

# Comparison of chemical contents and *in vitro* nutrient digestibility of maize stalks from high oil maize with conventional or specific fodder maize\*

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## ABSTRACT

Maize stalks of five cultivars, namely two high oil maize (HOM: HOM 647 and HOM 298), two conventional maize (CM: CAU 80 and CAU 3138) and a fodder maize (FM: Qingsi #1), were selected to examine the effect of maize cultivars on chemical composition and *in vitro* digestibility of their stalks. The result showed that HOM stalks had higher nutrient contents and higher digestibility of dry matter and neutral detergent fibre than CM stalks and FM stalks. Gas production of HOM stalks was greater than that of CM or FM stalks at each time point during 120 h *in vitro* incubation.

**KEY WORDS:** maize stalks, maize cultivars, chemical composition, *in vitro* digestibility, gas production

## INTRODUCTION

High oil maize (HOM) is a new cultivar of maize, which kernels yield not only higher oil but also more proteins, especially essential amino acids such as lysine and methionine, vitamin A and E, and other nutrients than those in conventional maize (CM). There were a few published reports on HOM stalks, which mainly

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dealt with the proximate analyses and HOM silage feeding experiments (Atwell et al., 1988; LaCount et al., 1995; Weiss and Wyatt, 2000). In China, the HOM cultivars usually have average kernel oil contents at more than 8%. In some cultivars, such as HOM 298, their oil contents of grains were over 10% (Chen, 2001). Furthermore, the HOM cultivars possess a favourite characteristic, e.g., maintenance of green colour in their stalks for long duration at the kernel milk line stage of complete maturity (Song, 2001). Based on these characteristics, HOM cultivar stalks appeal to an ideal fodder to dairy and beef cattle and other ruminant livestock. Therefore, in the present experiment, comparisons were made of chemical composition and *in vitro* digestibility of maize stalks from high oil maize with conventional or specific fodder maize.

## MATERIAL AND METHODS

The maize cultivars including two high oil maize (HOM 647 and HOM 298), two of conventional maize (CM; CAU 80 and CAU 3138) and one fodder maize (FM; Qingsi #1), which were formally bred at The National Maize Improvement Centre of China, were planted in the experimental field of China Agricultural University, Chang Ping Experimental Station, in 2003. The experimental field was prepared for identical soil type, fertilizer administration, water supply and other climatic conditions. The stalk samples were collected according to the maturity stage in September of 2003. Maturity stages were defined as 1/2, 3/4 and 4/4 milk line (ML) based on the position of ML in maize kernels. Considering optimum harvesting time schedules of the five different maize cultivars, the samples of HOM stalks and CM stalks were actually taken at 4/4 ML stage and the sample of FM at 3/4 ML stage. Each cultivar sample consisted of whole stalks from 10 plants.

The air dried whole maize stalks were ground to through 1.5 mm size screen using a Perten Laboratory Mill (Model 3100, Sweden), homogenized and analysed for the contents of dry matter (DM), ether extract (EE), crude protein (CP), crude ash, Ca, and P by AOAC procedures (1990). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were measured following the methods of Van Soest et al. (1991). Neither alpha amylase nor sodium sulphite was used in the NDF procedures. The content of sugar and starch was analysed with an enzymatic digestion procedure (Xiong et al., 1990) using amyloglucosidase (Sigma Cat. No. A-7255) to digest substrate sugars. Water soluble carbohydrates (WSC) was also determined with the above enzyme procedure (Xiong et al., 1990) with a minor modification that sample substrates were not treated with amyloglucosidase and gelatinization, but allowing substrates in the buffer solution tube to vibrate for 60 min, then filtrates were compared for chromatographic values. Starch content was calculated by subtracting WSC from the total sugar and starch.

*In vitro* digestibilities of DM, NDF and ADF (IVDMD, IVNDFD, IVADFD) were determined according to the procedures of Tilley and Terry (1963) with a minor modification. Namely, the ground stalk samples, weighed into specialized non-woven fabric bags and put into fermentation tubes, were anaerobically incubated with buffer-rumen fluid mixture solution in a water bath at 39°C for 48 h, shaking twice a day routinely. 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, NDF and ADF to calculate IVDMD, IVNDFD and IVADFD.

The *in vitro* gas production of the fermentation of the maize stalks was measured according to the method of Menke and Steingass (1988). Briefly, 200.0 mg of dry sample (substrate) were weighed into 100 ml special calibrated glass syringes, adding 30 ml of anaerobic buffer-rumen fluid mixture solution, and incubated at 39°C for 120 h in an incubator equipped with a rotor. The gas production was measured at the time intervals of 1, 2, 3, 4, 5, 6, 8, 10, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 56, 64, 72, 80, 88, 96, 104, 112 and 120 h, respectively.

The experiment was designed in a randomly factorial design. All data collected were presented on a DM basis and were subjected to analyse the variance using the General Linear Models procedure of SAS (1999).

## RESULTS

Chemical composition of three maize stalks was shown in Table 1. There were significant ( $P<0.002$ ) differences among three cultivars of maize stalks. HOM stalks had highest contents of readily digestible components (such as WSC, starch, EE and CP) and lowest contents of less digestible components (such as NDF and ADF). The average contents of WSC, starch and EE in HOM stalks were measured as, %: 21.8, 5.2 and 2.8, respectively, which were 19.8 folds (21.8 vs 1.1%;  $P<0.001$ ), 3.5 folds (5.2 vs 1.5%;  $P<0.001$ ), 2.0 folds (2.8 vs 1.4%;  $P<0.001$ ) as much as that of CM stalks. Meanwhile, the average contents of NDF, ADF and lignin in HOM stalks were, %: 57.7, 34.5 and 4.7, respectively, which were by 27.3% (57.7 vs 79.4%;  $P<0.001$ ), 32.0% (34.5 vs 50.7%;  $P<0.001$ ) and by 39.7% (4.7 vs 7.8%;  $P<0.001$ ) lower than that of CM stalks. The average contents of WSC, starch and EE in HOM stalks were higher than FM stalks by 246.0% (21.8 vs 6.3%;  $P<0.001$ ), 108.0% (5.2 vs 2.5%;  $P<0.003$ ) and 33.1% (2.8 vs 2.1%;  $P<0.012$ ), respectively. Moreover, the average contents of NDF, ADF and lignin

were lower than these of FM stalks by 17.3% (57.7 vs 69.8%;  $P<0.001$ ), 18.8% (34.5 vs 42.5%;  $P<0.001$ ) and 31.9% (4.7 vs 6.9%;  $P<0.001$ ), respectively. As to minerals, the content of crude ash in HOM stalks was lower ( $P<0.001$ ) than that of CM stalks or FM stalks; HOM stalks had higher P content (0.13 vs 0.07%;  $P<0.001$ ) but lower Ca content (0.43 vs 0.60%;  $P<0.001$ ) than CM stalks.

Table 1. Effect of maize cultivars on major chemical components of maize stalks

Item %DM	HOM		CM		FM	SEM	P value	Contrast, P =	
	HOM298	HOM647	CAU80	CAU3138				HOM vs CM	HOM vs FM
DM	35.38	35.15	62.19	70.42	28.57	3.16	<0.001	<0.001	0.044
WSC	24.3	19.2	1.3	0.9	6.3	0.21	<0.001	<0.001	<0.001
Starch	4.8	5.5	1.4	1.5	2.5	0.59	0.001	<0.001	0.002
EE	2.9	2.7	1.5	1.2	2.1	0.20	<0.001	<0.001	0.011
CP	6.1	7.0	6.4	6.0	7.6	0.12	0.001	0.321	0.019
Ash	5.6	6.2	8.1	7.3	8.0	0.05	<0.001	<0.001	<0.001
Ca	0.43	0.43	0.60	0.54	0.40	0.01	<0.001	<0.001	0.346
P	0.09	0.16	0.07	0.06	0.12	0.01	<0.001	0.001	0.701
NDF	56.7	58.7	79.0	79.8	69.8	0.17	<0.001	<0.001	<0.001
ADF	34.4	34.6	49.6	51.7	42.5	0.14	<0.001	<0.001	<0.001
Lignin	4.6	4.7	7.0	8.5	6.9	0.09	<0.001	<0.001	<0.001

As shown in Table 2, *in vitro* digestibilities of DM and fibrous fractions were significantly ( $P<0.001$ ) different among stalks of three cultivars. HOM stalks were

Table 2 Effect of cultivars on the *in vitro* digestibility of dry matter and fibrous fractions of maize stalks

Item %DM	HOM		CM		FM	SEM	P value	Contrast, P =	
	HOM298	HOM647	CAU80	CAU3138				HOM vs CM	HOM vs FM
IVNDFD	49.2	48.4	40.4	40.0	45.5	0.55	<0.001	<0.001	<0.001
IVADFD	45.4	45.0	37.3	34.7	43.1	1.08	<0.001	<0.001	0.161
IVDMD	68.2	66.8	48.4	49.1	58.6	0.42	<0.001	<0.001	<0.001

higher ( $P<0.001$ ) than CM stalks in IVDMD, IVNDFD and IVADFD, which on average were increased by 38.3% (67.5 vs 48.8%), 21.4% (48.8 vs 40.2%) and 25.6% (45.2 vs 36.0%), respectively. IVDMD and IVNDFD in HOM stalks were also higher ( $P<0.001$ ) than FM stalks, enhanced by 15.2% (67.5 vs 58.6%) and 7.3% (48.8 vs 45.5%), respectively.

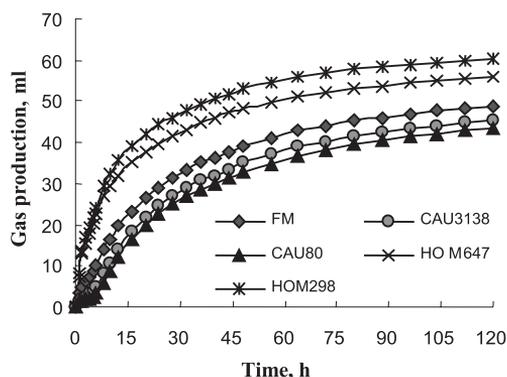


Figure 1. Effect of cultivars on *in vitro* gas production (ml/0.200 g DM) of maize stalks

The results of gas production rate are presented in Figure 1. Gas production had significant ( $P < 0.001$ ) differences among the three cultivars of maize stalks at all time points during incubation. Gas production of HOM stalks was not only greater ( $P < 0.001$ ) at all the time points than that of CM stalks, but also greater ( $P < 0.001$ ) than that of FM stalks, being enhanced by 80.3% (42.0 vs 23.3 ml) and 51.8% (50.7 vs 33.4 ml) for HOM stalks than those of CM stalks at 24 and 48 h, respectively; and 45.8% (42.0 vs 28.8 ml) and 29.3% (50.7 vs 39.2 ml) than those of FM stalks.

## DISCUSSION

Generally, as maturity of kernels advanced, the content of fibrous fraction in stalks was increased, while the digestibility was decreased. Harvest of conventional maize grains is usually accepted at 4/4 ML stage of kernels, but at this stage the stalks of CM have become dried over with poor nutritive value. In contrast, harvest of HOM grains at 4/4 ML stage produces not only larger yield of grains but also higher nutritional levels of by-product (stalks). The gas productions were significantly ( $P < 0.001$ ) higher for HOM stalks than CM and FM stalks, which is highly consistent with the higher contents of readily digestible components (such as WSC, starch, EE and CP) and lower contents of less digestible components (such as NDF and ADF) for HOM stalks than CM and FM stalks. The present study clearly suggests that the HOM can represent a favourable cultivar for ruminant feeding because of not only high oil grains but also great nutritive value of stalks probably used for making good silages. Similar to this result, Zhao (2003) also obtained a higher nutritive value in another variety of high oil maize stalks (HOM 115) relative to traditional maize stalks.

## CONCLUSIONS

Because of high contents of nutrients and high *in vitro* digestibility of DM and NDF, high oil maize cultivar stalks appeal a great potential to be utilized as a fodder or ensilage source for ruminant feeding.

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