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IMPACT OF STALK CUT HEIGHT AT DIFFERENT STAGES OF KERNELS MATURITY ON NUTRITIVE VALUE OF WHOLE PLANT CORN SILAGE FOR SHEEP

(With 2 Tables)

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تأثير إرتفاع تقطيع سيقان الذرة عند المراحل المختلفة لنضج الحبوب على القيمة الغذائية لسيلاج الذرة للأغنام

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أجريت هذه التجربة لدراسة تأثير ارتفاع مستوى تقطيع سيقان الذرة عند الحصاد فى المراحل المختلفة لنضج الحبوب على إنتاج المادة الجافة من المحصول الأخضر وجودة السيلاج المنتج وتركيبة الكيميائى ومعاملات هضمة فى الأغنام. تمت هذه الدراسة على هجين فردى عشرة وكان الحصاد عند المراحل الأتية لنضج الحبوب:١) الطور اللبنى (٧٠ يوم بعدالزراعة)، ٢) الطور العجينى (نصف الحبة عجين والأخر مازال لبن ، عند ٩٥ من الزراعة)، ٣) إكتمال نضج الحبوب (تيبس الحبة ، ١١٥ يوم من الزراعة). كان الحصاد فى كل مرحلة عمرية على ارتفاع ١١ سم أو ٣٣ سنتيمتر من سطح التربة. كانت اطوال التقطيع ٠,٩٣ تم ضغط ٧٥٠ كجم من كل معاملة فى أكياس بولى إيثيلين (بمعدل ٥٠ كجم لكل شيكارة) تم تعيين المادة الجافة فى كل مرحلة عمرية عند ارتفاع التقطيع ١١ ، ٣٣ سم لتحديد إنتاجية الفدان من المادة الجافة. بعد ٤٠ يوم من التخمر تم أخذ عينات لإجراء التحليل الكيميائى وعمل أختبارات جودة السيلاج. تم اجراء ٦ تجارب هضم على ٦ من ذكور الأغنام لتحديد معاملات الهضم. وجد أن تأخر الحصاد أدى إلى زيادة إنتاجية الفدان من المادة الجافة فى حين تعديل أرتفاع التقطيع أدى إلى انخفاضها.لوحظ أن تأخر الحصاد أوإرتفاع مستوى التقطيع إلى ٣٣ سم أدى إلى زيادة نسبة NFC وإنخفاض محتوى NDF و ADF واللجنين فى السيلاج. لوحظ إنخفاض نسبة البروتين كلما تأخر الحصاد من الطور اللبنى إلى مرحلة إكتمال نضج الحبوب فى حين تعديل إرتفاع التقطيع إلى ٣٣ سم أدى إلى إرتفاع فى محتواه. لوحظ أن تأخر الحصاد يؤدى إلى زيادة قيمة pH وإنخفاض حامض اللاكتيك فى السيلاج فى حين إرتفاع التقطيع إلى ٣٣ سم لم يؤثر فى قيمة pH أو مستوى حامض اللاكتيك. وجد أن معامل هضم المادة الجافة والبروتين وNDF و ADF لا يتغير بميعاد الحصاد. بينما تأخر الحصاد أدى إلى أنخفاض معامل هضم NFC. أدى تعديل

أرتفاع التقطيع إلى ٣٣ سم إلى زيادة معنوية فى معامل هضم المادة الجافة و NDF وADF بينما لم يتأثر هضم NFC. كذلك أدى تعديل أرتفاع التقطيع إلى ٣٣ سم إلى زيادة نسبة مجموع المواد الغذائية المهضومة. أتضح من نتائج هذه الدراسة أن تأخر الحصاد إلى الطور العجينى (نصف الحبة عجين والأخر مازال لبن) أو أكتمال نضج الحبوب (تيبس الحبة) وتعديل إرتفاع التقطيع إلى ٣٣ سم من سطح التربة أدى إلى تحسين القيمة الغذائية لسيلاج الذرة.

SUMMARY

This work was conducted to evaluate the impact of raising height of cutting at harvest (from 11 cm for normal cut to 33 cm for high cut) at three stages of kernels maturity just denting (JD), ½ milk line (½ ML), and Black layer (BL) on DM yield, composition and digestibility of whole-plant corn silage (WPCS) for sheep. One type of corn hybrid was harvested either at JD (early WPC); ½ ML (mid WPC) or BL (late WPC). The cutting height at harvest was altered to leave 11 cm or 33 cm of the stalk in the field. Dry matter yield was determined at harvest. After 40 days of ensiling, WPCS were analyzed to determine silage quality (pH and lactic acid) and chemical composition. Digestion coefficients of the different nutrients was measured in 6 rams. Dry matter yield increased as maturity progressed and decreased by alteration of cutting height. Advancing stage of maturity and increasing the height of cutting raised the concentrations of DM and NFC and reduced contents of NDF, ADF and lignin. Crude protein content decreased with maturity, but not affected by alteration of cutting height. As to the quality of silage, maturity increased the pH value and decreased lactic acid concentration, while alteration of cutting height did not have any effect. Digestion coefficient of DM, CP, NDF and ADF were not affected by maturity. While, that of NFC decreased as the stage of maturity progressed from JD to BL. Height of cutting increased ($P < 0.05$) the digestibility of NDF and ADF. So delaying maturity of corn and increasing the height of cutting improves nutritive value of its silage.

Key words: *Corn, silage, Kernels, nutritive value*

INTRODUCTION

Whole-plant corn harvested as silage (WPCS) is widely used worldwide in rations of ruminants. Today in Egypt, corn silage is one of the most popular forages fed to ruminants because it has a good

agronomic characteristics (yield high concentration of nutrients, and rapid harvest) and ensile well with low cost storage. It is a palatable and consistent feed which easily incorporated into mixes. Therefore, it has been of importance to determine the characteristics of WPCS that affect its feeding value, including variety, location, mechanical processing and maturity at time of harvest (Johnson *et al.*, 1999; Cammell *et al.*, 2000; Phipps *et al.*, 2000; Sutton *et al.*, 2000).

Maturity at harvest may affect WPCS nutritive value because it influences grain and moisture content as well as stalk digestibility. Maturity of WPCS can best be determined by the milk line position. The milk line is the interface between the liquid and solid portion of the kernel. The milk line will not appear until the corn is at the dent stage of maturity (Wiersma *et al.*, 1993). Harvesting when the kernels are just denting (JD) can be detrimental to the produced silage because of excessive losses of valuable nutrients from silo runoff and poor starch development in the kernel. In contrast, mature corn silage harvested at the black-layer stage (BL) of maturity is low in nutritive value because of reduced the digestibility of highly lignified stalk NDF (Wiersma *et al.*, 1993 and Van Soest, 1994); and kernels starch (Harrison *et al.*, 1996 and Bal *et al.*, 1997). Also, low moisture WPCS will increase harvest loss and the risk of more unstable silages as compaction is more difficult, thus increasing storage losses.

Recently, several studies have suggested that increasing the height of cutting, leaving a larger portion of less digestible stalk in the field) may improve the nutritive value of WPCS (Tolera and Sundstol, 1999; Curran and Posch, 2000). As Verbic *et al.* (1995), reported, highly digestible leaves and kernels (kernels representing 40 to 50% of plant dry matter) represent a larger proportion of the total dry matter in the high cut silage. Increasing the cutting height of WPCS from 12.7 to 45.7 decreased the concentration of NDF, ADF, and lignin but increasing the concentration of starch and NDF digestibility by 4.86% (Neylon and Kung, 2003). According to a statistical analysis on NDF digestibility of forage (Oba and Allen, 1999), a one-unit increase in forage NDF digestibility, *in vitro* or *in situ,* was associated with 0.17 kg increase in dry matter intake and 0.25 kg increase in 4% fat corrected milk yield.

This work was conducted to evaluate the impact of stalk cutting height (11 vs. 33 cm) at different stages of kernels maturity (1-prior to milk line formation (JD); 2- when the milk line descended to about half the length of the kernels (1/2 ML); and 3- when a black layer (BL)

appears at the base of kernels) on dry matter yield, composition and digestibility of WPCS for sheep.

MATERIALS and METHODS

Whole plant corn and silage making:

A corn hybrid of a type single cross-10, SC-10 was planted at beginning of May 2003 at a private farm in Kafr El-Sheikh Province. Early WPC was harvested prior to milk line formation when the kernels are just denting (JD), milk stage maturity, at 70 days after planting. Normal WPC was harvested when the milk line has descended to about half the length of the kernels (½ ML), at 95 days after planting. Late WPC was harvested when a black layer, (BL) appears at the base of the kernels where they attach to the cob at 115 days after planting.

The cutting height was altered to either leave approximately 11 cm (normal-cut WPCS), or 33 cm (high-cut WPCS) of the stalk in the field. About 750 kg of chopped whole corn (0.93 cm theoretical length of cut), at each stage of maturity was tightly packed into double polyethylene plastic bags (60 x 120 cm of 50 kg each). Bags were tightly closed to maintain anaerobic condition for proper fermentation. After 40 days of ensiling, one handful of silage in each treatment was sampled from all bags, thoroughly mixed, and kept frozen in the refrigerator till analyses.

Animals and digestibility trials:

Six apparently healthy mature rams (weighting on average 50 kg) were kept in a separate stalls individually, fastened by a head collier with a separate manger. Rams had free access to water and a mixture of limestone-calcium sulphate and sodium bicarbonate on the ratio of 50:30:20. Each digestibility trail was conducted on three rams. In the preliminary period, 10 days, the rams were fed WPCS *ad libitum* twice daily at 7 am and 5 pm and in the collection period (5 days) each ram was fed 90% of the minimum *ad libitum* intake with the application of water proof bag for fecal collection. Before offering the morning meal, fecal matter was weighed, mixed and sampled (one-tenth) for each ram.

Analyses:

Quality analyses:

Ten grams of WPCS samples were finely homogenized and used for determination of pH according to AOAC (1980). Fifteen grams of WPCS was processed according to AOAC (1980) and used to determine concentrations of lactic acid spectrophotometrically.

Chemical analyses:

After quartering, fresh chopped whole plant corn were dried at 60°C for 48 h, then temperature raised to 105°C for 3 hours to determine DM at harvest. Also, after quartering; WPCS and fecal matter samples were dried at 60°C for 48 hours, ground to pass through 1-mm screen. Dry ground daily fecal samples were composted for each ram and subsampled to be analyzed for DM (105°C), CP, EE, CF, ash (AOAC, 1995), NDF, ADF and lignin (Van Soest *et al.*, 1991). Nitrogen free extract (NFE) and non fibrous carbohydrates (NFC) were calculated by difference: NFE = 100-[CF% + CP% + EE% + ash%], according to AOAC (1980); while NFC = 100-[NDF% + CP% + EE% + ash%], according to NRC (2001).

Statistical analysis:

Data were subjected to analysis of variance using general models (GLM) procedure of SAS, 1995. Duncan's multiple range test was used to test the significancy among the different treatments using the principal procedure of SAS, 1995.

RESULTS

The nutrients composition of WPCS cut at 11 cm (normal) or 33 cm (high) and harvested when kernels at early; mid-; or late stages of maturity are presented in Table 1. Dry matter yield increased as maturity of kernels progressed from JD to BL stage of maturity while, increasing height of cutting of WPCS tended to decrease the DM yield (average of 8.7 ton/feddan for normal cut vs. 8.04 ton. for height cut). Advancing stage of maturity and increasing height of cutting raised the concentration of dry matter in the corn silage (average of 32.76% for high cut vs. 31.13% for normal cut). Height of cutting has the greatest effect on DM with WPCS harvested late. The concentration of CF tended to be lower when height of cutting was increased (average of 25.07% for high cut vs. 28.47% for normal cut). The concentration of NDF declined with advancing stage of maturity and increasing height of cutting. The density of NDF in high cut average 56.06% while in normal cut average 59.67% and the greatest reduction in NDF density was recorded with silage harvested at early stage of kernels maturity. Also, the concentration of ADF reduced with advancing stage of maturity and increasing cut height from 11 to 33 cm. Height of cutting has the greatest effect on ADF of WPCS harvested at mid-stage of kernels maturity.

Harvesting at high cut caused a reduction in the concentration of lignin (average of 4.02 vs. 3.18%) and the highest reduction was observed at early, and mid-stage of kernels maturity. The contents of NFE or NFC increased with advancing stage of kernels maturity and increasing height of cut and the greatest increase observed with WPCS harvested at early stage of maturity.

Also, Table 1 displays the pH values and lactic acid concentrations (% of DM) of WPCS. The values of pH increased with advancing stage of maturity but not altered by alteration of cutting height. Lactic acid concentrations decreased with progress of WPSC maturity but not affected by height of cutting. In general, the WPCS used in the present experiment was judged to be good quality.

Table 1: Effect of stalk cut height and kernels maturity on dry matter yield (at harvest), chemical composition (on DM basis) and quality of corn silage.

Item	Normal cut[1]				High cut[2]			
	Early [3]	Mid[4]	Late[5]	Average	Early [3]	Mid[4]	Late[5]	Average
DM ton/feddan	6.58	8.68	10.83	8.7	6.10	8.00	10.03	8.04
Composition (% of DM)								
DM	23.50	31.00	38.90	31.13	24.56	32.55	41.16	32.76
CP	8.96	8.40	8.29	8.55	9.180	8.46	8.30	8.65
CF	31.00	27.50	26.90	28.47	27.66	23.4	24.15	25.07
NDF	66.13	56.91	55.97	59.67	61.50	53.61	53.06	56.06
ADF	36.11	33.38	32.40	33.96	32.86	29.40	29.15	30.47
Lignin	4.46	3.51	4.08	4.02	3.12	2.58	3.84	3.18
EE	1.58	2.09	2.09	1.92	1.60	2.10	2.11	1.94
Ash	6.96	6.24	5.95	6.38	6.01	6.03	5.67	5.9
NFC[6]	16.37	26.36	27.70	23.48	21.71	29.80	30.86	27.46
NFE[7]	51.50	55.77	56.77	54.68	55.55	60.01	59.77	58.44
Quality characteristics								
pH	3.47	3.66	3.75	3.63	3.47	3.65	3.79	3.64
Lactic acid[8]	9.00	8.71	7.94	8.55	9.10	8.80	7.60	8.5

1 Corn silage cut to leave 11 cm in the field.
2 Corn silage cut to leave 33 cm in the field.
3 Prior to milk line formation in the kernels just denting.
4 When the milk line is 1/2 of the way down the kernels.
5 When a black layer appears at the base of the kernels.
6 NFC = 100- (NDF % + CP % + EE % + ash %).
7 NFE = 100- (CF% + CP % + EE% + ash %).
8 Percentage of DM

Table 2: Effect of stalk cut height and kernels maturity on dry matter intake, digestion coefficient and total digestible nutrients of corn silage for rams.

	Normal cut				High cut			
Item	Early	Mid	Late	Average	Early	Mid	Late	Average
Dry matter intake (kg)	0.91±0.01^{d}	1.06±0.03^{ab}	1.07±0.01^{ab}	1.01±0.05	0.98± 0.026^{c}	1.12±0.021^{a}	1.11±0.02^{a}	1.07±0.05
Dry matter	60.77±2.1^{b}	62.89±1.69^{ab}	61.66±1.78^{b}	61.77±0.61^{a}	63.30±1.9^{ab}	65.99±1.89^{a}	62.59±2.00^{ab}	63.96±1.04^{a}
CP	68.00±1.5^{a}	67.88±1.69^{a}	67.71±1.49^{a}	67.86±0.08^{a}	68.30±1.87^{a}	67.97±1.9^{a}	67.1±1.77^{a}	67.79±0.36^{a}
EE	60.30±2.01^{b}	67.70±1.95^{ab}	68.81±1.62^{ab}	65.60±2.67^{a}	61.58±1.59^{b}	70.10±2.51^{a}	71.90±2.2^{a}	67.88±3.09^{a}
CF	53.10±1.9^{c}	59.85±1.61^{ab}	57.80±1.61^{b}	56.92±2.00^{a}	61.4±01.3^{a}	62.00±1.27^{a}	59.05±1.55^{ab}	60.82±0.90^{a}
NFE	63.20±1.98^{ab}	64.21±1.49^{ab}	60.31±1.94^{c}	62.57±1.17^{a}	65.65±1.37^{ab}	67.04±1.37^{a}	61.±2.01^{c}	64.56±1.83^{a}
NDF	50.27±2.1^{bc}	51.79±1.76^{bc}	49.08±1.69^{c}	50.83±0.78^{a}	55.77±1.00^{a}	56.40±1.37^{a}	53.91±1.6^{ab}	55.36±0.75^{a}
ADF	44.21±2.25^{c}	47.60±1.9^{c}	44.40±1.77^{c}	45.40±1.1^{b}	52.81±1.56^{ab}	54.66±1.49^{a}	50.44±1.64^{b}	52.64±1.22^{a}
NFC	87.33±1.2^{a}	82.49±1.4^{b}	80.89±1.6^{b}	83.57±1.94^{b}	88.21±1.07^{a}	81.80±1.5^{b}	80.03±1.45^{b}	83.34±2.48^{a}
TND %	57.24	61.15	58.63	59.00	61.84	63.80	59.75	61.8

Means followed by the same letter are not significantly different according to Duncan multiple range test at 0.05 level of probability.

Dry matter intake, digestion coefficient and total digestible nutrients of WPCS cut at 11 cm or 33 cm and harvested at early; mid; or late stages of kernels maturity are shown in Table 2. Dry matter intake increased as maturity of kernels progressed from JD to BL stage of maturity and with increasing height of cutting. Dry matter digestibility of WPCS not affected as the stage of maturity advanced from early to late. Increasing height of cutting increased dry matter digestibility (average of 63.96% for high cut vs. 61.77% for low cut). The highest improvement in dry matter digestibility was recorded with silage harvested at ½ ML stage of kernels maturity. No difference ($P < 0.05$) in CP digestibility due to height of cutting and stage of kernels maturity. Digestion coefficient of CF; NDF and ADF not affected by stage of maturity but tended to be higher ($P < 0.05$) when height of cutting was increased. CF (average of 60.82 of high cut vs. 56.92 for normal cut); NDF (average of 55.36 for high cut vs. 50.38% of normal cut); ADF (average of 52.64% for high cut vs. 45.4% for normal cut). Digestibility of NFE and NFC decreased ($P < 0.05$) as the stage of maturity advanced from JD to BL. Altering height of cutting does not affect in NFE or NFC digestibility. Increasing the height of cutting increased TDN% (average of 61.80% for high cut vs. 59.00% for normal cut).

DISCUSSION

There were clear effects of the silage maturity at harvest on nutrient composition. As maturity progressed from JD to BL the DM content increased from 23.5 to 31.00 and 38.9% in early, mid and late maturity stage silage. This was accompanied by a decrease in percentage of CP; CF; NDF; ADF; lignin and an increase in NFE and NFC contents (Table 1). These variations in the nutrient composition of WPCS were due to an increase in grain proportion with advancing maturity stage (Hunt *et al.*, 1989; Harrison *et al.*, 1996; Bal *et al.*, 1997; Fernandez *et al.*, 2004; and Jensen *et al.*, 2005).

Increasing height of cutting numerically decreased DM yield by 7.48% (Table 1). Curran and Posch (2000) and Neylon and Kung (2003) each compared DM yields at cut heights and reported about a 12% decline in DM yield between cut heights that left 19.2 vs. 50 cm but only a 7% decline comparing cut heights of 20.4 vs. 50 cm, and about 5-10% when height of cutting was increased from 12.7 cm vs. 45.7 cm.

Increasing the cutting height of WPCS at harvest could be a method to improve its nutritive value, by reducing the concentrations (average) of CF (11.94%); NDF (6.05%); ADF (10.28%) and lignin (20.9%), but increasing the concentrations of (average) DM (5.24%); NFE (6.88%) and NFC (16.95%) Dominguez *et al.* (2002); Neylon and Kung (2003) reported that increasing the cut height from 23 to 71 cm or from 12.7 to 45.7 cm increased whole-plant DM and reduced concentration of NDF; ADF and lignin.

The concentrations of lactic acid were reduced in more mature silage (Table 1) and is most likely due to a combination of lower water soluble carbohydrates (sugars) and a reduction in growth of lactic acid bacteria because of a lowered water activity in the dried more mature crop. In general, the fermentation processes of the silages were satisfactory.

Dry matter intake significantly increased with maturity progressed and with increasing height of cutting (Table 2). This may be attributed to the lowering of NDF values with advancing of maturity and increasing height of cutting (Table 1). As NDF has been shown to be negatively correlated with dry matter intake. In other words, as the DNF in forages increases, animals will be able to consume less forage. Dry matter digestibility was not significantly ($P < 0.05$) affected by the stage of maturity (Table 2). Previous studies demonstrated that the increase in WPCS maturity only poorly affects DM total tract digestibility (Bal *et al.*, 1997; St Pierre *et al.*, 1987 and Johnson *et al.*, 2002) due to the increased proportion of grain concomitant to decrease digestibility of the stalk. Also, digestibility of NDF and ADF was not significantly ($P < 0.05$) affected by stage of maturity. These results were in consistent to previously reported by Di Marco *et al.* (2002) and opposite to results reported by Bal *et al.* (2000), Fernandez *et al.* (2004) and Jensen *et al.* (2005). Variations in NDF and ADF digestibility could be associated with climate; hybrids; crop management and animal factors. These factors may affect grain/stalk and also the complex structure of the cell wall, which finally influence the magnitude of microbial attack and the rate of passage through the digestive tract. Cone and Engels (1990) observed that sub-epidermal tissue of corn stalk were poorly digested when plants were grown at low temperature, but they were highly digested when grown at high temperature. Crude fiber digestibility not follow the same pattern of NDF and ADF digestibility. As crude fiber did not differentiate the components of the cell wall and often

underestimate good quality forage and overestimate poor quality forage (Van Soest, 1983). In this experiment crude fiber was analyzed to estimate NFE by difference. Values of CF and NFE were used to estimate TDN value. Digestibility values of NFC were higher than those of NFE. This may be attributed to NFC mainly composed of starch, lactic and acetic acid. Whereas, NFE includes starch, some of hemicellulose, and alkali insoluble lignin. In general, digestibility of NFC was reduced ($P < 0.05$) with increasing kernels maturity. Bal *et al.* (1997) reported reduced total tract starch digestion for BL silage versus the JD and 1/2 ML silages. This could be related to harder texture kernels for BL (Philippeau and Michalet-Doreau, 1997).

Increasing cutting height of WPCS at harvest could be a method to improve of its quality. As, their were clear affects for increasing height of cutting on nutrients digestibility. Digestion coefficient (average) of DM increased by 2.26%; CF increased by 3.9%; NDF by 4.98%; ADF by 4.98%; NFE by 2.02%; and TDN by 2.83%. These finding were similar to those reported by Oba and Allen (1999); Sutton *et al.* (2000); Neylon and Kung (2003). Most changes that have observed due to increased height of cut have been consistent with the fact that more fibrous and highly lignified stalks (Tolera and Sundstol, 1999) are left in the field. In addition, highly digestible leaves and kernels which representing 40% to 50% of DM weight (Verbic *et al.*, 1995) represent a larger proportion of the total DM in the high cut silage.

To make a decision on the optimal harvest time and cutting height of WPCS depends on many factors. Harvest of more mature corn at a late harvest time will generally increase DM yield per feddan, but it also increase the risk of more unstable silage as compaction is more difficult when DM content is higher. The increase in NFC, and decrease in NDF concentration, with increase maturity and cutting height can be advantage in situation where other fiber-rich forages make up a large proportion of the ration. In situation where the corn silage is the only, or nearly the only forage a lower proportion of NFC, and a higher proportion of NDF will be an advantage to assure proper physical structure of the ration.

Results of this work suggest that delaying maturity at harvest of corn silage to ½ ML or BL stage and increasing of cutting height improve nutritive value of the produced silage.

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