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Effect of processing dejuiced sweet sorghum residues on ruminal fermentation characteristics *in vitro*[*]

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ABSTRACT

The objective of this study was to examine the effect of processing dejuiced sweet sorghum residues on ruminal fermentation characteristics *in vitro*. Dejuiced sweet sorghum residues (DSSR) were subjected to three treatments: 1. direct ensilage (E), 2. ensilage of distillers after distillation of DSSR (ED), and 3. drying distillers after distillation of DSSR (DD). After fermentation, E and ED treatments both had perfect silage fermentation characteristics. Among the three treatments, E had the highest gas production, *in vitro* DM and NDF digestibilities, followed by ED and DD. The treatment had no significant effect ($P>0.05$) on *in vitro* NDF digestibility, the concentration of NH_3-N, total VFA, and individual VFA molar proportions, except for the molar proportions of acetic acid and butyric acid ($P<0.01$). The results indicate that treatment of dejuiced sweet sorghum residues with directly ensiling or ensiling distillers DSSR can improve their nutritive value.

KEY WORDS: sweet sorghum residues, *in vitro* rumen fermentation, gas production

INTRODUCTION

In recent years, it is a common practice that whole sweet sorghum plants (WSSP) are used for making fuel alcohol replacing cereal grains in Northern China. The use of WSSP for making fuel alcohol has many advantages, e.g., a

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high mass yield, high sugar content, easy to extract the sugars from the plant and low extracting sugar cost as well as time-saving effect due to the direct extraction of sugars from the whole plant juice (called as dejuicing). However, making fuel alcohol from WSSP is usually not feasible economically compared with use of fossil fuel. Therefore, many attempts were made on reducing the production cost of WSSP fuel alcohol. In the process of alcohol production, a great deal of dejuiced sweet sorghum residues (DSSR) is produced. Because DSSR products have up to 8% of residual sugars present, the WSSP alcohol plants would further extract such DSSR products to distillate more alcohol, which allows the WSSP alcohol process to produce distillers DSSR products. Because these two DSSR products are highly fibrous, and soft and moist in structures, there is a potential for them to be used as ruminant feeds.

Because moisture is high in DSSR, they have to be treated in some ways for a largely scale use. Although anaerobic ensilage of DSSR products is commonly used in making ruminant feeds from DSSR, there is less information about their nutritive value. The aim of the present study was to determine the effect of processing dejuiced sweet sorghum residues with direct ensiling, distillers ensiling or distillers drying on ruminal fermentation characteristics *in vitro*.

MATERIAL AND METHODS

Dejuiced sweet sorghum plants residues (DSSR) were obtained from the Guyunzhong Distillation Plant, Tuoketuo County, Inner Mongolia. The DSSR products were made from mechanically pressing a new hybrid of sweet sorghum plants developed by Henyi Development Center for Energy Technology, Beijing (China). The wet DSSR products were subjected to three treatments: 1. directly anaerobic ensilage (E), 2. anaerobic ensilage of distillers after distillation of DSSR (ED), and 3. drying distillers after distillation of DSSR (DD). The DSSR products (average length of 15 mm and moisture at 68%) and distillers DSSR (average length of 8 mm and moisture at 65%) were locally collected from the plant. The wet DSSR and distillers DSSR products were ensiled in 3 l volume laboratory glass jars (average 750 g silage DM) with a special gas leaking device. All the jars were filled and sealed within 20 min, and stored in an environment with ambient temperatures ranging between 22 and 25°C. The jars were opened on week 9 and sampled for standard chemical analysis. All the ensiled samples together with directly dried distillers DSSR samples were freeze-dried in a lyophilizer (10°C, shelf; Model 44C2-A, Beijing Boyikang Instrument Co., Ltd., Beijing) and ground through a 1-mm screen for further chemical analysis and *in vitro* fermentation test.

In vitro digestibilities of DM (IVDMD) and NDF (IVNDFD) were determined according to the procedures of Tilley and Terry (1963) with a minor modification.

Namely, the ground samples, weighed into specialized non-woven fabric bags and put into fermentation tubes, were anaerobically incubated with the buffer-rumen fluid mixture solution for 48 h in a water bath at 39°C, with shaking twice a day. Three replicates were used in each treatment of DSSR. The rumen fluid was obtained from 3 Holstein steers fitted with a permanent rumen fistula, which were fed a formulated ration of 30% roughages (1/3 dehydrated lucerne and 2/3 dry maize stalks) and 70% mixed concentrates. At the end of first phase of incubation (48 h), the fabric bags were removed from the tubes and aerobically incubated for further 48 h with pepsin solution (0.2% pepsin dissolved in 0.1 N HCl to achieve a final pepsin activity of 1:10.000). After incubation, the samples were analysed for residual DM and NDF to calculate IVDMD and IVNDFD.

An *in vitro* gas production study using above three samples was carried out based on the method of Menke et al. (1979). The air dried samples (200 mg) were weighted into each of three calibrated glass syringes (Häberle Maschinenfabrik GmbH, Germany). The syringes were prewarmed to 39°C, then 30 ml of mixed culture medium (consisting of ruminal fluid and buffer, ratio 1:2) were pipetted with an automatic pump into each syringe followed by incubation in a water bath at 39°C. Gas production was measured and recorded as the volumes of gas production (GP) in the calibrated syringes. Three parallel syringes of each treatment were prepared in this experiment. They were used to measure the gas production at 0, 1, 2, 3, 4, 5, 6, 8, 10, 12, 16, 18, 20, 24, 28, 32, 36, 40, 48, 56, 64, 72, 84, 96 and 120 h. Dynamic fermentation parameters were calculated by NON-LINEAR Model in SAS (1999). The model was $GP = B \times (1–\exp(–c \times (t - lag)))$. GP is gas production (ml) of 0.2000 g sample (DM basis) at time t; B is potentially maximum gas production (ml) of 0.2000 g sample; c is rate of gas production (h^{-1}); lag is delaying time of gas production (h); t is time of incubation *in vitro* (h). A part of syringes was taken out from the incubator at 24 h determination of ruminal pH, NH_3-N (Broderick and Kang, 1980) and VFA concentration (Erwin et al., 1961; SP-3420, Beifen Ruili Analytical Equipment Co., Beijing).

The effect of DSSR with different treatments on *in vitro* fermentation characteristics was statistically analysed by variance analysis (SAS, 1999).

RESULTS AND DISCUSSION

After ensiling fermentation, both E and ED treatments of DSSR had perfect silage fermentation characteristics. As shown in Table 1, there were significant differences in DM and NDF content among three different DSSR samples ($P<0.001$). Ensiling treatment decreased NDF content of DSSR, especially for E, non distillated DSSR product. The difference of the content of DM or NDF among three DSSR products was associated with the different treatments,

because ED and DD products, rather than E product, was subjected to further distillation treatment. The treatment also significantly influenced IVDMD of DSSR

Table 1. The two-stage digestibility of DM and NDF of dejuiced sweet sorghum residues with different treatments

	Treatments			SEM	P value
	E	ED	DD		
DM, %	44.18[b]	28.25[c]	92.28[a]	0.17	0.001
NDF, DM%	69.24[c]	74.40[b]	78.92[a]	0.49	0.001
IVDMD, %	51.38[a]	46.72[b]	39.78[c]	0.69	0.001
IVNDFD, %	38.55	37.08	32.83	1.41	0.065

[a,b,c] means in the same row with different superscripts differ significantly (P<0.05)

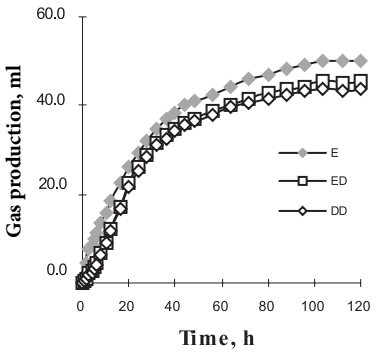

Figure 1. Dynamic fermentation trend of dejuiced sweet sorghum plants residues with different treatments

Table 2. *In vitro* gas production dynamics of dejuiced sweet sorghum residues with different treatments

Item	Treatments			SEM	P value
	E	ED	DD		
120 h GP1, ml/0.2 g	50.1[a]	45.6[b]	43.9[c]	0.46	0.001
B, ml/0.2 g DM	50.2[a]	46.3[b]	44.9[b]	0.50	0.001
C, h-1	0.036	0.035	0.03[6]	0.0004	0.209
Lag, h	-0.83[b]	1.85[a]	1.95[a]	0.14	0.001

[1] GP is gas production (ml) of 0.2000 g sample (DM basis) at time point t; B is potentially maximum gas production (ml) of 0.2000 g sample; C is rate of gas production (h^{-1}); Lag is delaying time of gas production (h); t is time point of incubation *in vitro* (h)

[a,b,c] means in the same row with different superscripts differ significantly (P<0.05)

Table 3. *In vitro* ruminal fermentation parameters (24 h) of dejuiced sweet sorghum residues with different treatments

Item	Treatment			SEM	P value
	E	ED	DD		
pH	6.74	6.73	6.74	0.01	0.280
NH3-N, mg/100 ml	24.10	27.67	28.44	1.59	0.199
Total VFA, mmol/l	44.34	48.14	40.03	3.83	0.386
VFA, mol%					
acetate,	65.91[b]	67.72[a]	69.00[a]	0.47	0.010
propionate	18.28	17.75	17.91	0.23	0.324
isobutyrate	1.59	1.62	1.46	0.06	0.191
butyrate	11.60[a]	10.20[b]	8.93[c]	0.23	0.001
isovalerate	2.62	2.72	2.70	0.08	0.675
Acetate /propionate	3.61	3.81	3.86	0.07	0.106

[a,b,c] means in the same row with different superscripts differ significantly (P<0.05)

(P<0.001). Compared with DD treatment, E and ED treatments increased IVDMD by 29.2 and 17.4 percentages, respectively. The higher digestibilities of IVDMD and IVNDFD due to ensiling of DSSR may be explained by the difference of *Lactobacillus* biomass and their metabolites produced from ensiling, which may be favourable for cellulolysis of rumen microorganisms. Similar to our results, Madibela and Modiakgotla (2004) also reported that ensiling fermentation of whole sweet sorghum plants increased the IVDMD. Ensiling treatment resulted in significantly higher (P<0.001) IVNDFD than drying distillers DSSR, but differences between two ensiling treatments were not significant (P>0.06).

The results of dynamic fermentation trend of DSSR with different treatments are presented in Figure 1 and Table 2. It was found that different treatments had significant influence on 120-h accumulative GP (P<0.001), potential GP (P<0.001) and lag time (P<0.001), but had no influence on rate of gas production (P>0.2). The 120-h accumulative and potential GP were greatly accordant with the results of IVDMD and IVNDF, indicating improved digestion of DSSR due to ensiling treatment. This study also suggests that *in vitro* gas production can be well used as a measurement of DM or OM digestibility. Fermentation lag time of E (-0.83 h) was much shorter (P<0.001) than DD (1.85 h) and ED (1.95 h), which suggests that ruminal fermentation lag time is likely associated with sugar content of DSSR samples.

As shown in Table 3, most of ruminal fermentation parameters of DSSR were unaffected by different treatments, except for the molar proportions of acetic acid and butyric acid (P<0.01). A main factor affecting the molar proportion of acetic acid and propionic acid is dietary non-structural carbohydrate (NSC) content. In this study, fermentation substrates among three treatments were different, in which the content of NSC was highest in E treatment, followed by DD and ED treatments. The

observation of molar proportion of acetic acid and butyric acid is in line with the NSC content of DSSR in the current study. Ruminal fermentation pH, the concentration of NH_3-N and total VFA did not differ among treatments, indicating no alteration of rumen fermentation pattern owing to DSSR treatment. The VFA molar proportions were in the normal range of rumen fermentation, which indicated that DSSR with different treatments did not lead to any abnormal fermentation. Even though this, the absolute value of total VFA concentration was at a relatively low level, suggesting that the fermentation of DSSR maintains at a low degree in this study.

CONCLUSIONS

Ensiling treatment of dejuiced sweet sorghum residues (DSSR), either direct ensilage or after distillation, increased *in vitro* dry matter digestibility and potential gas production, reduced fermentation lag time, but had no effects on dynamic fermentation parameters. These results indicate that treatment of DSSR with directly ensiling or ensiling distillers DSSR can improve their nutritive values, which caused by increasing WSC content and reducing NDF and ADF content.

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