Effect of Stubble Height on Silage Quality of Different Varieties of Whole-Plant Corn Postprint

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Abstract

This experiment aimed to study the effect of stubble height on the quality of whole-plant corn silage and to explore how stubble height should be selected for different corn varieties to provide theoretical support for the rational production and utilization of whole-plant corn silage. Three whole-plant corn varieties with different characteristics, widely planted in Heilongjiang Province, were used as experimental materials: high-starch variety Yanguang No. 1, high-protein variety Zhongyuandan 32, and high-yield variety Longfu 208. A single-factor experimental design was employed, with two stubble heights of 19 cm and 49 cm, for a total of 6 treatments, each with 2 replicates. Conventional nutrient composition, fermentation quality, and rumen degradability at 24, 30, and 48 h were determined. The results showed that: 1) For the nutrient composition of whole-plant corn silage, when stubble height increased from 19 cm to 49 cm, the crude protein (CP) and starch content of the three varieties increased significantly ($P<0.05$), while neutral detergent fiber (NDF) and acid detergent fiber (ADF) content decreased significantly ($P<0.05$). The dry matter (DM) and crude ash content of Yanguang No. 1 and Longfu 208 increased significantly ($P<0.05$). 2) The pH of whole-plant corn silage among treatments was not significantly different ($P>0.05$); as stubble height increased, the ammonia nitrogen/total nitrogen (NH3-N/TN) of the same variety of whole-plant corn silage decreased significantly ($P<0.05$), but the NH3-N/TN of Zhongyuandan 32 at 49 cm stubble height was still significantly higher than that of Yanguang No. 1 at 19 cm stubble height ($P<0.05$), indicating greater protein degradation, while Yanguang No. 1 had lower NH3-N/TN at both stubble heights, demonstrating superior fermentation quality; lactic acid (LA) and acetic acid (AA) content showed large differences among different varieties, while increasing stubble height had little effect on them. 3) As stubble height increased, the rumen dry matter degradability (DMD) and crude protein degradability (CPD) of whole-plant corn silage of each variety showed an increasing trend, while rumen neutral detergent fiber

degradability (NDFD) showed a decreasing trend. Among them, Yanguang No. 1 had the maximum 48 h rumen DMD at 49 cm stubble height, which was not significantly different from the 19 cm stubble height treatment (P>0.05), and this variety had the maximum 48 h rumen NDFD at 19 cm stubble height. These results indicate that increasing stubble height can increase the DM, CP, and starch content of whole-plant corn silage, but will decrease its NDF content and reduce the buffering capacity during fermentation, thus having little effect on fermentation indicators. Therefore, for high-starch, low-fiber corn varieties such as Yanguang No. 1, a lower stubble height can be selected to maximize both quality and quantity; while for high-protein or high-yield corn varieties such as Zhongyuandan 32 and Longfu 208, stubble height can be appropriately increased to improve silage quality.

Full Text

Effects of Cutting Height on Quality of Different Varieties of Whole Plant Corn Silage

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Abstract

This experiment investigated the effects of cutting height on whole plant corn silage quality and explored optimal cutting heights for different corn varieties to provide theoretical support for rational production and utilization of whole plant corn silage. Three corn varieties with distinct characteristics, widely cultivated in Heilongjiang Province, were selected: high-starch variety Yangguang No. 1, high-protein variety Zhongyuandan 32, and high-yield variety Longfu 208. A single-factor experimental design was employed with two cutting heights (19 cm and 49 cm), resulting in six treatments with two replicates each. Nutrient composition, fermentation quality, and rumen degradation rates at 24, 30, and 48 hours were measured. The results showed: (1) When cutting height increased from 19 cm to 49 cm, crude protein (CP) and starch contents increased significantly (P<0.05), while neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents decreased significantly (P<0.05) across all three varieties. Dry matter (DM) and ash contents of Yangguang No. 1 and Longfu 208 also increased significantly (P<0.05). (2) No significant differences in pH

were observed among treatments (P>0.05). With increasing cutting height, ammonia nitrogen/total nitrogen (NH_3-N/TN) decreased significantly for each variety (P<0.05). However, NH_3-N/TN of Zhongyuandan 32 at 49 cm cutting height remained significantly higher than that of Yangguang No. 1 at 19 cm cutting height (P<0.05), indicating greater protein degradation. Yangguang No. 1 showed lower NH_3-N/TN at both cutting heights, suggesting superior fermentation quality. Lactic acid (LA) and acetic acid (AA) contents varied considerably among varieties, with cutting height having minimal effect. (3) As cutting height increased, ruminal dry matter degradation rate (DMD) and crude protein degradation rate (CPD) showed an increasing trend, while ruminal neutral detergent fiber degradation rate (NDFD) decreased. Yangguang No. 1 at 49 cm cutting height exhibited the highest 48-hour ruminal DMD, which did not differ significantly from the 19 cm treatment (P>0.05), while this variety showed the highest 48-hour ruminal NDFD at 19 cm cutting height. These findings demonstrate that increasing cutting height can improve DM, CP, and starch contents while reducing NDF content and fermentation buffering capacity, thereby having minimal impact on fermentation indices. Therefore, for high-starch, low-fiber varieties like Yangguang No. 1, a lower cutting height can be selected to maximize both quality and quantity, whereas for high-protein or high-yield varieties like Zhongyuandan 32 and Longfu 208, cutting height can be appropriately increased to improve silage quality.

Keywords: whole plant corn silage; cutting height; corn variety; nutrient composition; fermentation quality; ruminal degradation rate

Introduction

Since the 1960s, silage production has increased substantially and become the primary method for preserving green forage, particularly whole plant corn silage. According to National Bureau of Statistics data, corn planting area in China reached 38,119.31 thousand hectares in 2015, while forage planting area accounted for less than 5% of this total, highlighting the growing conflict between human food and animal feed resources. Consequently, the importance of whole plant corn silage for herbivorous livestock as a grain-saving feed source has become increasingly evident. Whole plant corn silage is nutritionally rich, highly palatable, easily digestible, and has a long preservation period. It can increase milk yield while enabling year-round balanced supply, thereby ensuring healthy, rapid, and sustainable development of the dairy industry [1-2]. Heilongjiang Province is a major dairy farming region in China, with milk production accounting for approximately 15% of national output in 2014 and 2015. Yangguang No. 1, Zhongyuandan 32, and Longfu 208 are the primary corn silage varieties in Heilongjiang [3-5]. Yangguang No. 1 exhibits high starch content and low fiber content, Zhongyuandan 32 shows high protein content, and Longfu 208 demonstrates high biological yield, with all three varieties displaying high feeding value [5-6]. Research indicates that silage quality and biological yield of

whole plant corn are directly related to variety characteristics, harvest timing, and cutting height. Corn silage consists of high-starch ears and high-fiber stalks; higher cutting heights generally yield higher nutritional value, though different varieties show varying responses to cutting height in terms of post-ensiling nutritional quality [7-9]. In practice, cutting height is typically controlled between 15-45 cm [10]. This experiment selected three widely cultivated corn varieties in Heilongjiang to investigate nutrient composition before and after ensiling, fermentation quality, and ruminal degradation characteristics at two cutting heights (19 cm and 49 cm). The objective was to examine cutting height effects on whole plant corn silage quality and determine appropriate cutting heights for different varieties, providing theoretical support and practical guidance for rational production and utilization of whole plant corn silage.

1.1 Experimental Materials

Whole plant corn silage materials were sourced from Qiqihar City, Heilongjiang Province, including three varieties: Yangguang No. 1, Zhongyuandan 32, and Longfu 208.

1.2 Experimental Design and Silage Preparation

A single-factor experimental design was employed. Each of the three corn varieties was harvested at two cutting heights: conventional height (19 cm) and higher height (49 cm), totaling six treatments with three replicates per treatment. Whole plant corn materials were harvested using a silage harvester with a theoretical cut length of 1.5 cm, mixed thoroughly according to experimental design, and packed into polyethylene bags (35 cm × 45 cm) at approximately 2 kg per bag. After compaction, bags were vacuum-sealed and stored at approximately 25°C for 45 days before opening for sample collection and subsequent analysis. Sample collection before and after fermentation followed GB/T 14699.1-2005 "Feed Sampling" [11].

1.3 Nutrient Composition Analysis

Dry matter (DM), crude protein (CP), ether extract (EE), and ash contents of samples before and after fermentation were determined according to AOAC (2005) methods [12]. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were analyzed using an ANKOM Fiber Analyzer (USA) following the Van Soest analytical system [13]. Starch content was measured using a total starch assay kit (Megazyme K-TSTA, Ireland). Relative feed value (RFV) was calculated using the following formula:

$$RFV = \frac{DMI \times DDM}{1.29}$$

where DMI = dry matter intake and DDM = digestible dry matter.

1.4 Fermentation Quality Analysis

pH was measured using a Sartorius PB-10 pH meter [Sartorius Scientific Instruments (Beijing) Co., Ltd.]. Ammonia nitrogen (NH_3-N) content was determined by the phenol-hypochlorite colorimetric method [14]. Acetic acid (AA), propionic acid (PA), and butyric acid (BA) contents were analyzed by gas chromatography (Shimadzu GC-2010, Japan) [15]. Lactic acid (LA) content was measured by high-performance liquid chromatography (Waters-600, USA) [16].

1.5.1 Experimental Animals and Management

Two Holstein dairy cows fitted with permanent rumen fistulas (body weight 600 ± 20 kg) were used. Animals were fed twice daily (07:00 and 18:00) with free access to water. The diet was a total mixed ration (TMR) formulated according to "Nutrient Requirements of Dairy Cattle"[17]. Composition and nutrient levels are shown in Table 1 .

Table 1 Composition and nutrient levels of the diet (air-dry basis)

Items	Content
Ingredients	
Chinese wildrye	15.0
Corn silage	25.0
Corn	15.0
Wheat bran	5.0
Molasses	3.0
Soybean meal	8.0
Dried distillers grain	8.0
Cottonseed meal	5.0
Corn fiber feed	8.0
Corn germ meal	7.0
Premix[1]	1.0
Total	**100.0**
Nutrient levels[2]	
NEL/(MJ/kg)	6.8
CP	16.5
NDF	38.2
ADF	22.4

[1]Contained per kg of premix: VA 8,000,000 IU, VD 700,000 IU, VE 10,000 IU, Fe 1,600 mg, Cu 1,500 mg, Zn 10,000 mg, Mn 3,500 mg, Se 80 mg, I 120 mg, Co 50 mg.
[2]NEL was calculated, while other nutrient levels were measured values.

1.5.2 Rumen Degradation Rate Determination

Five grams of air-dried whole plant corn silage sample ground through a 1 mm sieve were placed in nylon bags (12 cm × 8 cm, 50 μm pore size), sealed with nylon string. Four bags were attached to each semi-flexible plastic tube and secured with nylon rope. Each cow had two replicates per time point. Bags were inserted into the rumen before morning feeding and incubated for 24, 30, and 48 hours before removal. Bags were rinsed under running tap water until the effluent was clear and odorless, then dried at 65°C to constant weight. DM, CP, and NDF contents were determined as described in section 1.3 to calculate ruminal degradation rates.

1.6 Data Processing and Statistical Analysis

Experimental data were analyzed using the ANOVA procedure in SAS 9.2 statistical software. Duncan' s multiple range test was used for mean comparisons, with $P<0.05$ considered statistically significant.

2.1 Nutrient Composition of Whole Plant Corn Before Ensiling

Nutrient composition of whole plant corn before ensiling is shown in Table 2 . At the same cutting height, Yangguang No. 1 had the highest starch content, significantly higher than Zhongyuandan 32 and Longfu 208 ($P<0.05$), while showing the opposite pattern for NDF and ADF contents. For CP content, Zhongyuandan 32 was highest among the three varieties, not significantly different from Yangguang No. 1 ($P>0.05$) but significantly higher than Longfu 208 ($P<0.05$) at the same cutting height. As cutting height increased, all three varieties showed similar trends in nutrient composition: CP and starch contents increased significantly (except for Longfu 208), while NDF and ADF contents decreased significantly ($P<0.05$). Ether extract content did not differ significantly between the two cutting heights for any variety ($P>0.05$).

Table 2 Nutrient contents of whole plant maize before silage (air-dry basis)

Items	DM	CP	NDF	ADF	Starch	EE
Yangguang No. 1						
19 cm	36.48	6.12	48.14	22.94	24.03	2.51
49 cm	38.21	6.86	45.31	20.49	29.87	2.55
Zhongyuandan 32						
19 cm	35.31	6.21	52.28	28.28	17.60	2.72
49 cm	36.44	7.08	46.05	25.44	24.81	2.98
Longfu 208						
19 cm	33.88	4.56	50.50	27.13	19.30	2.51
49 cm	36.45	6.35	47.78	25.61	21.15	2.55

Items	DM	CP	NDF	ADF	Starch	EE
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.038

In the same row, values with different lowercase superscripts indicate significant differences (P<0.05), while same or no superscripts indicate no significant difference (P>0.05). The same applies below.

2.2 Nutrient Composition of Whole Plant Corn Silage

Nutrient composition of whole plant corn silage is presented in Table 3 . At the same cutting height, Yangguang No. 1 had the highest DM and starch contents, significantly higher than the other two varieties (except compared with Zhongyuandan 32 at 19 cm cutting height) (P<0.05). Zhongyuandan 32 had the highest CP content, though differences among varieties at the same cutting height were not significant (P>0.05). With increasing cutting height, CP and starch contents increased significantly (P<0.05), while NDF and ADF contents decreased significantly (P<0.05) across all three varieties. DM and ash contents of Yangguang No. 1 and Longfu 208 also increased significantly (P<0.05).

Table 3 Nutrient contents of whole plant corn silage (air-dry basis)

Items	DM	CP	NDF	ADF	Starch	EE	Ash
Yangguang No. 1							
19 cm	31.36	6.45	48.71	28.59	32.90	2.51	3.73
49 cm	33.64	7.40	44.08	24.49	36.77	3.40	3.41
Zhongyuandan 32							
19 cm	31.26	6.61	55.04	29.63	26.85	2.55	4.17
49 cm	32.33	7.44	50.18	28.30	31.54	3.40	3.95
Longfu 208							
19 cm	27.18	6.16	52.21	30.56	23.35	2.72	4.57
49 cm	30.68	7.23	49.63	27.62	28.14	2.98	3.90
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

2.3 Fermentation Quality of Whole Plant Corn Silage

Fermentation quality parameters are shown in Table 4 and Table 5 . No significant differences in pH were detected among any treatments (P>0.05). At the same cutting height, Zhongyuandan 32 had the highest LA content, significantly different from Yangguang No. 1 (P<0.05). Longfu 208 showed significantly higher AA content than both Yangguang No. 1 and Zhongyuandan

32 (P<0.05), though the latter two did not differ significantly (P>0.05). For the LA/AA ratio, Zhongyuandan 32 reached its maximum at 49 cm cutting height, not significantly different from Yangguang No. 1 (P>0.05) but significantly higher than Longfu 208 (P<0.05). With increasing cutting height, LA content of Longfu 208 increased significantly (P<0.05), while NH_3-N/TN decreased significantly across all three varieties (P<0.05). Neither PA nor BA was detected in any treatment.

Table 4 pH and NH_3-N/TN of whole plant corn silage

Items	Yangguang No. 1	Zhongyuandan 32	Longfu 208	P-value
pH				
19 cm	3.85	3.82	3.88	<0.001
49 cm	3.83	3.80	3.86	
NH_3-N/TN/%				
19 cm	1.74	2.40	2.47	<0.001
49 cm	1.46	2.06	1.97	

Table 5 Organic acid contents of whole plant corn silage (DM basis)

Items	LA/%	AA/%	LA/AA	PA/%	BA/%
Yangguang No. 1					
19 cm	1.31	0.80	1.64	-	-
49 cm	1.64	1.46	1.13	-	-
Zhongyuandan 32					
19 cm	1.60	1.07	1.49	-	-
49 cm	1.71	1.19	1.44	-	-
Longfu 208					
19 cm	1.29	2.55	0.59	-	-
49 cm	1.67	2.08	0.80	-	-
P-value	<0.001	<0.001	<0.001		

"-" indicates not detected.

2.4 Relative Feed Value (RFV) of Whole Plant Corn Silage

RFV values calculated from post-fermentation NDF and ADF contents are presented in Figure 1 [Figure 1: see original paper]. Increasing cutting height significantly increased RFV of whole plant corn silage (P<0.05), with significant differences among varieties at the same cutting height (P<0.05). Yangguang No. 1 at 49 cm cutting height achieved the highest RFV. Notably, at 19 cm cutting height, Yangguang No. 1' s RFV was similar to that of Zhongyuandan 32 and Longfu 208 at 49 cm cutting height, with no significant difference (P>0.05).

Figure 1 RFV of whole plant corn silage. Data columns with different lowercase superscripts indicate significant differences (P<0.05).

2.5 Rumen Degradation Rate of Whole Plant Corn Silage

Rumen degradation rates are shown in Table 6 . At the same cutting height, Yangguang No. 1 exhibited the highest ruminal DMD and CPD at all time points, with differences reaching significance at 48 hours compared with the other two varieties (P<0.05). Rumen NDFD among the three varieties showed variable patterns across different time points. With increasing cutting height, ruminal DMD increased for each variety at the same time point, with significant changes observed at 48 hours for Zhongyuandan 32 and Longfu 208 (P<0.05) but not for Yangguang No. 1 (P>0.05). As degradation time extended, Yangguang No. 1 at 49 cm cutting height achieved maximum ruminal DMD, which did not differ significantly from the 19 cm treatment (P>0.05). Ruminal NDFD showed a decreasing trend with increasing cutting height within each variety, with significant changes observed at 48 hours for Yangguang No. 1 and Zhongyuandan 32 (P<0.05). Among varieties, ruminal NDFD of Yangguang No. 1 at 49 cm cutting height was similar to that of Zhongyuandan 32 at 19 cm cutting height, with no significant difference (P>0.05).

Table 6 Ruminal degradation rate of whole plant corn silage (air-dry basis)

Items	Time/h	Yangguang No. 1	Zhongyuandan 32	Longfu 208	SEM	P-value
		19 cm	49 cm	19 cm	49 cm	19 cm
DMD	24	46.88	50.68	37.01	42.35	40.03
	30	65.53	69.12	55.89	62.24	55.11
	48	75.68	76.45	60.45	68.85	58.73
CPD	24	16.38	11.83	22.79	21.89	17.39
	30	29.17	27.34	33.47	35.61	27.60
	48	50.68	47.96	48.45	45.94	45.94
NDFD	24	29.17	35.24	33.47	41.31	35.61
	30	42.35	45.97	40.03	44.10	41.15
	48	49.50	48.85	43.46	44.39	46.85

3.1 Nutrient Composition of Whole Plant Corn

Yangguang No. 1, Zhongyuandan 32, and Longfu 208 are widely cultivated corn silage varieties in Northeast China, exhibiting significant differences in nutritional characteristics. Yangguang No. 1 shows high starch content with low NDF and ADF contents; Zhongyuandan 32 demonstrates high CP content; while

Longfu 208, despite having the lowest CP content, shows intermediate levels of other nutrients and reportedly high biological yield. The measured nutrient composition of these three varieties in this experiment aligns with previous studies on common corn silage varieties in Northeast China by Qi et al. [5] and Wu et al. [6].

Research demonstrates that silage quality and biological yield of whole plant corn are closely related to both variety characteristics and cutting height control, with different varieties responding differently to cutting height in terms of post-ensiling nutritional quality. Ding et al. [18] reported that corn stalk leaves have the highest CP content while stalk rinds have the highest ADF content, with substantial nutritional differences among plant parts. Different cutting heights affect the proportional composition of stalks, leaves, and ears in whole plant corn, thereby influencing silage nutritional value. However, Neylon and Kung [7] and Lynch et al. [9] suggested that increasing cutting height may reduce buffering capacity during ensiling, resulting in non-significant differences in fermentation indices. Therefore, this study proposes that for different corn varieties, simply increasing cutting height may not necessarily improve post-fermentation quality; rather, appropriate cutting height should be selected based on inherent nutritional characteristics.

3.2 Nutrient Composition of Whole Plant Corn Silage

Post-fermentation analysis revealed that DM content of whole plant corn silage decreased compared with pre-ensiling values, though increasing cutting height reduced DM loss. Among the six treatments, Yangguang No. 1 at 49 cm cutting height showed the highest DM content, significantly higher than other varieties at the same cutting height, though not significantly different from Zhongyuandan 32 at 19 cm cutting height. This indicates that variety-specific nutritional characteristics substantially influence post-fermentation quality. NDF, ADF, and CP contents showed slight increasing trends after ensiling, likely due to relative content changes resulting from DM loss. No significant pH differences were observed among the six treatments after fermentation, consistent with Lynch et al. [9], possibly because increased cutting height reduced fermentation buffering capacity while adequate fermentation time allowed pH to stabilize near optimal levels. Data showed that increasing cutting height significantly reduced NH_3-N/TN; however, for the high-protein variety Zhongyuandan 32, NH_3-N/TN at 49 cm cutting height remained significantly higher than that of Yangguang No. 1 at 19 cm cutting height, indicating greater protein decomposition. In contrast, the high-starch, low-NDF variety Yangguang No. 1 maintained low NH_3-N/TN at both cutting heights, demonstrating superior fermentation quality. Therefore, this study suggests that for high-starch, low-NDF varieties like Yangguang No. 1, good fermentation status can be achieved at both conventional and higher cutting heights.

Based on RFV results, increasing cutting height significantly increased whole plant corn silage RFV, with Yangguang No. 1 showing high values at both

cutting heights. Notably, Yangguang No. 1 at 19 cm cutting height achieved RFV similar to that of Zhongyuandan 32 and Longfu 208 at 49 cm cutting height, indicating that high-starch, low-fiber varieties can maintain high RFV even at lower cutting heights.

3.3 Rumen Degradation Rate of Whole Plant Corn Silage

This study found that increasing cutting height increased ruminal DMD and CPD for all varieties, consistent with Lynch et al. [9]. The six treatments showed different ruminal DMD patterns across time points, likely due to variety-specific differences in rapidly degradable fractions, slowly degradable fractions, and degradation rates. However, at 48 hours, Yangguang No. 1 at 49 cm cutting height achieved maximum ruminal DMD, which did not differ significantly from the 19 cm treatment but was significantly higher than the other two varieties at this time point. Previous research suggests that ruminal NDFD at 24, 30, and 48 hours can serve as relevant indicators for biological evaluation of whole plant corn silage [7,9,19]. In this study, NDFD was low at 24 hours but increased rapidly thereafter, with Yangguang No. 1 at 19 cm cutting height reaching maximum NDFD at 48 hours. Ruminal NDFD decreased with increasing cutting height, consistent with Lynch et al. [9] but contrary to Neylon and Kung [7] and Caetano et al. [8]. However, this decreasing trend diminished with extended degradation time, possibly because NDF constitutes approximately 50% of whole plant corn silage and degrades slowly in the rumen. Incomplete NDF degradation at 24, 30, and 48 hours, combined with substantial differences in rapidly and slowly degradable fractions between cutting heights, resulted in higher ruminal NDFD at lower cutting heights. Therefore, this study concludes that to ensure both high ruminal DMD and NDFD while maximizing silage yield per unit land area, high-starch, low-fiber varieties like Yangguang No. 1 can utilize lower cutting heights to achieve higher yield and good fermentation quality, whereas high-protein or high-fiber varieties may benefit from increased cutting height to improve ruminal degradation rates.

Conclusions

1. Increasing cutting height can improve DM, CP, and starch contents of whole plant corn silage while reducing NDF content and decreasing fermentation buffering capacity, thereby having minimal impact on fermentation quality.
2. For high-starch, low-fiber corn varieties such as Yangguang No. 1, lower cutting heights can be selected to maximize both quality and yield.
3. For high-protein or high-yield corn varieties such as Zhongyuandan 32 and Longfu 208, cutting height can be appropriately increased to improve silage quality.

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Note: Figure translations are in progress. See original paper for figures.