EFFECT OF DRY MATTER LEVELS AND SOURCE OF SOLUBLE CARBOHYDRATE ON QUALITY AND NUTRITIVE VALUE OF CORN STOVER SILAGE

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ABSTRACT

The study was conducted in the nutrition laboratory belongs to Animal Production Department - College of Agriculture/Al-Qasim Green University to investigate the effect of dry matter (DM) levels (25, 30, 35 and 40%) of yellow corn stover (YCS) and the soluble carbohydrates sources (SCS) (cane molasses (C-M), date molasses (D-M) and corn flour (C-F)) on quality and nutritive value of produced silage. The results showed that increasing the DM levels before ensiling decreased ($P<0.01$) the percentage of DM loss, lower percentage of 9.78% was estimated in the silage samples made with a level of 40% DM. Some parameters of quality and nutritive value of silage including Fleig points (Fp) and aerobic stability (AS) were improved ($P<0.01$) in an ascending manner, while the higher *in vitro* DM digestibility (IVDMD) of 69.37% was associated with the samples made with a level of 35% DM. With regard to the effect of the SCS, the results showed that making YCS silage by the addition of C-M enhanced ($P<0.01$) Fp, AS and IVDMD as compared with other additives, values were 95.37 points, 97.55 hours, and 86.53%. However, silage samples made by the addition of C-F were characterized with less ($P<0.01$) DM loss percentage. The quality characteristics and nutritive value of silage were also affected by the interaction between the level of DM of YCS and the SCS added at ensiling.

Key words: silage quality, corn stover, dry matter, molasses, aerobic stability

تأثير مستوى المادة الجافة ومصدر الكربوهيدرات الذائبة على الخصائص النوعية والقيمة الغذائية لسايلج سيقان واوراق الذرة الصفراء

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الخلاصة

اجريت الدراسة في مختبر التغذية التابع الى قسم الانتاج الحيواني - كلية الزراعة / جامعة القاسم الخضراء للتحري عن تأثير مستوى المادة الجافة (25 و 30 و35 و 40%) في اوراق وسيقان الذرة الصفراء ومصدر الكربوهيدرات الذائبة (السكر ومولاس التمر وطحين الذرة مولاس قصب) على القيمة الغذائية ونوعية السايلج المصنع لمدة 60 يوم. وقد اظهرت النتائج ان زيادة مستوى المادة الجافة قبل السيلجة ادت الى انخفاض معنوي (P<0.01) في نسبة الفقد بالمادة الجافة وسجلت نماذج السايلج المصنعة بمستوى 40% مادة جافة اقل نسبة بلغت 9.78% ولوحظ حصول تحسن معنوي (P<0.01) في بعض معايير نوعية السايلج وقيمته الغذائية على نحو تصاعدي شملت قيم فليغ والثباتية الهوائية, فيما ارتبط اعلى هضم مختبري للمادة الجافة الذي بلغ 69.37% بالنماذج المصنعة بمستوى 35% مادة جافة. اما بالنسبة الى تأثير مصدر الكربوهيدرات, فقد بينت النتائج ان تصنيع نماذج سايلج اوراق وسيقان الذرة بإضافة مولاس قصب السكر قد عزز (P<0.01) قيم فليغ والثباتية الهوائية والهضم المختبري للمادة الجافة مقارنة بالإضافات الاخرى, اذ بلغت القيم 95.37 نقطة و97.55 ساعة و 86.53%. الا ان النماذج المصنعة بإضافة طحين الذرة قد تميزت باقل (P<0.01) نسبة فقد بالمادة الجافة. كما تأثرت خصائص نوعية السايلج وقيمته الغذائية ايضا بالتداخل بين مستوى المادة الجافة في اوراق وسيقان الذرة ومصدر الكربوهيدرات الذائبة المضافة عند السيلجة.

كلمات مفتاحية: نوعية السايلج, اوراق وسيقان الذرة, مادة جافة, مولاس, ثباتية هوائية

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Introduction

Animal production in Iraq suffers from several problems, foremost of which those are related to nutrition, such shrinking the areas of arable land and green pastures. Therefore, attention can be directed to improve the poor and medium quality roughages by ensiling. Ensiling is a common way for preserving moist crops, extending their storage period and improve their palatability through lactic acid fermentation occurred under anaerobic conditions (25). The level of DM of the crops intended for ensiling plays an important role in the quality of silage. Ensiling dried crops poses a challenge to produce good quality silage due to low water soluble carbohydrates (WSC) and population of lactic acid bacteria (LAB) contents, in addition to the resisting rapid decline in pH (18). High moisture is an encouraging factor for the growth of clostridia and an increase in DM loss through effluent, protein degradation and production of butyric acid, leading to decrease digestibility of silage (10). The importance of soluble sugars in silage making is that it is the substrate on which LAB depends in their metabolism during silage fermentation (6). Kung (17) indicated the possibility of producing good quality and digested silage at the level of the original crop if its WSC content is sufficient for the fermentation.

Studies were conducted to investigate the effect of the level of DM of the ensiled materials and the addition of SCS on the quality characteristics and nutritive value of silage. Hu *et al*. (11) reported higher ($P<0.01$) DM loss percentage in whole corn crop silage with increasing DM level to 40.6%, but the silage produced was more stable against aerobic spoilage than that made with a level of 33.1% DM. Khan *et al*. (14) referred to an increase in the percentage of DM loss in corn crop silage made by the addition of C-M. Gao *et al*. (7) observed that Fp of grass silage made by the addition of pectin, starch and fructose was higher ($P<0.01$) than that made by the addition of C-M. Based on the above, the current study was conducted to investigate the effect of DM level of YCS and SCS added at ensiling on the quality characteristics and nutritive value of silage produced.

MATERIALS AND METHODS

A few of yellow corn plants were cut just before harvesting the ears, and they were chopped manually to a length of 1-1.5 cm after removing the ears. Then the chopped materials was field wilted for 5 and 8 hours to raise the DM level to about 25-30% and 35-40%, respectively. Dry matter levels of 25, 30, 35 and 40% of YCS were adjusted by adding calculated amounts of water based on equation derived by (28).

The soluble carbohydrate sources (SCS) including C-M, D-M and C-F were added to the chopped YCS and their quantities were determined on the basis of the actual content of WSC in 8% of C-M. Accordingly, the amount of D-M and C-F equivalent to that percentage of C-M was 6.30 and 29 g per 100 g of DM of the stover, respectively. Urea was added to all samples at a rate of 2% to enhance nitrogen content and to provide relative protection for the protein content of YCS from degradation during ensiling.

The quantities of all additives were estimated on the basis of the DM of YCS. The number of treatments included in the study were 12 treatments representing the interaction of four levels of DM and the mentioned SCS, with five replicates per each.

The chemical composition of YCS determined according to AOAC (1) methods, contained 39.77 and 45.26% DM after field wilting for 5 and 8 hours, respectively, 7.08% ash, 6.96% CP, 2.34% ether extract (EE), 74.39, 38.13, 19.09, 19.04 and 36.26 of NDF, ADF, ADL, cellulose, and hemicellulose determined according to the method of (8), respectively. The *in vitro* dry matter digestibility (IVDMD) of YCS determined according to the method of (30), was 60.66%. Soluble sugars content of SCS estimated according to the method of (21), were 34.65, 43.91 and 9.55% for C-M, D-M and C-F, respectively.

After mixing the chopped materials with the additives solutions, the mixture including ensiled material was packed in double nylon bags at a rate of 500 g per each sample, and

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they were manually pressed to expel the air and immediately sealed. The five replicates of each treatment were placed inside a plastic bag and kept in a pit silo which was then covered with soil and pressed well to ensure that no air may entered and left for 60 days. Samples were opened thereafter to determine the parameters of silage quality and nutritive value. DM loss was calculated as a percentage of the difference in the total DM content of the silage samples, depending on the sample's weight and the percentage of its DM content before and after ensiling. The Fleig point was estimated according to the following equation developed by (14):

Fleg value (Fp) = 220 + (2 × %DM – 15) – 40 × pH.

Aerobic stability (AS) was estimated according to the method of (19). Buffering capacity (BC) was estimated according to the method of (27). Data were statistically analyzed as factorial experiments in a complete randomized design using SAS (29)

RESULTS AND DISCUSSION

Table 1 shows the effect of DM level of YCS and the SCS added at ensiling on the quality and nutritive value of produced silage. The results showed that there was a significant ($P<0.01$) decrease in the percentage of DM loss with increasing the level of DM of YCS, the percentages were 13.41, 12.15, 12.06 and 9.76% in the silage samples made with a level of 25, 30, 35 and 40% DM, respectively. Since there was no indication of a loss through aerobic degradation, such as the presence of molds, the DM loss of silage samples made with a level of 25% DM may be due to the formation of effluent. Kim and Adesogan (15) concluded that the low level of DM during ensiling leads to high loss percentage through effluent and slow decrease in pH. The result of a current study is in agreement with the result of (24), who noticed a significant ($P<0.05$) decrease in the percentage of DM loss due to ensiling corn crop at the levels of 34 and 41% DM.

The Fleig point (Fp) was significantly ($P<0.01$) increased with increasing the level of DM of YCS at ensiling. Higher ($P<0.01$) Fp was estimated in the silage samples made with a level of 40% DM as compared with those made with a level of 25% DM, values were 103.25 and 75.19 points, respectively. Since silage fermentation is closely related to the DM level of ensiled materials, the effect of that level of DM on the pH values may be the reason for the increase in the Fp observed in a current study. Kilic (15) indicated that the Fp depends on the DM level of the ensiled materials and the changes in pH during fermentation.

Regarding the buffering capacity (BC), the results revealed that the silage samples made with a level of 40% DM were characterized by the lower BC of 77.41 as compared with the higher BC of 87.76 mEq NaOH/100 g of DM associated with the samples made with a level of 35% DM. The higher BC capacity of the later samples may be due to the occurrence of proteolysis. Oude Elferink *et al*. (26) reported that the ammonia produced by proteolysis increases the BC of the silage. However, our result differs from that obtained by (28) in which higher BC was significantly ($P<0.05$) associated with corn residues silage made with a level of 40% DM, while the lower BC was associated with those made with a level of 25% DM, BC values were 113.13 and 82.66 mEq of NaOH/100 g DM of silage.

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Table 1 - Effect of dry matter level and soluble carbohydrate source on the quality characteristics and nutritional value of yellow corn stover silage (mean ± SE)

Items[1]	Dry matter level % (DM)				soluble carbohydrates sources (SCS)[2]			*P*	
	25	30	35	40	C-M	D-M	C-F	DM level	SCS
DM loss, %	13.41[a] ± 1.07	12.15[b] ± 1.01	12.06[b] ± 0.63	9.76[c] ± 0.94	12.54[b] ± 0.68	15.06[a] ± 0.38	7.94[c] ± 0.44	**	**
Fp, point	75.19[d] ± 3.00	89.89[c] ± 1.26	98.67[b] ± 0.38	103.25[a] ± 0.84	95.37[a] ± 1.81	88.68[b] ± 3.33	91.20[b] ± 2.97	**	**
BC, mEq NaOH/100 g DM	82.08[b] ± 1.28	82.51[b] ± 1.51	87.76[a] ± 1.55	77.41[c] ± 1.69	84.51[a] ± 2.07	79.24[b] ± 0.81	83.57[a] ± 1.19	**	**
AS, hour	40.33[b] ± 1.76	87.87[a] ± 14.78±	101.47[a] ± 7.47	112.80[a] ± 7.82	97.55 ± 12.63	77.10 ± 7.11	82.20 ± 9.23	**	NS
IVDMD, %	65.60[c] ± 0.67	65.96[c] ± 0.72	69.37[a] ± 0.48	67.58[b] ± 0.67	68.53[a] ± 0.73	67.53[a] ± 0.45	65.33[b] ± 0.49	**	**

Means with different letters differ significantly at the level of * ($P<0.05$) or ** ($P<0.01$)
DM loss= dry matter loss; Fp= Fleig point; BC= Buffering capacity; AS= Aerobic stability; IVDMD=In vitro dry matter digestibility[1]
SCS= soluble carbohydrate sources; C-M= cane molasses; D-M= date molasses; C-F= corn flour[2]

The results also indicated an ascending increase ($P<0.01$) in the aerobic stability (AS) with increasing the DM level of YCS at ensiling. Samples made with a level of 25% DM were not kept stable more than 40.33 hours before the initiating of the aerobic spoilage, while the stability of those made with a level of 40% DM against aerobic spoilage were extended for 112.80 hours. The improvement in AS in those samples may be due to the presence of higher amounts of acetic acid and propionic acid. Moon (22) found that acetic acid and propionic acid have the ability to inhibit the activity of yeasts at a low pH level.

The difference in the concentration of WSC after ensiling could be another reason for the above mentioned difference in AS. Muck (23) emphasized that silage samples containing high level of WSC are more susceptible to the growth and activity of yeasts that metabolize these sugars to ethanol. Our result agrees with the results of (11), who noted that the samples of corn crop silage made with a level of 40.6% DM were more resistant against aerobic spoilage than those made with a level of 33.1% DM. However, Arriola *et al*. (2) reported no significant effect of DM level of on AS when making corn silage with DM levels of 25, 32 and 37%.

The results of a current study also showed a significant ($P<0.01$) increase in the IVDMD from 65.60 and 65.96% in the silage samples made with the levels of 25 and 30% DM, respectively, to 69.37 and 67.58% in those made with the levels of 35 and 40%, respectively. The increase in the IVDMD may be due to the improvement of fermentation in the former samples leading to partial degradation of the cell wall components and increase digestion accordingly. Huisden *et al*. (12) demonstrated that silage fermentation can improve the digestion of cell wall components and provide more soluble sugars for production of lactic acid. Ivan (13) stated that the variation in silage digestibility depends mainly on the chemical composition, especially the cell wall and lignin contents.

Regarding the effect of the SCS added to the YCS at ensiling on the quality characteristics and nutritive value of the silage, the results showed a significant ($P<0.01$) decrease in the percentage of DM loss in the samples made with the addition of C-F by 4.6 and 7.12% as compared with the those made by the addition of C-M and D-M, respectively. Addition of SCS in different quantities depending on their content of WSC can lead to such that difference in the percentage of DM loss. The addition of C-F increased DM content of DM of the samples of YCS silage which may compensated for the DM loss during fermentation, where it was added at 29, while C-M and D-M were added at 8 and 6.30 g/ 100 g DM of YCS.

The high content of WSC in C-M and D-M may enhanced the fermentation in samples made by the addition of these additives leading to increase the percentage of DM loss. Cai *et al*. (5) emphasized that most DM loss occurs through fermentation processes. The result of a current study is consistent with the results obtained by (14), in which, they observed that addition of C-M to corn stover at ensiling increased the percentage of DM loss.

The samples made by the addition of M-M were characterized with a higher ($P<0.01$) Fp as compared with the samples made by the addition of C-M and C-F, Fp values were 95.37, 88.68 and 91.20 points, respectively. The potential improvement in the fermentation of silage samples made by the addition of C-M improved Fp value. This is in agreement with the results of (32), where the addition of C-M increased the Fp values in the samples of YCS silage by 19.36 points as compared with those made by the addition of ground barley grains.

Buffering capacity (BC) was significantly ($P<0.01$) improved by 5.27 and 4.33 mEq of NaOH/ 100 g DM in silage samples made by the addition of D-M as compared with those made by the addition of C-M and C-F, respectively. These differences in BC may be due to the effect of the SCS additives used in a current study on silage fermentation. Tucker (31) referred to the inverse correlation between BC and acidity of silage in addition to the role of ammonia resulting from protein degradation in neutralizing acids produced during ensiling and increasing BC (26).

The IVDMD in the samples of YCS silage made by the addition of C-M or D-M were significantly (P<0.01) improved as compared with those made by the addition of C-F, the IVDMD were 68.53, 67.53 and 65.33%, respectively. The improved IVDMD in samples made by the addition of C-M or D-M may be due to partial degradation of the cell wall components. Similarly, Baytok *et al*. (4) concluded that the addition of C-M enhanced the degradation of cell wall components during ensiling as a result of increased providing with the soluble sugars and improving the rate of silage fermentation.

In spite of the above, the addition of C-M at ensiling in the study conducted by (12) did not affect the DM digestibility of the whole corn silage. Even though, Yilmaz and Gursoy (32) observed the priority (P<0.01) of the whole corn silage made by the addition of ground barley at a level of 5% as compared with the silage made without or by the addition of C-M at a level of 2%.

Table 2 shows the effect of the interaction between the DM level of YCS and the SCS added at ensiling on the quality characteristics and nutritive value of the silage. Higher DM loss of 16.45% was associated with silage samples made with a level of 25% DM and the addition of C-F, whereas, samples made by the addition of C-F with all levels of DM and those made with a level of 40% DM and the addition of C-M were associated the lower (P<0.01) percentages. The reason for that improvement may be due to the fact that the amount of C-F added in making samples of silage compensated for the DM loss in those samples. The high moisture content in samples made at a level of 25% DM and the addition of D-M may be the reason for the high percentage of DM loss due to the possible increase in effluent, a situation that cannot be exist in case of samples made by the addition of C-F. Gordon *et al*. (9) demonstrated that making silage with high moisture content in ensiled materials leads to DM loss through effluent or through clostridial fermentation.

The higher (P<0.01) Fp of 105.14 points was estimated in samples of YCS silage made at a level of 40% DM and the addition of C-M, while the lower value of 66.81 points was estimated in those made at the level of 25% DM and the addition of D-M. The former high value may be due to the improvement of fermentation as a result of the suitability of the level of DM to the activity of LAB, in addition to the enhancing role of molasses to the activity of these organisms by providing easily fermented

Table 2 - The effect of the interaction between the level of dry matter and the soluble carbohydrates sources on the quality characteristics and nutritional value of yellow corn stover silage (mean ± SE)

DM level	25			30			35			40			*P*
SCS[1]	M	D	C-F	M	D	C-F	M	D	C-F	M	D	C-F	
DM loss, %)	15.87^{ab} 0.60±	16.45^{a} 0.44±	7.92^{de} 0.36 ±	13.46^{c} 0.37±	15.87^{ab} 0.24±	7.13^{e} 0.65±	12.23^{c} 0.30±	14.04^{bc} 0.90 ±	9.92^{d} 1.09±	8.61^{de} 1.21±	13.88^{bc} 0.71±	6.80^{e} 0.77±	**
Fp, point	87.40^{d} 2.61±	66.81^{e} 5.19±	71.36^{e} 1.52±	89.37^{d} 0.61±	88.56^{d} 0.62±	91.74^{cd} 3.84±	99.59^{ab} 0.41±	97.47^{bc} 0.55±	98.96^{ab} 0.70±	105.14^{a} 1.36±	101.88^{a} b 0.85±	102.73^{a} b 1.86±	**
BC, mEq NaOH /100 g DM	86.18^{bc} 2.33±	78.60^{de} 1.07±	81.46^{cde} 1.87±	87.47^{ab} 2.03±	80.54^{cde} 1.72±	79.52^{de} 2.76±	92.88^{a} 1.58±	81.35^{cde} 1.85±	89.06^{ab} 1.43±	71.52^{f} 2.66±	76.46^{ef} 1.24±	84.24^{bcd} 1.00±	**
AS, hour	46.60^{de} 1.50±	40.80^{e} 2.55±	33.60^{e} 1.60±	129.80^{a} 38.36±	59.80^{cde} 6.88±	74.00^{bcd} e 9.52±	92.20^{abc} d 13.80±	103.00^{a} bc 9.97±	109.20^{a} b 16.11±	121.60^{a} b 17.59±	104.80^{a} bc 6.57±	112.00^{a} b ±15.95	*
IVDMD, %	65.33^{cd} 1.05±	68.27^{b} 0.18±	63.21^{d} 0.68±	67.67^{bc} 1.75±	64.71^{d} 0.66±	65.51^{cd} 0.87±	70.92^{a} 0.62±	69.47^{ab} 0.60±	67.73^{bc} 0.63±	70.21^{ab} 0.80±	67.67^{bc} 0.27±	64.86^{d} ±0.68	**

Means with differ significantly at the level of * ($P<0.05$) or ** ($P<0.01$)

[1] DM loss= dry matter loss; Fp= Fleig point; BC= Buffering capacity; AS= Aerobic stability; IVDMD=In vitro dry matter digestibility

SCS= soluble carbohydrate sources; C-M= cane molasses; D-M= date molasses; C-F= corn flour[2]

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source of carbohydrates. Kilic (15) clarified that the Fp depends on the level of DM and the pH of the silage.

With regard to the effect of the interaction between the DM levels of YCS and the SCS added at ensiling on the BC, the results showed that BC was improved ($P<0.01$) from 92.88 in the silage samples made with a level of 35% DM and the addition of C-M to 71.52 mEq of NaOH/ 100 g DM in those made with a level of 40% DM and the addition of C-M. The correlation between BC and the quality of fermentation and its role in the preservation of nutrients may explain why the samples made with a level of 40% DM and the addition of C-M were well responded to a rapid decrease in pH.

The results also showed that the samples of YCS silage made with a level of 30% DM and the addition of C-M were characterized by the higher ($P<0.05$) stability against aerobic spoilage which was extended for 129.80 hours, while those made with a level of 25% DM and the addition of C-F were less stable and aerobically spoiled after 33.60 hours only after exposure to air. The variation in AS may be due to the rapid metabolic rate of soluble carbohydrates in the samples that were quickly spoiled by the activity of aerobic microorganisms.

Results of the interaction data between the DM levels of YCS and the SCS added at ensiling indicates a significant improvement ($P<0.01$) in the IVDMD from 63.21 in samples made with a level of 25% DM and the addition of C-F to 70.92% in those made with a level of 35% DM and the addition of C-M. The improvement in the IVDMD can be explained on the basis of the degradation of the cell wall components during ensiling that may be enhanced as a result of the addition of C-M. Similar result was obtained by (3), they attributed the increase in digestibility of wheat straw silage due to the addition of C-M to the improvement in the fermentation and its reflection on the digestion of cell wall components.

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