Effect of dry matter levels and soluble carbohydrate sources on sensory and fermentation characteristics of corn stover silage

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Abstract

The study was conducted in the nutrition laboratory of Animal Production Department - College of Agriculture -Al-Qasim Green University to investigate the effect of ensiling corn stover (CS) at different dry matter (DM) levels (25, 30, 35 and 40%) and the soluble carbohydrates (SC) sources (cane molasses (M), date molasses (D) and corn flour (F) added at ensiling time on sensory and fermentation characteristics. The results revealed that CS ensiled at 30 and 35% DM levels were characterized by the lower ($P<0.01$) pH values of 3.84 and 3.83, and higher ($P<0.05$) lactic acid concentration (LA) of 4.24 and 4.48% of the DM, respectively. The lower ($P<0.05$) ammonia nitrogen (NH_3-N) concentration of 2.33 %TN was detected in the CS samples ensiled at 30 and 40% DM levels. Higher ($P<0.01$) concentration of the residual water soluble carbohydrates (WSC) was detected in the CS samples ensiled at 25, 30 and 40% DM levels. Regarding the effect of SC, results showed that the lower ($P<0.01$) pH values were recorded in the CS samples ensiled with the addition of M, in which lower ($P<0.01$) residual WSC of 3.88 % of DM, and total volatile fatty acids (TVFA) concentration of 8.23 mmol/100 g DM were also observed as compared with those ensiled the addition of D and F, which were characterized by the lower LA concentration.

Key words: corn stover، silage، dry matter، soluble carbohydrates، fermentation

Introduction

The increasing population increases the need to exploit available animal resources to meet human demand for animal protein, and this requires optimal production of ruminant diets. Silage is a common practice to preserve excess crops and ensure the availability of feed throughout the year. Moreover, if well made, silage can be a suitable feed for ruminants. Saeed [34] indicated the possibility of producing more palatable feed from crop residues by ensiling.

Silage is produced by storing crops and their residues at an appropriate DM level in anaerobic conditions, where lactic acid bacteria (LAB) convert soluble carbohydrates into organic acids, especially lactic acid (LA), leading to reduce pH and ensuring the preservation process [39]. The DM level of the ensiled crops plays an important role affecting silage fermentation. Ensiling too dry materials leads to restrict fermentation and may be exposed to damage as a result of slow decrease in pH [37]. In the case of wet materials, there will be an increase in the amounts of effluent, DM loss, proteolysis, an increase in the concentration of butyric acid, and a decrease in the palatability and digestibility of the silage [8].

Soluble carbohydrates are the basic substrate for the growth of LAB required to maintain good fermentations [28]. According to Ferreira [15], the minimum recommended

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level required to ensure good quality fermentations ranges between 6 and 12% DM. Based on above, the current study was conducted to investigate the effect of DM level of corn stover ensiled with different soluble carbohydrate sources on the sensory properties and fermentation characteristics of silage produced.

Materials and methods

Corn stover (CS, leaves and stems) was chopped to a length of about 1-1.5 cm. The materials were wilted at the field for 5 and 8 hours to raise the DM content level to about 40% and 45%, respectively. The DM levels were then adjusted to 25, 30, 35, and 40% by adding amounts of water calculated according to the equation adopted by Saeed [35]. Cane molasses (M, 34.65% WSC), date molasses (D, 43.91% WSC) and corn flour (F, 9.55% WSC), were added to the chopped CS, their amounts were estimated to be equivalent to the content of water soluble carbohydrates (WSC) in 8% of M. Accordingly, the amounts of D and F were 6.30 and 29 g /100 g DM of stover, respectively. Urea was added to all samples of ensiled CS at 2% level on DM basis to enhance the nitrogen (N) content and to provide relative protection of the protein in the CS from decomposition during ensiling. Twelve different CS silage treatments were prepared, representing the factorial arrangement of 4 levels of DM (25, 30, 35, and 40%), and 3 sources of SC (C, D and F), with five replicates each. The ensiled materials were well mixed, packed into double nylon bags at about 500 g/sample, were manually compressed to expel the trapped air and sealed directly. The replicates of each silage treatment were placed inside a nylon bag and stored in pit silos that were covered with soil and pressed well to prevent entry of air. The ensiling period was 60 days, after which the samples were opened successively to determine sensory properties and fermentation characteristics.

Determination and analysis

Sensory characteristics of silage including color, smell, texture and presence of molds were determined as described by Saeed [34]. Water extracts of each sample of CS silage were prepared by mixing 50 g of silage with 500 ml of distilled water for 10 min and filtered through 4 layers of cheese cloth and filter paper thereafter [25]. The pH of silage sample was immediately measured in the water extract using a pH meter. Extracts were then kept frozen at -20ºC until subsequent determination. The WSC content of the SC sources and samples of ensiled CS were determined according to the WSC colorimetric method [19]. Lactic acid concentration in the ensiled CS was determined according to the colorimetric method [18]. Ammonia nitrogen (NH_3-N) and total volatile fatty acids (TVFA) concentrations were determined in water extract according to the MgO distillation [3] and Markham [26] methods, respectively. The obtained data were analysed as a 4×3 factorial arrangement for 4 DM levels, 3 SC sources using Statistical Analysis System [36].

Table 1- Chemical composition of wilted corn stover

Item	%
Ash	7.08
Crude protein, CP	6.96
Ether extract, EE	2.34
Crude fiber, CF	36.35
Nitrogen free extract, NFE	47.27

Chemical analysis was performed according to the AOAC [3] methods.

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Results and Discussion

Sensory properties

As shown in table 2, the color of the ensiled CS samples was varied between dark and light green. This variation may be due to the effect of additives. Rostini [32] indicated that the color of silage is affected by the type and level of additives. Catchpool [9] related such variation to the decomposition rate of chlorophyll during ensiling. Moreover, Rostini [33] reported that the color changes of ensiled materials are a result of respiration processes of aerobic microorganisms that continue as long as oxygen remains, because the heat of oxidizing sugar to CO_2 and H_2O is often the reason for those color changes.

The odor was generally acceptable and varied from the odor of fruit to date vinegar. The odor of the CS samples ensiled with the addition of M or D was better than those ensiled with the addition of F. This may be due to the fermentation quality during ensiling of the CS using those two additives. There is evidence for that in terms of lower pH ($P<0.01$) and high LA content (Table 3). The absence of an unpleasant odor may enhance the fermentation quality. Saeed [35] believed that the variation in the odors emitted from silage may be due to the difference in the organic acids content, and this is reflected on the differences in pH. Alikhani [2] observed that the addition of cane molasses improved the sensory properties of sunflower silage.

The texture of the silage which, was determined according to the aggregation of the silage, all samples of CS silage were well aggregated, and those ensiled with addition of M or D showed greater aggregation and firmer shape than those ensiled with addition of F. This may be due to the viscous nature of M or D in binding the parts of the ensiled materials. In general, the texture of all silage samples was natural, and no slimy or sticky texture was observed. The samples of CS ensiled at 40% DM, especially those to which F was added, had a dry texture, and those ensiled at 25% DM were characterized with a wet texture. The dry and wet texture shown can be attributed to the difference in the DM content of those samples.

The moldiness was observed in samples of CS ensiled with addition of F, especially at the level of 40% DM, specifically at the surface of the silage and near the places where the bags were closed. This could be a result of some oxygen remaining at the closure zone due to insufficient pressure [35]. Weinberg [39] confirmed that the efficiency of silage pressing depends on the DM content of the ensiled materials, and that the high DM leads to some oxygen remaining between the parts of the silage, which makes it susceptible to mold growth.

Fermentation characteristics

Table 3 shows the effect of the DM level in the CS and the source of soluble carbohydrates added at ensiling on the fermentation characteristics. The results revealed that the lowest ($P<0.01$) pH values were recorded in the samples of CS ensiled at 30 and 35% DM, compared to that recorded in those ensiled at 25 and 40% DM levels. This result is consistent with the findings of Hu [21] in which, increasing the DM level of the corn crop from 33 to 40% increased ($P<0.01$) pH values from 3.60 to 3.69. However, Saeed [35] indicated that there was a significant decrease ($P<0.01$) in the pH values of corn crop residue ensiled at 25 and 30% DM compared to residues ensiled at the level of 35 and 40% DM, the values were 3.73 and 3.88 vs. 4.21 and 4.33, respectively. The high pH value in the samples of CS ensiled at 25% DM in the current study may be due to the high moisture content. Gordon [17] indicated that high moisture content interferes with the rapid

Table 2 - Effect of dry matter level and soluble carbohydrate source on the sensory characteristics of corn stover silage

DM level, %	25			30			35			40		
SC sources[1]	M	D	F	M	D	F	M	D	F	M	D	F
Color [2]	DG	DG	LG	DG	DG	LG	DG	DG	LG	DG	DG	LG
Odor [3]	DV	DV	DV	FV	FV	DV	FV	FV	FV	FV	FV	DV
Texture	W-A	W-A	W-A	W-A	W-A	W-A	W-A	W-A	L-A	W-A	W-A	L-A
Presence of mold	-	-	+	-	-	+	-	-	+	-	-	+

[1] SC, soluble carbohydrate sources: M, cane molasses; D, date molasses; F, corn flour
[2] Color: DG, dark green; LG, light green;
[3] Odor abbreviations: DV, date vinegar; FV: fruit vinegar
[4] Texture abbreviations: W-A, well aggregate; L-A: less aggregated

Table 3 - Effect of dry matter level and soluble carbohydrate sources on the fermentation characteristics of yellow corn stover silage (Mean ± SE)

Fermentation characteristics	Dry matter level % (DM)				soluble carbohydrates (SC)			*P*	
	25	30	35	40	M	D	F	DM	SC
pH	3.97^{a} ± 0.07	3.84^{b} ± 0.02	3.83^{b} ± 0.01	4.00^{a} ± 0.01	3.81^{b} ± 0.03	3.94^{a} ± 0.04	3.98^{a} ± 0.03	**	**
WSC	3.95^{a} ± 0.01	3.58^{b} ± 0.13	3.94^{a} ± 0.05	3.88^{a} ± 0.06	3.88^{b} ± 0.02	4.02^{a} ± 0.01	3.61^{c} ± 0.11	**	**
LA	3.63^{b} ± 0.28	4.24^{ab} ± 0.29	4.48^{a} ± 0.20	4.05^{ab} ± 0.28	4.49^{a} ± 0.17	4.03^{ab} ± 0.27	3.78^{b} ± 0.23	*	*
NH3-N	3.11^{ab} ± 0.30	2.33^{b} ± 0.30	3.43^{a} ± 0.54	2.33^{b} ± 0.32	2.77 ± 0.44	2.50 ± 0.26	3.13 ± 0.28	*	NS
TVFA	8.62^{a} ± 0.11	8.54^{ab} ± 0.06	8.18^{b} ± 0.28	8.69^{a} ± 0.03	8.23^{b} ± 0.23	8.66^{a} ± 0.01	8.63^{a} ± 0.03	*	**

Means with different letters differ significantly at the level of * ($P<0.05$) or ** ($P<0.01$); NS. Insignificant
SC, soluble carbohydrate sources; M, cane molasses; D, date molasses; F, corn flour
WSC, water soluble carbohydrates (% DM); LA, lactic acid (% DM); NH_3-N, ammonia nitrogen (% TN); TVFA, Total volatile fatty acids (mmol/100 g DM)

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growth of LAB, leading to an increase in the effluent; such factors contribute to resist the decrease in pH. Whereas, the highest pH values in samples of CS ensiled at 40% DM may be due to the presence of air pockets inside the silage mass. Schroeder [37] referred to the difficulty of expelling air when packing crops with a high DM content. While Wayne [38] reported that the increase in pH may be due to the limited activity of LAB as a result of the high DM content.

Results showed that high ($P<0.01$) WSC residual was remained in the CS samples ensiled at 25, 35 and 40% DM compared with those ensiled at 30% DM. As a pattern of change, this result agrees with that obtained by [21] in which a significant decrease ($P<0.01$) in the residual WSC as a result of increasing the DM content from 33 to 40%. The lower content of WSC in CS samples ensiled at 30% DM in a current study may indicate that more extensive fermentations occurred in those samples compared to the other samples, by which much WSC was consumed.

Higher ($P<0.05$) content of LA was detected in the samples of CS ensiled at 35% DM compared with those ensiled at 25% DM, the values were 4.48 and 3.63% of DM. A similar result was obtained by Postulka [29]. Samples of CS ensiled at 30 and 40% DM did not differ significantly in LA content between them and with those ensiled at 35% DM in the current study, with superiority in favor of the latter by 0.24 and 0.43% of DM, respectively. In another study, LA content was not significantly affected by ensiling whole corn plant at DM content between 33 and 40% despite a slight increase from 3.02 to 3.21% of DM [21]. The LA concentration in the current study indicates that CS silage was of good quality. Kung [24] confirmed that the ideal concentration of LA in the silage ranges between 2-4% of DM.

Regarding the effect of the DM levels of the CS at ensiling on the concentration of NH_3-N, the results showed that higher ($P<0.05$) values of 3.43 in the samples of CS ensiled at the 35% compared with 3.11, 2.33, and 2.33% of TN in those ensiled at 25, 30 and 40%, DM respectively. This result is consistent with the findings of Saeed [35], in which a lower ($P<0.01$) concentration of NH_3-N was detected in the yellow corn crop residues ensiled at 25 and 30% DM compared with residues ensiled at 35 and 40% DM levels. Arriola [5] found that NH_3-N concentration was decreased ($P<0.05$) by 1.1 and 1.6% of TN in corn crop silage with an increase in the DM level from 25 to 32 and 37%. However, Hu [21] observed a significant increase ($P<0.01$) in the concentration of NH_3-N with increasing the DM level in the corn crop before ensiling from 33 to 40%. The significant increase ($P<0.05$) in the concentration of NH_3-N in the CS samples ensiled at 35% DM level, despite the high concentration of LA to 4.48% and the decrease in pH to 3.83, may be due to the decomposition of the protein content during fermentation by some plant proteolytic enzymes. Oude Elferink [27] indicated the continued activity of some proteolytic enzymes even at low pH levels. The significant decrease ($P<0.05$) in the concentration of NH_3-N in the CS samples ensiled at 30% DM level can be attributed to the decrease in pH to 3.84. Because the rapid decrease in pH limits proteolysis by inhibiting plant proteolytic enzymes and hinders the decomposition of amino acids and the consequent reduction in volatile nitrogen [11]. The decrease in NH_3-N in CS samples ensiled at 40% DM level can be linked to the high concentration of VFA in those samples and their role in hindering the decomposition of crude protein.

The results showed higher ($P<0.05$) concentration of TVFA to 8.62 and 8.69 mmol/100 g DM was associated with the CS samples ensiled at 25 and 40% DM levels compared with those ensiled at 35% DM level in which TVFA concentration was 8.18 mmol/100 g DM. The result is consistent with that obtained by Castro [10], a significant increase ($P<0.01$) in the concentration of TVFA in ryegrass silage was observed as a result of increasing the level of DM before ensiling from 39 to 53%.

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Whereas, Saeed [35] observed a significant decrease ($P<0.01$) in the TVFA concentration in the silage of corn crop residues by increasing the level of DM levels from 25 to 30, 35 and 40%. Hilscher [20] also indicated a decrease in the concentration of TVFA in corn crop silage by increasing the level of DM before ensiling from 37 to 43%. The increase in the concentration of VFA in CS samples ensiled at a level of 25% DM in the current study can be attributed to a shift in the fermentations pathway due to high moisture, leading to an increase in the production of fermentable acids, especially acetic acid. A similar conclusion was reported by Goeser [16].

Regarding the effect of the soluble carbohydrate sources added at ensiling of CS on the fermentation characteristics, the results showed that a lower ($P<0.01$) pH was recorded in CS ensiled with M as compared to those ensiled with D or F, the mean values were 3.81, 3.94, and 3.98, respectively. This result is consistent with that obtained by [7], in which the pH of Mott grass silage was decreased ($P<0.05$) by about 0.8 due to the addition of M as compared with F. In another study, the pH in sugarcane residue ensiled with M was decreased ($P<0.05$) by 0.27 compared with the addition of F [30]. The significant decrease in the pH of CS ensiled with M in the current study may be due to an increase in the LA concentration as a result of providing LAB with high quantities of dissolved sugars, as shown in the table. Schroeder [37] considered WSC as one of the most important factors that controlled acid production in silage.

Regarding the residual content of WSC, the results showed that higher ($P<0.01$) content was detected in the CS samples ensiled with D compared with those ensiled with M in which, the WSC content was higher ($P<0.01$) than in those ensiled with F, the mean values were 4.02, 3.88 and 3.61%, respectively. This result disagreed with that indicated by Zhang [40] in their study on the effect of the SC sources on fermentations of grass silage, where lower residual WSC content was found in samples of the silage made with the addition of M compared with those made with the addition of F, the mean values were 1.82% and 2.15% DM, respectively. The significant variation in the residual WSC contents found in the current study among CS samples as affected by addition of different SC sources (M, D and F) may be due to the extent or rate of their decomposition by LAB. Abu-Ellol [1] pointed out the potential effect of the SC sources added at ensiling on the properties of silage fermentations.

The results of the current study revealed that the mean LA concentration was increased ($P<0.05$) from 3.78% in CS samples ensiled with addition of F to 4.49% DM in those ensiled with addition of M, and LA concentration in CS samples ensiled with addition of D was 4.03% DM. A similar result was obtained by [7], higher increase ($P<0.05$) in LA concentration was detected in grass silage prepared with the addition of 5% cane molasses compared with 5% corn flour (3.88 vs. 3.84% DM, respectively). No significant differences in LA concentration were reported by Arslan [6] due to the addition of cane molasses or ground barley at ensiling of grass in spite of slight increase in the fever of molasses treatment. Rodrigues [30] obtained similar results in sugarcane ensiled with cane molasses or corn flour. The soluble sugars found in M and D may be more suitable for the activity of LAB than those found in F. Kung [24] reported that providing fermentation media with sufficient and suitable soluble sugars increases the activity of LAB, thus producing large quantities of LA a.

The statistical analysis showed that the source of SC added at ensiling of corn stover (CS) had no significant effect on the NH_3-N concentration in the silage. This is consistent with the results obtained by Zhang [40], in which it was observed that there was no significant difference in the concentration of NH_3-N in grass silage as a result of adding 4% cane molasses or 5% corn flour, the mean values were 2.66% and 3.02% of TN, respectively.

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Arslan [6] also indicated that there was no significant effect of ensiling grass with 5% cane molasses or ground barley as a source of SC on the NH_3-N concentration.

Regarding the effect of the SC sources on the concentration of TVFA, the results showed that a higher increase ($P<0.01$) was detected in the CS samples ensiled with the addition of D and F compared to those ensiled with M, the mean values were 8.23, 8.66, and 8.63 mmol/100 g DM, respectively. This result is consistent with the results of Jaelani [22] who observed an increase in the TVFA concentration in algae silage ensiled with addition of cane molasses by about 1.3 compared with those ensiled with the addition of rice bran. However, Cheng [12] mentioned to the superiority ($P<0.05$) of grass silage ensiled with the addition of cane molasses on the TVFA concentration compared with addition of sucrose. The high TVFA concentration detected in CS samples ensiled with the addition M in the current study may be due to the fact that the molasses content of WSC was more suitable for the activity of silage microorganisms, such as lactic acid bacteria, acetic acid bacteria, and other bacteria that produce the rest of the acids in the silage. Arbabi and Ghoorchi [4] showed that there was an increase in the content of TVFA in silage by increasing the soluble sugar available for fermentation.

Regarding the effect of the interaction between the DM levels of CS and the SC sources on the fermentation characteristics of the prepared silages, the results showed that lowest ($P<0.01$) pH of 3.8 was recorded in the CS samples ensiled at 35% DM level with the addition of M compared with 4.15 recorded in those ensiled at 25% DM level with the addition D. The lowest LA concentration (3.09% of DM) in the later may indicate that those samples were affected by high moisture content. Kim and Adesogan [23] believed that ensiling materials with high moisture leads to slower the pH decrease, increased DM loss and decreased LA production due to poor fermentation. Thus, the DM level of 35% can be ideal for fermentation of CS as evidenced by the lowest pH.

Results of interaction also showed that highest ($P<0.01$) concentration of the WSC remained was associated with the CS samples ensiled at 35% DM level with the addition of M, while the lowest concentration ($P<0.01$) was associated with those ensiled at 35% DM level with the addition of F. The larger quantity of F added compared with M or D due to the lower WSC content, have led to increase the final DM content in these samples, the case that may have made compression process less efficient, hence, air remaining between parts of the silage mass. The presence of oxygen enhances the growth of the yeasts and their ability to survive during storage [14]. During which, yeasts metabolize soluble sugars into ethanol and carbon dioxide [31]. Results revealed that CS samples ensiled at 40% DM level with the addition of M were characterized with a higher ($P<0.05$) LA concentration, while lower ($P<0.05$) concentration was detected in those ensiled at 25% DM level with D. This result may be related to the difference in the moisture. Kung [24] indicated that the materials ensiled with DM levels less than 30% are more susceptible to clostridia fermentation than those preserved at 30% DM level or higher, metabolizing soluble sugars or lactic acid into butyric acid.

Regarding the effect of the interaction between the DM level in CS and the source of soluble carbohydrates added at ensiling on the NH_3-N concentration, the results showed that lower ($P<0.05$) concentration of 1.56% was detected in the CS samples ensiled at 30% DM level with the addition of M, while the higher ($P<0.05$) concentration of 4.34% TN was detected in those ensiled at 25% DM level with the M. The moisture (25% DM) media may provide an ideal environment for clostridia activity, breaking down protein and producing more ammonia [13].

The results revealed that higher ($P<0.01$) TVFA concentration was associated with CS samples ensiled at 40% DM level with the addition of F, whereas lower ($P<0.01$)

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Table 4 - The effect of the interaction between the level of dry matter and the soluble carbohydrates sources on the fermentation characteristics of the corn stover silage (Mean ± SE)

DM level	25			30			35			40			*P*
SC	M	D	F	M	D	F	M	D	F	M	D	F	
pH	3.64^{e} ± 0.06	4.15^{a} ± 0.12	4.13^{ab} ± 0.03	3.83^{d} ± 0.01	3.82^{d} ± 0.01	3.86^{d} ± 0 .08	3.80^{d} ± 0.01	3.83^{bcd} ± 0.02	3.86^{d} ± 0.01	3.97^{bcd} ± 0.01	3.95^{cd} ± 0.01	4.07^{abc} ± 0.03	**
WSC	3.97^{ab} ± 0.05	3.95^{abc} ± 0.01	3.95^{abc} ± 0.01	3.78^{bc} ± 0.03	4.02^{ab} ± 0.04	2.94^{d} ± 0.11	3.88^{abc} ± 0.03	4.06^{a} ± 0.04	3.87^{abc} ± 0.15	3.90^{abc} ± 0.01	4.04^{ab} ± 0.03	3.69^{c} ± 0.17	**
LA	4.04^{ab} ± 0.31	3.09^{b} ± 0.19	3.76^{ab} ±0.78	4.26^{ab} ± 0.41	4.30^{ab} ± 0.84	4.15^{ab} ± 0.10	4.53^{ab} ± 0.07	4.88^{a} ± 0.36	4.05^{ab} ± 0.46	5.14^{a} ± 0.34	3.86^{ab} ± 0.35	3.15^{b} ± 0.29	*
NH_3-N	4.34^{a} ± 0.49	2.30^{bc} ± 0.09	2.68^{abc} ± 0.40	1.56^{c} ± 0.09	1.69^{bc} ± 0.37	3.73^{ab} ± 0.31	3.49^{abc} ± 1.39	3.74^{ab} ± 0.70	3.05^{abc} ± 0.78	1.68^{bc} ± 0.45	2.27^{bc} ± 0.38	3.04^{abc} 0.70±	*
TVFA	8.67^{a} ± 0.36	8.65^{a} ± 0.02	8.54^{a} ± 0.02	8.42^{a} ± 0.18	8.63^{a} ± 0.03	8.57^{a} ± 0.03	7.19^{b} ± 0.69	8.67^{a} ± 0.02	8.66^{a} ± 0.11	8.62^{a} ± 0.07	8.70^{a} ± 0.02	8.76^{a} 0.04±	**

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

SC, soluble carbohydrate sources; M, cane molasses; D, date molasses; F, corn flour

WSC, water soluble carbohydrates (% DM); LA, lactic acid (% DM); NH_3-N, ammonia nitrogen (% TN); TVFA, Total volatile fatty acids (mmol/100 g DM)

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concentration was associated with those ensiled at 35% DM level with addition of M. The mean values were 8.76 and 7.19 mmol/100 g DM, respectively. Since the fatty acids represent one of the end products of the breakdown or assimilation of soluble sugars in the anaerobic conditions [37]. The variation in the TVFA concentrations in the ensiled CS samples could be a result of the fermentation nature and the conditions that occurred during ensiling, in addition to the difference in the metabolizing rate of WSC present in the soluble carbohydrates added. The higher concentration of soluble sugars in the CS samples that were associated with the lowest TVFA concentration and the lower concentration of those soluble sugars in the CS samples that were characterized by the higher TVFA concentration may explain this discrepancy.

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