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Effects of Maturing Stage of Corn Hybrids on Silage Yield, Feeding Value for Dairy Cows and Milk Production in a Cold Region of Japan

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ABSTRACT : This experiment was conducted to evaluate the effects of differently maturing corn hybrids on silage production and milk production per unit area in the northern part of Japan, where grain development occurs under decreasing ambient temperature. Both hybrids were harvested at the same time. The stages of maturity for the early-maturing hybrids (EH; 80 d relative maturity) and the mid-maturing hybrids (MH; 93 d relative day) were early dent and late dough stage, respectively. The plant yields for MH were higher than those for EH. The dry matter (DM) content of MH was lower than that for EH, and the effluent loss for MH silage was greater than that for EH silage. Therefore, the DM yields of prepared silage per area were similar for both treatments. Twelve multiparous mid-lactation Holstein cows (58±13 days in milk) were fed diets based on EH or MH silage in a crossover design with two 3-week periods. Cows were fed 3 kg of hay crop silage (DM basis) and either EH or MH silage *ad libitum*, and concentrates were supplied to meet NRC requirement for dairy cows. Silage DM intake for EH was found to be higher ($p<0.05$) than that for MH (10.0 vs. 9.1 kg/day). Milk production and milk composition for EH were similar to those for MH. Feed efficiency per total feed intake was similar in both treatments, although the feed efficiency per concentrate intake tended to be higher for the EH than that for the MH diet. These results indicate that differences in maturation in corn hybrids affect the effluent production of silage and the silage intake of dairy cows. It may be advantageous to plant early hybrid corn with a reduction in effluent production of silage as well as a reduction in purchased feed costs for dairy cows under the climatic conditions of the northern part of Japan. (**Key Words :** Corn Silage, Maturity, Effluent Loss, Intake, Milk Production)

INTRODUCTION

Corn (Z*ea mays*. L) silage is a major component of diets fed to dairy cows because of the high energy yield per unit area, the ease of mechanization and storage, and the uniformly high feeding value. Even though the grain-to-stalk ratio and whole plant dry matter (DM) yields are important determinants of the adaptability of a corn hybrid to silage production, the most important determinant is digestible DM per unit area, or for dairy farmers, milk yield per unit area. In northern climates such as the Hokkaido region of Japan where grain development occurs under decreasing temperatures, determining the most suitable hybrid is important for maximum milk production per unit area. The moisture content of whole plant corn (WPC) is inversely related to the stage of maturity at harvest, and the DM content of early-maturing hybrids (EH) is probably higher than that of mid- or late-maturing hybrids when they are planted in the same region and harvested at the same time. The DM content of herbage affects not only the plant DM yield but also the effluent loss. McDonald (1991) has reported that the volume of effluent produced from a silo is primarily influenced by the DM content of the ensiled crop, and that no effluent would be formed from silage under conditions when the DM content of ensiled crop is approximately 290 g kg^{-1}or more.

Therefore, differences in maturity among corn hybrids may affect not only the DM yield per unit area (Valdez et al., 1989), the fermentative quality of silage and the nutritive value of corn silage (Bal et al., 1997), but also the effluent loss of silage and the milk production per unit area. Agronomic trials have shown that the DM yields of whole plant corn are maximized by harvesting at the two-thirds

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milk line to the black-layer stage (Ganoe and Roth, 1992). However, Harrison et al. (1996) reported higher milk production for cows fed silage from WPC harvested at the one-half milk line stage versus that for cows fed silage from WPC harvested at the BL stage. Johnson and McClure (1968) have observed that the highest digestible energy per unit area is achieved by harvesting between the dough dent and glaze stage. These reports indicate that the optimum milk production per unit area is affected by the maturity of corn silage. There is limited information concerning the effects of maturity of corn hybrids on effluent loss and silage production or on lactating performance in northern climates where grain development occurs under decreasing temperature. Therefore, the following experiments were conducted to evaluate the effects of maturation with two differently maturing hybrids used as silage in the diets of dairy cows on the silage yield per unit area, on DM intake (DMI) of corn silage and on milk production and composition.

MATERIALS AND METHODS

Silage preparation

The early-maturing hybrid (EH) “Noruda (80 d relative maturity) and the mid-maturing (MH) hybrid” P3795 (93 d relative maturity) were planted on May 25 at 75,000 plants/ha in the Hokuren Livestock Experimental Farm, located in the northwest of Hokkaido. The fields had similar soils, and the same agronomic practices were used for the two corn hybrids. Both hybrids were harvested with a conventional forage harvester with a theoretical chop-length of 0.95 cm on September 25 and were collected into a wagon. The total yield was measured by weighing individual wagonloads of chopped corn. The chopped forages were ensiled in 20-m long silage bags for 210 d before the start of the feeding trial to dairy cows, and were simultaneously ensiled in four steel silos (200 L) for measurement of the effluent losses of the silage.

Experimental design and diets for the lactation trial

Prior to the lactation trial, the apparent digestibility of nutrients and the total digestive nutrients for both types of corn silage were measured by the total fecal collection method using eight mature wether (average BW = 72±12 kg). Wether were divided into two groups and fed either EH or MH silage at a maintenance allowance (MAFF, 1995) once daily as a sole diet. The experimental period consisted of a 7-day adaptation to the diets and 7 days of fecal sample collection. Silage and fecal samples were dried in a forced-air oven for 48 h at 60°C and then ground through a Wiley mill (1-mm screen) followed by chemical analysis.

For 12 multiparous Holstein cows with an average BW of 657±75 kg, DIM of 58±13, and BCS of 3±0.3, a crossover design was used with three 3-wk periods. Cows were housed in individual tie stalls, exercised daily for 2 h, and milked twice daily in their stalls at 05:00 and 16:00 h. Cows were offered hay-crop silage (3 kg DM) and either EH silage or LH silage *ad libitum*, then supplemented concentrates were offered to the cows to meet the NRC requirements for dairy cows (1989).

The hay-crop silage was offered to cows at 5:00 AM once daily, and corn silages and concentrates were offered at 5:00 AM, 4:00 PM, and 10:00 PM three times daily. The cows had free access to water and mineral blocks at each stanchion. The first 2 weeks of each experimental period was for diet adaptation, with feed, orts, feces and milk sampling being carried out during the last week of each period. Milk weights were recorded at each milking, and milk fat and protein concentrations were determined in AM and PM samples obtained on 2 consecutive days during the last week of each period by infrared analysis (Milko scan, Fujihira Co. Ltd.). Body weight and body condition scores were recorded at the same time after the AM milking on the day before the start of the trial and on the last day of each period. The amounts of feed offered and orts were recorded daily. Fecal samples were collected daily five times during the last 5 days of each period. Fecal samples were dried in a forced-air oven at 60°C for 48 h and then ground through a Wiley mill (1-mm screen). A fecal composite was made for each cow within the period for chemical analysis.

Chemical analysis

Hay-crop silage, corn silages, and concentrates were sampled daily during the last week of each period and pooled by treatment within the period for nutrient analyses. Orts were sampled on days 15 to 21 of each period and composites by cow within the period. Samples were dried in a 60°C forced-air oven for 48 h and then ground through a Wiley mill (1-mm screen). Feed and ort composites were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), acid detergent fiber (ADF), acid detergent lignin (ADL), neutral detergent fiber (NDF), and starch. DM was determined by oven-drying at 135°C for 2 h, and OM was calculated as weight loss on ashing at 550°C. The total nitrogen content was determined by the Kjeldahl Method (AOAC, 1990), and the CP content was calculated as the nitrogen ×6.25. NDF was analyzed by the method of Goering and Van Soest (1970), with the exception that sodium sulfite and decahydronaphthalene were omitted. ADF and ADL were assayed by a modification (Horii and Abe, 1972) of the method of Goering and Van Soest (1970). Cellulose and hemicellulose concentrations were estimated by the subtraction of ADL from ADF and ADF from NDF, respectively. Starch was measured by an enzymatic method after samples were hydrolyzed with perchloric acid. Silage

Table 1. Plant and silage yield and effluent loss of corn hybrids[1] used in the experiment

	Hybrids	
	Early-maturing	Mid-maturing
Whole plant		
Dry matter		
(g/kg)	280	251
Yield		
(ton/ha)	57.57	70.68
(ton DM /ha)	16.12	17.74
Effluent loss[2]		
(%)	1.66	7.69
(ton/ha)	0.96	5.44
Silage		
Dry matter		
(g/kg)	273	245
Yield		
(ton/ha)	56.61	65.24
(ton DM/ha)	15.45	15.98

[1] Field population densities were 75,000 plants/ha.
[2] Effluent loss (%) was calculated as the ratio of silage weight to the preserved herbage weight.

pH was determined as follows: approximately 70 g of duplicate samples was diluted with distilled water to 210 g in a blender jar. Samples were filtered through double layers of cheesecloth to measure pH and VFA. The pH was measured using a glass electrode pH meter, and VFA was measured by gas chromatography.

Statistical analysis

Cow performance and digestibility data were analyzed using the general linear models procedure of SAS (1988) for a crossover design. All mean comparisons were by the least significant difference method after a significant ($p<0.05$) treatment effect. The significance of effects was designated at $p<0.05$ unless otherwise noted.

RESULTS AND DISCUSSION

The harvesting stage of maturity for EH was dough dent and that for MH was milk early dough, respectively. The plant yield, DM content, percentage of effluent loss, and silage production are shown in the Table 1. The plant yield for MH hybrid was higher ($p<0.05$) than that for EH by approximately 20%. The moisture content for the MH hybrid was higher than that for the EH hybrid and is related to kernel development. This trend has also been reported by Hunt et al. (1989).

The effluent losses as measured by the effluent production from the experimental steel silo were 1.7% of the storage weight for EH and 7.7% for MH, respectively. These values were higher than estimated values using the equation of Bastiman (1976). The difference in the effluent loss between the actual value in our study and the estimated value by the equation of Bastiman (1976) may be due to several factors such as the silo type, surface pressure, and nature of the crop. The effluent production calculated using values of effluent loss obtained from experimental steel silos was 0.96 ton/ha for EH and 5.44 ton/ha for MH, respectively. Therefore, the DM yield of silage production per hectare was estimated to be similar for EH to that for MH, although the silage production per area was calculated to be 10% higher for MH than for EH without the effluent loss.

The chemical compositions of the whole plant and silages are presented Table 2. The concentrations of NDF and ADF were higher for the MH hybrid than those for the EH hybrid in both herbage and silage. This difference is related to the increase in the proportion of grain in WPC as it matures. Similar results were observed by Valdez et al. (1989) with early- and late-maturing corn planted at high population densities. Higher lignin and lower starch contents were observed for MH hybrids than that for EH hybrids in both herbage and silage. McDonald et al. (1991) have suggested that fermentation losses can be restricted somewhat by ensiling the higher dry matter content with more mature silage (300 to 350 g/kg). In this study, even early-maturing hybrids could not mature to the 2/3 milk line

Table 2. Chemical composition of corn silages used in the experiment

	EH		MH	
	Herbage	Silage	Herbage	Silage
pH		3.9		3.9
Organic matter (OM, g/kg DM)	951	949	942	943
Crude protein (CP, g/kg DM)	78	76	76	75
Neutral detergent fiber (NDF, g/kg DM)	409	439	436	477
Acid detergent fiber (ADF, g/kg DM)	237	253	243	307
Acid detergent lignin (ADL, g/kg DM)	27	30	30	41
Starch (g/kg DM)	223	255	192	217
Volatile basic nitrogen (g/kg total N)		67		81
Lactic acid (g/kg DM)		48.7		53.1
Acetate (g/kg DM)		25.6		29.0
Propionate (g/kg DM)		0.1		0.2
Butyrate (g/kg DM)		0.0		0.0

Silages were made from different maturing hybrid: EH = Early-maturing hybrid, MH = Medium maturing hybrid.

Table 3. Effects of the maturing of corn hybrids on digestibility in sheep

	Silage		SE
	EH	LH	
OM[1]	0.611	0.577	0.02
CP[1]	0.454	0.491	0.02
NDF[1]	0.377	0.356	0.03
ADF[1]	0.397	0.396	0.02
Total digestible nutrients (TDN)	0.619	0.582	0.02

[1] Abbreviations see Table 2.

stage under the cold weather condition in the northern part of Hokkaido in Japan, which resulted in a low DM content of WPC.

The silage pH was similar for both types of silage. Lactate and acetic concentrations for MH silage tended to be higher than for EH silage. This result might be caused by the higher moisture content of MH silage compared with that for EH silage. However, both corn silages showed good fermentative quality, with low pH and low concentrations of ammonia-N.

The apparent digestibilities for sheep fed either EH or MH silage are shown in Table 3. The total digestive nutrient (TDN) of EH silage tended to be higher than that of MH silage ($p<0.1$). However, no differences were observed for the apparent digestibilities of nutrients among silages because of the high variability of values among sheep. Generally, it is considered that the optimum harvesting stage of corn silage is the 2/3 milk line stage, and the TDN content of corn silage harvested at the 2/3 milk line stage is approximately 65% in Japan. In the present study, the TDN contents of EH and LH silage were 61.1 and 58.8%, respectively. The low TDN content of corn silage in this study was due to cold weather in 1998 when the study was carried out. Even the early-maturing hybrid could not mature to the yellow ripe stage under the wet and cool conditions at the time of harvest.

Table 4. Ingredients and chemical composition of total diets used in the lactation experiment

	Diets	
	EH[1]	MH
Ingredients (%)		
EH corn silage	43.4	-
LH corn silage	-	39.7
Timothy-clover silage[2]	11.6	11.9
Beet pulp [2]	9.3	9.4
Soybean meal[2]	14.6	9.8
Compound feed[2, 3]	20.2	28.4
Mineral supplement[4]	0.8	0.8
Chemical composition[5] (g/kg)		
OM	933	933
CP	176	169
NDF	339	346
ADF	201	216
Starch	180	180
TDN[6]	714	708

[1] Silage were made from different maturing hybrids: EH = Early-maturing hybrid, MH = Mid-maturing hybrid.
[2] The chemical compositions of timothy-clover silage, beet pulp, soybean meal, and compound feed (DM basis) were 909, 920, 932, and 934 g/kg for OM; 102, 126, 484, and 239 g/kg for CP; 596, 363, 109, and 144 g/kg for NDF; 340, 211, 94, and 87 g/kg for ADF, respectively.
The starch content of the compound feed was 316 g/kg.
[3] Power lead 20 (Kumiai Shiryou Ltd.)
[4] Contained 35% Ca, 5% P, 6% Mg, 0.1% Zn, 0.1% Fe, 0.025% Mn, 0.01% Co, 0.005% Cu and 0.005% I.
[5] Abbreviations see Table 2.
[6] Estimated from the feeding standard of NRC (1989).

The ingredient and nutrient composition of the experimental diets used in the lactation trial are presented in Table 4. The feed intake, the forage-to-concentrate ratio, and the nutrient sufficiency for the feeding standard of NRC are presented in Table 5. The DMI of EH silage was found to be 10.0 kg/day, which was significantly higher than the 9.1 kg/day of MH silage. However, the total feed intake was similar among treatments because of the concentrates

Table 5. Feed intakes, forage-to-concentrate ratio, and the nutrient sufficiency with regard to the feeding standard of NRC

	Diets		SEM	Significant difference
	EH	MH		
Feed intake				
Corn silage (kg DM/day)	10.0	9.1	0.12	p<0.01
Grass silage (kg DM/day)	2.7	2.7	0.03	NS
Concentrates (kg DM /day)	10.4	11.0	0.11	p<0.01
Nutritional intake[2]				
DM (kg/day)	23.0	22.8	0.08	NS
CP (kg/day)	4.0	3.9	0.02	p<0.05
NDF (kg/day)	7.8	7.9	0.04	NS
ADF (kg/day)	4.6	4.9	0.03	p<0.05
TDN (kg/day)	16.4	16.2	0.06	p<0.05
Forage-to-concentrate ratio	57:43	54.:46		
Nutrient sufficiency to feeding standard of NRC				
TDN (%)	94	96	2.5	NS
CP (%)	100	95	1.3	p<0.05

Silages were made from differently maturing hybrids: EH = Early-maturing hybrid, MH = Mid-maturing hybrid.
Abbreviations see Table 2.

Table 6. Average values of milk yield, milk composition, live weight, and feed efficiency of dairy cows fed on corn silages of different maturities

	Diets		SEM	
	EH	MH		
Composition				
Fat (%)	3.73	3.76	0.11	NS
Protein (%)	2.89	2.87	0.04	NS
Solids-not-fat (SNF) (%)	8.53	8.48	0.03	NS
Yield				
Actual milk (kg/d)	43.0	43.4	0.56	NS
4% FCM (kg/d)	41.1	41.6	0.56	NS
Protein (kg/d)	1.2	1.2	0.01	NS
Fat (kg/d)	1.6	1.6	0.04	NS
Mean BW (kg)	683	680	3	NS
BW change (kg/d)	4	3	2.8	NS
Body condition score (BCS)	3.07	2.98	0.06	NS
Feed efficiency	1.82	1.79	0.03	NS

Silages were made from differently maturing hybrids: EH = Early-maturing hybrid, MH = Mid-maturing hybrid.
SEM = Standard error of the mean.
NS; not significant (p>0.05).
The feed efficiency was the ratio of FCM (kg) to feed intake (kg DM).

offered to cows to meet the nutritional requirements for dairy cattle (NRC, 1989). Cows consumed 11% more (p<0.05) DM of EH silage than MH silage, which is in agreement with some of earlier studies in which the effects of the maturity of corn silage on DMI in dairy cows were evaluated (Huber et al., 1965; Bal et al., 1997). The DMI of corn silage in this study was lower than in previous studies (Oshita et al., 1999; Milligan et al., 2002), for which it was reported that the consumption of corn silage DM was approximately 13.0 kg/day. The difference in corn silage intake might result from the difference in the maturity of the corn.

Steen et al. (1998) have observed a negative relationship between forage moisture content and forage DM intake; as such, the difference in DMI between EH and MH silage might be due to a difference in moisture content. The potential for the low DMI of MH silage with high moisture could be related to its low pH (Shaver et al., 1984). However, the silage pH was similar among treatments in our trial, so the lower DMI for MH silage could not be attributed to a lower silage pH. Generally, feeds high in fiber (NDF or ADF) typically take longer to degrade than less fibrous feeds. In the present study, the EH silage had less NDF, ADF, and ADL compared to the MH silage. Fibrous components of EH silage might be more degradable and more passable from the rumen, and it might cause a higher DM intake for EH silage compared with MH silage.

The total feed intake for the MH diet was similar to that for the EH diet, and the sufficiency of TDN in relation to the feeding standard of NRC for the EH and MH diet[s was found to be 94 and 96%, respectively.

Milk yield, milk composition, BW, and feed efficiency are shown in Table 6. There were no significant differences in milk yield, FCM yield, and milk composition. No treatment difference (p>0.05) was observed for average BW or BW change.

Our result is inconsistent with the results of Bal et al. (1997) and Valdez et al. (1989), who observed higher milk yields as the silage maturity increased, primarily due to the greater silage DM intake. The inconsistency of results between the previous study and our study might result from this difference in feeding methods, total mix ration (TMR) diet for previous study, whereas corn silage *ad libitum* and concentrates were offered to meet the NRC requirement (1989) in this study.

These results indicate that differences in maturation among corn hybrids affect the silage production and forage intake for dairy cows. Consequently, it may be advantageous to plant early hybrid corn to reduce effluent production of silage and to decrease purchased feed costs in northern climates like the northeast of Hokkaido where grain development occurs under decreasing temperatures.

IMPLICATIONS

Silage production per area for early-maturing corn was found to be similar to that for mid-maturing corn due to the higher DM content and less effluent loss; while the fresh plant yield appears to be lower for early-maturing hybrids than for mid-maturing hybrids. Cows consuming the early-maturing corn silage consumed 10% more DM than those consuming mid-maturing corn. However, no differences were observed in milk production, composition, production efficiency, or apparent digestibilities. The data suggest that it is advantageous to plant early-maturing hybrids to reduce effluent loss of silage and to decrease purchased feed costs in cool regions like the east of Hokkaido.

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