composition, NDFD, and whether corn is processed. The potential DMI and TDN content of corn silage are estimated, and then used to predict milk production. We used the Milk2006 model to compare the hybrids grown in our study (Table 3). The variation in estimated DMI from the corn silages was due to NDF content and NDFD, while differences in estimated milk yield per tonne of silage reflected differences in TDN and DMI. The estimated energy content was then combined with DM yield to estimate milk yield per hectare of silage.

Table 3. Estimated energy content, corn silage intake, and milk yield from a 3-year study conducted in western Canada based on the Milk2006 model. Only samples harvested 28 to 40% DM content are shown.

Location	Est. NE_L (Mcal/kg DM)	Max. CS DMI (kg/d)	Estimated milk yield (tonne/tonne DM of CS)	Estimated milk yield (tonne/ha of CS)
Lacombe, AB (n = 89)				
Mean	1.46	10.3	3.45	32.43
Min	1.21	8.4	3.00	13.74
Max	1.71	13.5	4.29	66.06
Lethbridge, AB (n=48)				
Mean	1.53	11.6	3.66	69.21
Min	1.39	8.6	3.15	43.96
Max	1.64	14.2	4.06	81.26
Vauxhall, AB (n = 85)				
Mean	1.46	10.2	3.44	47.37
Min	1.21	7.1	2.53	28.95
Max	1.68	14.0	4.18	67.17
Elm Creek, MB (n=33)				
Mean	1.49	10.5	3.51	67.38
Min	1.40	9.2	3.17	43.88
Max	1.64	12.2	4.04	86.57

▪ Conclusions

Chemical composition and digestibility of corn silage grown in western Canada are highly variable, which will affect intake and milk production of cows. At the very minimum, it is important to analyze corn silage for starch, NDF, and NDFD content, as these components will determine intake potential and energy (TDN and NE_L) content. It is important to harvest silage at the optimum DM content to promote fermentation in the silo. Because later maturing hybrids may not reach the desired DM content before the first frost occurs, it may be necessary to sacrifice yield to ensure quality by selecting a hybrid that is adapted to the local growing environment. Furthermore, to maximize the energy content of the silage, the starch in the silage needs to be available, and thus kernel processing is needed.

▪ References

Baron, V., K. Beauchemin, P. Juskiw and R. R. Doce. 2014a. Managing short-season corn and small-grain silage in Western Canada. In: Oba, M. (ed.) Proc. 35th Western Nutrition Conference, 24-25 Sept, Edmonton, AB, pp 147-161.

Baron, V.S., H.H. Najda and F.C. Stevenson. 2006. Influence of population density, row spacing and hybrid on forage corn yield and nutritive value in a cool-season environment. Can. J. Plant Sci. 86: 1131-1138.

Brown, D. M. and A. Bootsma. 1993. Crop heat units for corn and other warm-season crops in Ontario. Ontario Ministry of Agriculture and Food, Toronto. Factsheet No. 93-119, Agdex 111/31, 4 p.

Cusicanqui, J.A. and J.G. Lauer. 1999. Plant density and hybrid influence on corn forage yield and quality. Agron. J. 91:911-915.

Der Bedrosian, M. C., K. E. Nestor Jr. and L. Kung Jr. 2012. The effects of hybrid, maturity, and length of storage on the composition and nutritive value of corn silage. J. Dairy Sci. 95:5115–5126.

Kung, L. Jr. 2009. Getting the most out of your silage. WCDS Advances in Dairy Technology 21:349-357.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2016. Nutrient Requirements of Beef Cattle, Eighth Revised Edition. Washington, DC: The National Academies Press. doi:177226/19014.

NRC. 2001. Nutrient Requirements of Dairy Cattle. 7th Revised Edition, National Academy Press, Washington, D.C.

Lewis, A.L., W.J. Cox and J.H. Cherney. 2004. Hybrid, maturity and cutting height interactions on corn forage yield and quality. Agron. J. 96:267-274.

Oba, M. and M. S. Allen. 1999.Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Owens, F. 2014 Maximizing nutritional value of corn silage: starch vs. NDF digestibility. In: Oba, M. (ed.) Proc. 35th Western Nutrition Conference, 24-25 Sept, Edmonton, AB, pp 121-146.

Schwab, E. C., R. D. Shaver, J. G. Lauer and J. G. Coors. 2003. Estimating silage energy value and milk yield to rank corn hybrids. Anim. Feed Sci. Technol. 109:1-18.