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Comparison of chemical composition, starch gelatinization and *in vitro* ruminal fermentation characteristics of different types of maize grains*

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ABSTRACT

Three types of maize grains from high yield maize (HYM), high protein maize (HPM) and high oil maize (HOM) were used in the present study to compare their chemical compositions, starch gelatinization and *in vitro* ruminal fermentation characteristics based on chemical analysis and the *in vitro* gas production method. The results showed that the type of maize had significant effect ($P<0.05$) on the contents of CP, ether extract and starch, starch gelatinization, 48-h gas production, rumen fermentation rate, potential gas production, 12-h and 24-h *in vitro* ruminal digestibilities of dry matter and starch. Of three types of maize grains, HYM had better merits than HOM and HPM in most energy traits, though almost all *in vitro* ruminal fermentation parameters including pH, NH_3-N, VFA concentration and molar percentages of individual VFA were not significantly different ($P>0.05$) among maize types. It was concluded that compared with other two types of maize grains, high yield maize hybrid showed a great potential to be used as energy feed source of ruminant animals.

KEY WORDS: maize type, chemical composition, starch gelatinization, *in vitro* ruminal fermentation, gas production

INTRODUCTION

Maize grains are commonly used as energy feed sources of ruminant animals in the world. Because the grains usually consist of up to 50% of complete rations of

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beef and dairy cattle and sheep, their chemical compositions, starch gelatinization and rumen fermentation characteristics are largely considered by farmers. Recently in China, maize breeding scientists have developed some special hybrids of maize, including high yield maize (HYM), high protein maize (HPM) and high oil maize (HOM) as well as others. The rapidly increasing ruminant production occurring in China entails a great use of these maize grains in ruminant feeding. However, there is little information about their chemical compositions and ruminal fermentation traits. Therefore, we designed this study to compare the chemical composition, starch gelatinization and ruminal fermentation characteristics of different types of maize grains based on chemical analysis and an *in vitro* gas production method.

MATERIAL AND METHODS

Three types of maize grains, i.e. high yield maize (HYM), high protein maize (HPM) and high oil maize (HOM), were donated by National Maize Breeding Centre of China Agricultural University, America Renessen Corporation, and the Institute of Agricultural Products of Chinese Academy of Agriculture Science, respectively. They were all ground in a super-speed mill (0.5 mm sieve, Perten Laboratory Mill 3100). The ground samples were sealed in a plastic envelope until future chemical assay and *in vitro* ruminal fermentation.

An *in vitro* gas production incubation was carried out according to the procedure of Menke et al. (1979). Briefly, 200 mg of maize grain samples and 30 ml buffered rumen fluid were put into each of calibrated glass syringes (HFT000025, Häberle Maschinenfabrik GmbH, Germany). Ruminal fluid was obtained from three fistulated native steers fed with diets consisting of 55% roughage (Chinese wild rye grass and lucerne pellets) and 45% mixed concentrate. The gas production was recorded at 0, 1, 2, 3, 4, 5, 6, 8, 10, 12, 16, 18, 20, 24, 28, 32, 36, 40 and 48 h. Dynamic fermentation parameters were calculated by NON-LINEAR Model in SAS (1999). The model was $GP = B \times (1 - \exp(-c \times t))$. GP is gas production (ml) of 0.2000 g sample (DM basis) at time t; B is potential gas production (ml) of 0.2000 g sample; c is rate of gas production (h^{-1}); t is time of incubation *in vitro* (h). After 12 and 24 h of fermentation, three glass syringes per maize incubation were taken out from the incubator for determination of ruminal dry matter and starch degradability. The incubation contents obtained from 24 h incubation were immediately measured for ruminal pH, and then centrifuged at 8000 *g* for 15 min under 4°C. The supernatant liquids were used for determination of NH_3-N (Broderick and Kang, 1980) and VFA concentration (Erwin et al., 1961; SP-3420, Beifen Ruili Analytical Equipment Co., Beijing). The experiment was repeated twice on different days.

The contents of moisture and ether extract (EE) of maize grain samples were determined by routine methods (AOAC, 1990). The content of crude proteins was measured by the procedure described by the AOAC (1990) with an N Analyzer (Rapid N III, Elementar, Germany). The starch content and gelatinization of maize grain samples were determined by the amyloglucosidase hydrolysed method (Xiong et al., 1990). The effect of maize types on chemical compositions, *in vitro* ruminal dry matter and starch digestibilities, and rumen fermentation characteristics was statistically analysed by variance analysis (SAS, 1999).

RESULTS AND DISCUSSION

As shown in Table 1, maize type significant affected the content of dry matter (DM), crude protein (CP), ether extract (EE) and starch ($P<0.01$). As expected, HOM and HPM had higher content of EE ($P<0.001$) and CP ($P<0.01$) than HYM; however, HOM had the highest content CP, followed by HPM and HYM. This result indicated that regardless of the grain yield factor, HOM should be a more acceptable maize type, because it was high not only EE, but also CP. As to starch content, HYM had the highest content of starch, followed by HPM and HOM, likely suggesting a high energy property of HYM relative to HOM and HPM. Our observation was in agreement with the results of Luo et al. (2002) and Li et al. (2004), who reported different hybrids of maize had remarkable difference of chemical composition.

Table 1. Comparison of chemical composition and starch gelatinization among different types of maize grains[1]

Items	Type of maize grains			SEM	P value
	HOM	HYM	HPM		
Dry matter, %	89.45^{c}	90.95^{a}	90.04^{b}	0.01	<0.001
Crude protein, %DM	10.31^{a}	9.06^{c}	9.51^{b}	0.04	<0.001
Ether extract, %DM	8.21^{a}	4.66^{b}	4.41^{b}	0.21	0.002
Starch, %DM	67.03^{b}	73.94^{a}	73.26^{a}	0.01	0.003
Starch gelatinization, %DM	29.99^{b}	39.33^{a}	25.48^{b}	0.01	0.007

[1] HOM - high oil maize; HYM - high yield maize; HPM - high protein maize

Starch gelatinization reflects the degree at which starch is utilized by rumen microbes or intestinal enzymes. In the three types of maize grains, HYM from CAU 108 showed the highest value of starch gelatinization, followed by HOM and HPM, suggesting more ready digested characteristics of HYM than HOM and HPM. Different starch gelatinization among three various types of maize grain starch may be related to the difference in starch micro-cryptal structure and required gelatinization temperature as stated by Leach (1965). Using various maize grains, Zhao et al. (1997) also obtained the similar result that maize types significantly influenced starch gelatinization temperature.

Table 2 showed the result of *in vitro* DM and starch digestibility after incubation of 12 and 24 h, respectively. Maize type significantly influenced the *in vitro* DM and starch digestibility (P<0.01). No matter what incubation time (12 or 24 h) was used, HYM had much higher DM digestibilities than HOM (P<0.01) and HPM (P<0.05). However, *in vitro* rumen starch digestibilities either 12 or 24 h incubation were not significant different (P>0.2) among three maize grains, although 24 h *in vitro* rumen digestibility of HYM was slightly higher than HOM and HPM (P<0.01). Though different cereal grains with different starch digestibilities had been well documented (Kellems and Church, 2002), very less information has been available about the difference of starch digestion characteristics among different types of maize gains within only one cereal breed. Our result was consistent with the observation of Flachowsky et al. (1992), and coincidence to the starch content and gelatinization discussed above. The lower DM and starch digestibility *in vitro* of HOM and HPM relative to HYM may be improved through some grain processing, e.g., steam-flaking in practice.

Table 2. *In vitro* ruminal dry matter and starch digestibility of different types of maize grains[1]

Items	Type of maize grains[1]			SEM	P value
	HOM	HYM	HPM		
$RDMD_{12}$	47.41[c]	59.03[a]	53.42[b]	0.02	0.005
$RDMD_{24}$	64.38[b]	73.45[a]	70.13[a]	0.02	0.018
RSD_{12}	85.60	87.91	86.92	0.01	0.231
RSD_{24}	97.41[b]	98.10[a]	97.84[b]	0.01	0.007

[1] HOM - high oil maize; HYM - high yield maize; HPM - high protein maize
$RDMD_{12}$ - *in vitro* ruminal dry matter digestibility after 12 h
$RDMD_{24}$ - *in vitro* ruminal dry matter digestibility after 24 h
RSD_{12} - *in vitro* ruminal starch digestibility after 12 h
RSD_{24} - *in vitro* ruminal starch digestibility after 24 h

The results of gas production are presented in Figure 1 and Table 3. There were significant differences in actual gas production, gas producing (fermentation) rate and the potential gas production (P<0.01). The potential gas production of HYM and HPM was higher (P<0.005) than HOM; the rumen fermentation rate of HYM was also higher than other two maize grains (P<0.001). The *in vitro* gas production mostly reflected the degree of carbohydrate fermentation by rumen microbes and the energy content involved in the feedstuffs. Based on this result, the energy value of HYM for ruminant animals may be higher than HOM and HPM.

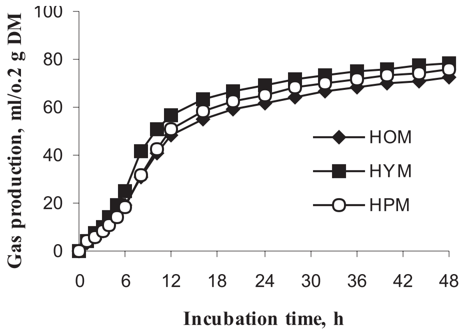

Figure 1. Dynamic change of the gas production of different type maize grains

As shown in Table 3, the type of maize grains did not significantly influence *in vitro* ruminal fermentation parameters (P>0.1), including *in vitro* rumen pH, the concentration of NH_3-N and VFA, individual VFA molar percentages and acetate to propionate ratio. These results indicate that different type of maize grains used as animal feeds may not alter rumen fermentation pattern.

Table 3. Gas production and *in vitro* fermentation parameters of different types of maize grains

Item	Type of maize grain			SEM	P value
	HOM	HYM	HPM		
Potential gas production, ml/0.2 g DM	76.52^{b}	80.98^{a}	80.87^{a}	0.61	0.003
Gas production rate, h^{-1}	0.066^{b}	0.079^{a}	0.065^{b}	0.001	<0.001
In vitro rumen pH	6.47	6.42	6.43	0.01	0.112
NH_3-N, mg/100 ml	15.77	11.90	14.58	1.09	0.107
Total VFA, $mmol \cdot l^{-1}$	66.15	75.79	73.61	2.67	0.160
VFA molar percentages, mol%					
acetate	65.60	66.03	65.92	0.41	0.761
propionate	21.07	21.34	20.77	0.28	0.443
iso-butyrate	0.64	0.70	0.73	0.07	0.671
butyrate	9.94^{a}	9.36^{b}	9.76^{a}	0.09	0.037
isopente	1.98	1.89	2.00	0.07	0.598
valerate	0.76	0.68	0.82	0.13	0.769
A/P molar percentages, A/P	3.11	3.09	3.17	0.06	0.642

[1] HOM - high oil maize, HYM - high yield maize, HPM - high protein maize

CONCLUSIONS

In comparison with high oil maize and high protein maize grains, high yield maize grains had higher rumen carbohydrate fermentation traits, including high gas production, fast fermentation rate, and great *in vitro* rumen DM and starch digestibilities. However, all *in vitro* rumen fermentation parameters were similar among three types of maize grains. Further studies attempting on the response of animal performance to feeding different types of maize grains would be necessary to find out their overall nutritional values.

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