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Influence of Hybrid and Maturity on the Nutritional Value of Corn Silage for Lactating Dairy Cows 1: Intake, Milk Production and Component Yield

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Abstract: Two Iranian corn hybrids, Single Cross 704™ (S.C.704) and Three Way Cross 647™ (T.W.C.647) were used to evaluate the effects of hybrid and maturity on intake, milk yield and composition when corn was fed as silage in the diet of Holstein cows. Corn hybrid S.C.704 harvested at one-third milk-line and black layer (BL) while harvesting times for hybrid T.W.C.647 were at one-third and two-third milk-line maturity stages. Eight multiparous cows were used in a replicated experiment with a 4×4 Latin square design with 21-d periods. Diets containing 50% forage (67% corn silage and 33% chopped alfalfa hay) and 50%concentrate (DM basis) were fed as total mixed rations. Milk, 3.5% FCM and ECM, fat yield, protein percentage and production did not differ among treatments. Dietary treatments affected milk fat, lactose and total solids concentrations. Milk fat concentration differed among treatments and decreased with advancing stage of maturity which was significant for T.W.C.647. Dry matter intake, silage and nutrients intake were affected by treatment ($P<0.05$) and was the lowest for hybrid S.C.704 harvested at BL. Although cows fed corn silage harvested at BL consumed less dry matter, but they produced milk more efficiently (1.43 vs. 1.28 to 1.31). Hybrid effect was only observed for lactose and total solids and no hybrid effect was observed for milk production, fat and protein content and yield. Corn silage hybrids at 37% of dietary dry matter intake did not have any major impact on dairy cattle performance and nutritive value of the hybrids harvested at one-third milk-line.

Key words: Whole plant corn silage, milk production, dairy cows

Introduction

Whole plant corn silage is a popular forage source for ruminants due to its high yielding properties, energy content, relatively high palatability, and incorporating easily into TMR (Cherney *et al.*, 2004; Kononoff and Heinrichs, 2003; Kononoff *et al*., 2003; Moss *et al*., 2001; Neylon and Kung, 2003; Pierre *et al.*, 1987). Thus it is an important forage component of dairy feeding programs in Iran too. Recently, agronomists, nutritionists, and dairy producers have placed increased emphasis on factors effecting the nutritive value of whole plant corn silage (WPCS) (Bal *et al*., 2000).

Hybrid, maturity, and moisture content at feeding are some of the factors that can alter the nutritive value of corn silage (Johnson *et al*., 2002a; Kononoff *et al*., 2003). Previous papers have documented the effects of hybrid (Barriere *et al*., 1995; Huhtanen *et al*., 2003) and maturity (Bal *et al.*, 1997; Harrison *et al*., 1996) of corn silage on performance of lactating dairy cows fed corn silage-based rations.

Several studies have shown differences between hybrids in nutrient composition of WPC (Hunt *et al*., 1993; Johnson *et al*., 1985; Qiu *et al*., 2003; Xu *et al*., 1995). Barriere *et al*. (1995) and Oba and Allen (1999) reported improved DMI and milk yield in dairy cattle due to hybrid-related improvements in whole plant corn nutritive value. Commercial corn hybrids that are to be harvested for silage have been selected on the basis of agronomic traits such as grain yield and disease resistance (Bal *et al*., 2000; Clark *et al*., 2002; Hunt *et al*., 1993) and differences in the nutritive value of WPCS related to corn genetics have been ignored (Bal *et al*., 2000).

The stage of maturity at harvest is a major factor in determining the nutritive value and fermentation characteristics of corn silage (Filya, 2004; Johnson *et al*., 1999) therefore, in an attempt to optimize nutrient value and achieving high milk production , ensiling at proper stage of kernel maturity as measured by the milk-line (ML) is often recommended (Bal *et al*., 1997; Moss *et al*., 2001).

Studies have concluded that ensiling corn at ½ to 3/4 ML is often considered optimum for yield, DM content and quality traits (Hunt *et al*., 1989; Wiersma *et al*., 1993). Huber *et al*. (1965) reported increase in silage DMI and in milk production of cows as the maturity of whole plant corn at harvest advanced from the soft stage to the hard dough stage whereas Harrison *et al*. (1996) found higher milk production for cows fed silage from WPC harvested at the one-half milk-line stage versus the BL stage.

Up to now, there is no published study available comparing performance of dairy cows consuming diets containing the Iranian commercial corn hybrids

Table 1: .Agronomic data of the corn hybrids harvested at different maturity

Hybrid period (Day)	Stage of maturity	Planting date	Harvesting date	Growth
S.C.704[1]	1/3 ML[2]	9 June 2004	26 September	110
S.C.704	BL[3]	9 June 2004	14 October	128
T.W.C.647[4]	1/3 ML	7 July 2004	19 October	106
T.W.C.647	2/3 ML[5]	9 July 2004	3 November	120

[1]S.C.704= Hybrid Single Cross 704. [2]1/3ML= One-third milk-line. [3]BL= Black layer. [4]T.W.C.647= Hybrid Three Way Cross 647. [5]2/3ML= Two-third milk-line.

Table 2: Composition of total mixed rations

Ingredient	(% of DM)
Corn silage[1]	33.77
Alfalfa hay, chopped	16.62
Barley grain, ground	9.55
Corn grain, ground	5.73
Cotton seed meal	9.55
Whole cotton seed	5.73
Soybean, 44% CP	9.17
Beet sugar pulp, dried	7.64
Salt	0.1
Sodium bicarbonate	0.8
Mineral-vitamin premix[2]	1.34

[1]Diets were contained corn silages of two hybrid harvested at different kernel maturity.

[2]Premix contained (DM basis): 12% Ca, 18.6% Na, 2% P, 2.05% Mg, 2.25 g/kg Mn, 1.25 g/kg Fe, 7.7 g/kg Zn, 3 g/kg S, 14 mg/kg Co, 1.25 g/kg Cu, 56 mg/kg I, 10 mg/kg Se, 250,000 IU/kg vitamin A, 50,000 IU/kg vitamin D3, 1500 IU/kg vitamin E

harvested at varying maturity used as silage. Therefore, the objective of this experiment was to evaluate hybrid and maturity effects of corn silage on nutrients intake, milk production and component yield of lactating dairy cows.

Materials and Methods

Planting and harvest: In this study, Single Cross 704 (S.C.704™) (125-135 d maturity, late maturing) and Three Way Cross 647 (T.W.C.647™) (125-135 d maturity, late maturing), two corn hybrids, provided by seed and plant improvement institute (Karaj, Iran) adapted to the region of Isfahan Province were used. The former is a hybrid that has been produced from controlled inbreeding between two inbred lines. The latter is produced from controlled inbreeding between a single cross hybrid and an inbred line.

The two hybrids were sown with equal planting rate of 75,000 seed/ha on about 3-ha adjacent fields with rows 0.75 m apart in early June and early July 2004 for hybrid S.C.704 and T.W.C.647, respectively at Isfahan University of Technology teaching and research farm (Isfahan Province, Iran, 32 32 N 51 23 E 1630 m above sea level). Each hybrid fields were divided into two plots of 1.5 ha each which were harvested at two different kernel maturity stages. Agronomics data of corn hybrids are presented in Table 1.

According to the primary design of experiment, T.W.C. 647 hybrid was harvested at 1/3 and 2/3ML, however second harvesting time of S.C.704 hybrid at 2/3 ML delayed to BL due to silo construction problems.

Forages were harvested using a conventional chop harvester (Claas saulgau GMBH, 7968 Saulgau) with the same theoretical length of 2 cm , ensiled in separate trench silos, sealed with two layers of plastic sheeting and covered with clay then allowed to ferment at least for 70 d before opening. Three representative samples of fresh chopped maize were collected at each stage and stored at -17^{o}C.

Cows, management and experimental design: Eight multiparous Holstein cows averaging 178±33 DIM, were assigned to a replicated 4×4 latin square design with 21-d periods (16 d for adaptation and 5 days for data collection). Four diets with different hybrid and maturity stage, were formulated to meet NRC requirements containing corn silage, chopped alfalfa hay and concentrate mix of 33.77, 16.62 and 49.61 percent, respectively (Table 2). Cows were kept in individual stalls and had free access to salt block and water.

Cows were fed enough TMR in two separate feedings at 0800 and 1600 h to allow 5-10% orts. The a.m. and p.m. feedings constituted 40 and 60% of the total feed offered each day, respectively. Cows were milked three times daily at 0600, 1300 and 2100 and allowed for 30-min exercise period outside before milking at 1300.

At the beginning of each period, representative samples of experimental silages were collected and stored at -17^{o}C for later analyses.

Chemical composition of fresh chopped whole plant corn and experimental silages are presented in Table 3. Diets were adjusted at the beginning of each period for DM changes in the corn silage.

Feed and milk sampling and analysis: On the last five days of each periods, offered and refusal feed weights were measured for DMI determination. Also feed samples of each treatment were composited by mixing equal amounts to have 3 representative samples and frozen at $-17\,^{o}$C for later analyses.

At the end of the experiment, all samples were oven-dried to a constant weight at 55^{o}C, ground to pass a 1-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA) and analyzed for organic matter by ashing in a muffle at 600^{o}C overnight and CP according

Table 3: Chemical composition of fresh corn forage and experimental silages harvested at different maturities

	Hybrid			
	S.C. 704[1]		T.W.C. 647[2]	
Item	1/3ML[3]	BL[4]	1/3ML	2/3ML[5]
Fresh forage				
DM%	22.57	37.78	26.86	30.58
OM, % of DM	92.18	93.17	90.55	93.51
CP, % of DM	9.34	7.62	8.42	6.37
NDF, % of DM	45	43.6	46.8	45.2
ADF, % of DM	27.05	26.35	28.38	25.1
Cellulose, % of DM	25.8	24.7	26.5	24.1
Ash, % of DM	7.82	6.83	9.45	6.49
pH	6.3	6.1	6.4	5.8
Experimental silages				
DM%	21.8	37.35	25.8	27.53
OM, % of DM	92.47	93.26	91.60	92.88
CP, % of DM	9.04	7.52	7.55	6.53
NDF, % of DM	49.1	48.84	49.62	47.93
ADF, % of DM	31.75	29.74	30.45	29.68
Hemicellulose[6], % of DM	17.4	19.1	19.2	18.3
Cellulose, %of DM	29.60	26.68	26.84	25.6
Lignin, %of DM	2.15	3.05	3.62	4.08
Ash, % of DM	7.53	6.74	8.4	7.12
pH	4.03	4.1	3.83	4

[1]S.C.704 = Single Cross 704. [2]T.W.C. 647=Three Way Cross 647. [3]1/3ML= One-third milk-line. [4]BL= Black layer. [5]2/3ML= Two-third milk-line. [6]Calculated as NDF-ADF.

Table 4: Chemical composition of experimental diets based on two corn hybrids harvested at different maturities

	Hybrid			
	S.C. 7041		T.W.C. 6472	
Item	1/3ML[3]	BL[4]	1/3ML	2/3ML[5]
DM%	42.24	55.66	46.65	51.23
OM, % of DM	91.46	91.58	91.06	91.22
CP, % of DM	16.21	15.43	15.27	15.3
NDF, % of DM	41.96	40.11	42.48	42.34
ADF, % of DM	29.08	27.93	30.27	29.89
Hemi cellulose[6], % of DM	23.72	21.05	24.12	22.42
Cellulose, % of DM	12.88	12.17	12.22	12.44
Lignin, % of DM	5.36	6.89	6.14	7.47
Ash, % of DM	8.54	8.42	8.94	8.78

[1]S.C.704 = Single Cross 704. [2]T.W.C. 647 = Three Way Cross 647. [3]1/3ML = One-third milk-line. [4]BL= Black layer. [5]2/3ML= Two-third milk-line. [6]Calculated as NDF-ADF.

to the Kjeldahl procedure (Association of Official Analytical Chemists, 1975) on the Tecator Auto-analyzer (Hoganas, Sweden). Determination of NDF and ADF were made with the ANKOM (Fairport, NY) fiber system in the hot water rinse using heat stable "-amylase and Na_2SO_3 for NDF. Lignin was determined according to the procedure suggested by ANKOM Technology, using 72% sulfuric acid. Wet samples of fresh corn forage and corn silage were also extracted and analyzed for pH, using a portable pH meter(Corning.Eel, Model7).

During these days milk production was measured, samples were taken and analyzed for fat, protein, and lactose and total solids using the infrared technique (Milko-scan 133, Foss Electric, Hillerod, Denmark). Efficiency of feed conversion computed by dividing milk or 4% FCM yield by DMI.

Statistical analysis: Effects of treatments were statistically tested by GLM model procedure of SAS (Version 6.12, SAS Inst. Inc., Cary, NC). The model included square, cow within square, period, dietary treatment, and residual error. Comparisons between the four dietary treatment mean values were made using Duncan's multiple range Test. Differences between individual treatment means at P<0.05 are reported in the Table 5 and 6. Contrasts were made for: 1) Hybrid S.C.704 harvested at 1/3ML vs. BL., 2) Hybrid S.C.704 harvested at 1/3ML vs. hybrid T.W.C.647 harvested at 1/3ML., 3) Hybrid T.W.C.647 harvested at 1/3ML vs. 2/3ML.

Results and Discussion

Chemical composition of corn silages and TMR: The chemical compositions of the corn silage treatments are presented in Table 3. Dry matter content of whole plant corn forage and silage were higher for advanced maturities. This trend was also reported by Hunt *et al*. (1989) and was similar to other published data where the whole-plant corn DM concentration increased as maturity advanced (Xu *et al*., 1995). The difference in whole plant DM with advancing maturity was mainly due to differences in DM of the grain (McDonald *et al*., 1991). Crude protein content of corn plant forage and experimental silages tended to decrease whereas OM content increased as maturity proceeded. This could be due to the relatively higher leaf content of the stover at the earlier maturity stages and the higher ash content of the leaves than the other morphological fractions of the stover (Tolera *et al*., 1998). Lower lignin content of the silages from corn hybrids harvested at the 1/3ML stage was likely due to relative greater lignification of the mature plants (Filya, 2004).

Neutral detergent fiber, ADF and cellulose concentrations were less for advanced matured fresh forage and final silages in both hybrids. This decline was related to the increase in the proportion of grain in WPC (Bal *et al*., 1997) and increase in lignin (Filya, 2004) as matured. Similar trends was also reported by Johnson *et al*. (1999) where concentrations of NDF and ADF in whole crop maize silage decreased as maturity proceeded from ML to BL stage.

pH was affected by kernel maturity of corn silage and increased with advancing maturity. Lower pH of less mature corn silage could be related to its higher moisture and water soluble carbohydrate contents (McDonald *et al*., 1991).

Table 5: Treatment effects on dry matter, silage and nutrients intake

	S.C.704[1]			T.W.C.647[2]			Contrast (P Value)		
Intake	1/3ML	BL	1/3ML	2/3ML	SE	P	(1)	(2)	(3)
DM	21.86^{a}	20.00^{b}	21.72^{a}	21.65^{a}	0.25	0.0026	0.0006	0.41	0.90
Silage	7.38^{a}	6.75^{b}	7.34^{a}	7.31^{a}	0.09	0.0007	0.0025	0.83	0.90
OM	20.01^{a}	18.36^{b}	19.82^{a}	19.59^{a}	0.25	0.0043	0.0006	0.32	0.67
NDF	9.18^{a}	8.03^{b}	9.22^{a}	9.24^{a}	0.11	0.0001	0.0001	0.81	0.93
ADF	6.35^{a}	5.54^{b}	6.54^{a}	6.50^{a}	0.09	0.0001	0.0001	0.46	0.84
CP	3.54^{a}	3.11^{c}	3.32^{b}	3.43^{ab}	0.05	0.0002	0.0001	0.02	0.33
Hemicellulose	3 2.83^{a}	2.49^{b}	2.68^{a}	2.74^{a}	0.04	0.0007	0.0001	0.03	0.50
Cellulose	5.21^{a}	4.14^{b}	5.22^{a}	4.95^{a}	0.08	0.0001	0.0001	0.96	0.13

a, b, c values in the same row that share different superscript are statistically different(P<0.05).

[1]S.C.704 = Single Cross 704. [2]T.W.C.647 = Three Way Cross 647. [3]Calculated as NDF-ADF.

Table 4 shows the nutrient composition of the diets as consumed. Concentrations of OM, Cellulose and ash varied little among treatments. Dietary CP concentration of treatment containing corn hybrid S.C.704 harvested at 1/3ML was higher compared with the other treatments. That is due to higher CP content of corn silage. Dry matter content of diets increased whereas NDF and ADF concentrations decreased as corn maturity advanced in both hybrids. These nutrients followed similar trends in the diets as in the silages. Diet NDF and ADF concentrations exceeded NRC (2001) minimum guidelines.

Nutrients intake: The data for dry matter intake, silage and nutrients intake and treatment contrasts are given in Table 5. Dry matter intake, silage and other nutrients intakes were affected by treatment (P<0.05) and was the lowest for hybrid S.C.704 harvested at BL. The lowest dry matter and nutrients intake was mainly due to the low silage intake. This is in agreement with Phipps *et al*. (2000) who reported that feeding corn silage harvested at 39% DM resulted in lower forage intake compared to corn silage with 26 to 29%DM.

Fiber is generally retained in the reticulo-rumen longer than other feed components and variation in NDF digestion kinetics can influence the filling effect of feed over time in which greater rates of digestion and passage will reduce filling effects of NDF in reticulo-rumen (Allen, 2000). Oba and Allen (2000) hypothesized that reducing physical fill in the rumen by feeding more degradable NDF increases DMI and productivity to a greater extent when animals are fed a high NDF compared to a low NDF diet. Allen (2000) also reported that DMI and forage NDF digestibility are positively related and a one-unit increase in forage NDF digestibility resulted from *in vitro* or *in situ* was associated with 0.17 kg increase in DMI. Therefore the physical nature of the ration containing silage harvested at BL possibly is the reason of lower digestible NDF or passage rate that produced maximal gut fill and limited intake.

There were significant effect of maturity on DMI, silage and nutrient intakes for hybrid S.C.704 at BL (contrast 1, Table 5) whereas no maturity effect observed for hybrid T.W.C.647 when harvested at 1/3ML or 2/3ML (contrast 3). There were no hybrid effects on silage and nutrient intakes between two hybrid harvested at 1/3 ML except for CP and hemicellulose intake.

Milk yield and composition: Means for milk production and composition by diets are shown in Table 6. Dietary treatments affected milk fat, lactose and total solids concentrations. Milk fat concentration differed between treatments and decreased with advancing stage of maturity in both hybrid where significant and non significant reductions were observed for hybrid T.W.C.647 and S.C. 704, respectively (contrasts 1 and 3).

A similar decline in milk fat content also reported by Phipps *et al*. (2000) and Sutton *et al*. (2000). The lack of significant reduction of milk fat content for hybrid S.C.704 with advancing maturity was possibly related to less digestible starch and more effective fiber in this treatment because harvesting corn silage at higher DM promotes falling of leaves and less efficient chopping at harvesting (Pierre *et al*., 1987).

There was no significant effect of treatments on protein percentage and production. Increasing milk protein yield by advancing maturity have been reported by a number of studies (Bal *et al*., 1997; Cammell et al., 2000; Phipps *et al*., 2000). In the study conducted by Bal *et al*. (1997), Milk protein production was highest (p<0.05) for cows fed silage harvested at the 2/3 ML stage, than that of silage harvested at the ED , 1/4ML or BL stages. They have noted that this result was possibly because of higher starch content of silage from corn harvested at the 2/3 ML compared to early stages and the higher starch digestibility of silage from corn harvested at the 2/3 ML stage than that of silage from corn harvested at the BL stage.

There were no differences in milk, 3.5%FCM, ECM and fat yield across the treatments. Although milk production

Table 6: Treatment effects on milk production and composition

	S.C.704[1]		T.W.C.647[2]			Contrast (P value)			
	1/3ML[3]	BL[4]	1/3ML	2/3ML[5]	SE	P	(1)	(2)	(3)
Item	%								
Fat	3.88[b]	3.73[b]	4.10[a]	3.83[b]	0.04	0.00	0.11	0.04	0.01
Protein	2.98	2.95	2.99	2.97	0.02	0.22	0.13	0.61	0.36
Lactose	5.18[b]	5.27[a]	5.26[a]	5.28[a]	0.01	0.00	0.00	0.00	0.53
Total solids (kg/d)	12.14[b]	12.13[b]	12.41[a]	12.21[b]	0.05	0.01	0.86	0.00	0.03
Milk	27.37	27.51	26.63	27.47	0.3	0.22	0.76	0.13	0.10
3.5% FCM	29.03	28.55	29.00	28.88	0.35	0.86	0.45	0.98	0.84
ECM6	26.83	26.60	26.80	26.84	0.3	0.97	0.67	0.96	0.95
Fat	1.06	1.03	1.08	1.05	0.01	0.37	0.27	0.53	0.30
Protein	0.81	0.81	0.79	0.81	0.01	0.46	0.96	0.19	0.20
FCM/DMI	1.35	1.47	1.39	1.37	0.27	0.18	0.04	0.45	0.68
Milk/DMI	1.28[b]	1.43[a]	1.28[b]	1.31[b]	0.02	0.01	0.00	0.44	0.57

a,b values in the same row that share different superscript are statistically different(P<0.05).
[1]S.C.704 = Single Cross 704. [2]T.W.C.647 = Three Way Cross 647. [3]1/3ML= One-third milk-line.
[4]BL= Black layer [5]2/3ML= Two-third milk-line.
[6]ECM(kg/d)=milk(kg/d)×[38.3×fat(g/kg)+24.2×protein(g/kg)+16.54×lactose(g/kg)+20.7}/31.40 (16).

is correlated to dry matter intake. In this experiment differences in DMI did not yield milk production differences. Cows fed corn silage harvested at BL consumed 8% less DM intake however an inverse effect was observed for production of milk efficiency (kg of milk/kg of feed consumed) in which the corn silage harvested at BL stage was more efficient (P<0.05) however, efficiency of 4%FCM production [4%FCM (kg/day)/DMI (kg/day)] was not different among the treatments.

Contrast 2 revealed hybrid effects only for lactose and total solids and no hybrid effect observed for milk production, fat and protein content and yield. Similar effect found by Bal *et al*. (2000). Also there were no significant effects of corn maturity on milk protein concentration that is in agreement with Cammel *et al*. (2000) (contrast 1 and 3).

Conclusion: The results of the current study suggest that feeding the corn silage harvested at BL stage of maturity decreased feed , silage and nutrient intake and cows consumed 8% less DM but did not have a major impact on performance of mid lactating dairy cows. Comparisons revealed hybrid effect only for lactose and total solids and no hybrid effect observed for milk production, fat and protein content and yield. This study also showed that there were no differences in milk production among cows fed silage of hybrid S.C.704 harvested at 1/3 ML compared to that of hybrid T.W.C.647 harvested at 1/3 or 2/3 ML stages however, milk component percentages were higher for hybrid T.W.C.647. Bal *et al*. (1996) and Phipps *et al*. (2000) demonstrated that the optimal DM content of corn silage for inclusion in dairy cow diets is between the 30 and 35% dry matter.

Johnson *et al*. (2002b) in their study, indicated that maximum nutritive value was obtained between one-half ML and two-thirds ML. As evidences observed in our study the milk line considerably differed between plants in the same field therefore we do not suggest considering milk line as an indicator of harvesting Iranian corn hybrids and harvesting should be done based on WPC dry matter content to achieve optimum DM.

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Abbreviation key: S.C.704=hybrid single cross 704; T.W.C.647=hybrid three way cross 647; WPCS=whole plant corn silage; BL=black layer; 1/3ML=one-third milk-line; 2/3ML=two-third milk-line.