



# Quality of Chopped Maize Can Be Improved by Processing

Filip Jančík <sup>\*</sup> , Petra Kubelková, Dana Kumprechtová, Radko Loučka, Petr Homolka, Veronika Koukolová, Yvona Tyrolová  and Alena Výborná

Department of Nutrition and Feeding of Farm Animals, Institute of Animal Science, 10400 Praha, Czech Republic; kubelkova.petra@vuzv.cz (P.K.); kumprechtovad@seznam.cz (D.K.); loucka.radko@vuzv.cz (R.L.); homolka.petr@vuzv.cz (P.H.); koukolova.veronika@vuzv.cz (V.K.); tyrolova.yvona@vuzv.cz (Y.T.); vyborna.alena@vuzv.cz (A.V.)

\* Correspondence: jancik.filip@vuzv.cz; Tel.: +420-267009650

**Abstract:** The aim of this study was to assess the effect of different maize processing technologies, comparing treatments with conventional rollers (control), MCC MAX rollers and a Shredlage crop processor on the quality of chopped maize. All the three types of chopped maize were harvested on the same day from the same field where the same maize hybrid was grown. The chemical composition of chopped maize, degree of grain processing and particle size fractions, and the effect of the treatments on rumen disappearance of dry matter, organic matter, NDF and starch were assessed. The highest degree of grain processing was achieved with the Shredlage processor (79.2%), and at the same time this processing method had a tendency to produce the highest proportion of physically effective fibre (37.2%). Compared to the conventional rollers (control), the chopped maize produced using the Shredlage processor had higher disappearance of dry matter, organic matter and NDF after 48 h of rumen incubation and of starch after 24 h of incubation. The MCC MAX rollers provided higher disappearance of all nutrients compared to the control treatment after both 24 and 48 h of incubation.

**Keywords:** maize; chopped silage; disappearance; physically effective fibre



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## 1. Introduction

Good maize silage crop processing during harvest improves silage compaction and fermentation and helps preserve nutrients [1]. At the same time, kernels should be well processed to increase digestibility. Good processing of kernels (1 mm roll clearance) has been shown to increase starch digestibility [2] and reduce the cut length by 15 to 30% [3]. However, forages with a high proportion of small particles can have an adverse effect on digestion. They can reduce saliva production, rumen pH and fibre digestibility [4]. Smaller forage particles spend less time in the rumen and are less available for microbial digestion. This reduces digestibility, especially of fibre, due to the relatively low rate of digestion [5]. For these reasons, in recent years, new technologies for processing maize silage have been developed and increasingly used, where the length of cut is higher in order to increase the proportion of physically effective fibre (peNDF) and achieve a high degree of kernel processing at the same time.

The peNDF concept was introduced to explain the physical effect of NDF (in particular the effect of feed particle length) on chewing activity and saliva production. The peNDF concept is based on the hypothesis that long fibre particles (>8 mm) promote rumination and salivary secretion, which leads to neutralizing acid production during the rumen digestion. Therefore, Johnson et al. [6] recommended increasing the theoretical length of cut to 1.9 cm. Increasing the theoretical length of cut (TLC) above 19 mm and widening the clearance of kernel processing rollers can potentially reduce nutrient digestibility and animal performance [7]. Leonardi et al. [8] suggested that when increasing the mean particle length of forages with greater TLC, it is important to minimize the proportion of

particles retained on the coarsest sieves, to prevent sorting. A simple and quick way to measure the particle size distribution of different feeds or mixed rations is to use the Penn State Particle Separator (PSPS) [9] with 19 mm, 8 mm and 4 mm sieves.

The Shredlage technology is ranked among the new technologies for processing maize silage that meet both of the above requirements (i.e., excellent grain processing and a sufficient peNDF). This technology makes it possible to extend the TLC up to 30 mm [10], thus resulting in a significant increase in the peNDF compared to conventional technology. Another new technology is the MCC MAX rollers, where there is a possibility of a range of cut lengths of 10 to 22 mm. By reducing the gap between the rollers to 1 mm, this technology is able to significantly increase the kernel breakage in maize silage, even during late maize harvesting [11]. The studies published to date have mainly been devoted to the assessment of conventional and Shredlage technologies. From our point of view, it is possible to assess the quality of these technologies directly from chopped maize, and, at the same time, it is possible to assess the quality of future silage from these parameters.

The aim of this study was to assess the effect of different methods of processing on the quality parameters of the chopped maize.

## 2. Materials and Methods

### 2.1. Experimental Material and Methods of Processing

During the 2018 maize harvest, a Claas Jaguar 860 forage harvester was used, equipped with conventional rollers with a 30% difference in roller speed, 1 mm roll clearance and a TLC of 14 mm. This treatment is referred to as the control. Furthermore, we used the Claas Jaguar 870 forage harvester equipped with either an MCC MAX (MAX) crop cracker with a 30% difference in roller speed, 1 mm clearance and a TLC of 14 mm, or a Shredlage (SHR) crop processor with a 50% difference in roller speed, 1 mm clearance and a TLC of 27 mm.

The plants were harvested for experimental purposes at the optimum dry matter content (about 35%) for silage making, using the three technologies mentioned above. All the maize harvesting methods were applied in one field (15 ha; elevation 415 m above sea level, brown earthy loam) where the JUVENTO hybrid was grown (stay-green hybrid; three-line hybrid intended for silage production with high organic matter digestibility; FAO 230; grain—intertype with a tendency to flint; KWS). Each treatment was applied randomly in a plot of about 0.1 ha of the field. The maize for each treatment was chopped into one tractor trailer. Samples of the chopped maize were taken by hand from three locations in the trailer for each treatment, in amounts of approximately 10 kg.

### 2.2. Chemical Analyses and Rumen Disappearance Testing

Three chopped maize samples (three replicates per treatment or method of processing) were taken from each treatment and subsequently analysed for dry matter (#934.01), ash (#942.05), crude protein (CP; #976.05), fat (6-hour extraction with petroleum ether), crude fibre (CF), neutral detergent fibre (NDF; #2002.04), acid detergent fibre (ADF), acid detergent lignin (ADL; #973.18) and starch (#920.40) [12]. The particle size distributions were measured with a PSPS using 19 mm, 8 mm and 4 mm sieves. By multiplying the particle fraction above 8 mm with the NDF content, the physically effective NDF (peNDF) was calculated. The quality of kernel processing was assessed by measuring the percentage of starch particles passing through a 4.75 mm sieve [13], where less than 50% indicates poor processing, 50% to 70% indicates satisfactory processing and above 70% indicates excellent processing.

The different types of chopped maize in the study were also evaluated for rumen disappearance (in situ method). Two Holstein dairy cows equipped with rumen cannulas were used. Each fresh sample was weighed into three nylon bags per cow, for three incubation times, in amounts of 15 g per bag (size 10 × 20 cm; mesh size 51 µm). The disappearance of dry matter and organic matter (incubation times of 12 h, 24 h and 48 h), starch (incubation times of 12 h and 24 h) and NDF (incubation times of 24 h and 48 h) was assessed.

### 2.3. Statistical Analysis

The results were evaluated using the GLM procedure in SAS software [14]. The statistical model for the results on chemical composition and particle size fractions was  $Y_{ij} = \mu + T_i + e_{ij}$ , where  $Y_{ij}$  is the dependent variable,  $\mu$  is the overall mean,  $T_i$  is the treatment ( $i = 1$  to 3) and  $e_{ij}$  is the random error ( $j = 1$  to 3). The statistical model for the results from the in situ experiment was  $Y_{ijk} = \mu + T_i + c_j + e_{ijk}$ , where  $Y_{ijk}$  is the dependent variable,  $\mu$  is the overall mean,  $T_i$  is the treatment ( $i = 1$  to 3),  $c_j$  is a random effect of the cow ( $j = 1$  to 2) and  $e_{ijk}$  is an error term. Significant differences between lsmeans were compared using the Scheffe test.

## 3. Results and Discussion

### 3.1. Chemical Composition of Chopped Maize

With regard to essential nutrient content, there were no significant differences in organic matter, CP, fat, starch, fibre or fibre fractions between the treatments (processing methods), except for ADF, where a difference of 2.6 percentage units was found between SHR and MAX (Table 1). Significant differences were found in the dry matter content, where apparently the maize stand was not of even quality across the plot, and dry matter was higher for the SHR method of harvest compared to the other two. This is probably also related to the weather, since there was a lack of rainfall, leading to premature drying of the crop. This is also shown, for example, by the starch content values of just above 20%. As reported by Loučka et al. [15], values are commonly around 30%. However, when maize plants are drying out rapidly, it is preferable to maintain the optimum dry matter content rather than waiting for a higher starch content and consequently having major problems during ensiling, especially when compacting high-dry-matter silage. Harvesting in the experimental year took place one month earlier than is usual in this locality. The content of NDF (above 50%) or crude fibre (above 23%) was also higher compared to normal values, which tend to be about 5 percentage units lower [15,16].

**Table 1.** Chemical composition of chopped maize using conventional and innovative systems.

	Control	SHR	MAX	SEM	<i>p</i>
Dry matter, %	33.5 <sup>b</sup>	37.2 <sup>a</sup>	33.4 <sup>b</sup>	0.52	<0.001
OM, % of DM	95.9	95.8	96.1	0.52	0.80
CP, % of DM	8.8	8.5	9.0	0.27	0.16
Fat, % of DM	1.8	1.7	2.0	0.26	0.58
CF, % of DM	24.5	25.4	23.3	0.25	0.06
NDF, % of DM	52.7	53.5	50.7	1.50	0.17
ADF, % of DM	28.1 <sup>ab</sup>	29.2 <sup>a</sup>	26.6 <sup>b</sup>	0.51	0.01
ADL, % of DM	2.8	3.2	2.8	0.30	0.24
Starch, % of DM	20.1	20.2	20.9	1.02	0.63

SHR = Shredlage processing; MAX = processing using MCC MAX (MAX) crop cracker; OM = organic matter; CP = crude protein; CF = crude fibre; NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin. Means within rows with different superscript letters indicate a significant difference at  $p < 0.05$ .

### 3.2. Particle Size, Physically Effective Fibre and Kernel Processing

The benefits of improving maize processing technologies are shown in Table 2. In particular, the degree of kernel processing (and therefore starch availability), expressed as % starch passing through the 4.75 mm sieve, shows how important the introduction of innovative maize silage harvesting technologies has been. An improvement in starch disappearance of up to 5% for better processed maize silage compared to poorly processed maize silage (percentage of starch passing through a 4.75 mm sieve below 50%) was reported by Ferreira and Mertens [13]. Compared to the control treatment (the commonly used maize harvesting technology with conventional cracking rollers), kernel processing was significantly better for both the innovative technologies (MAX and SHR). In the comparison between SHR and MAX, kernel processing was higher, and was excellent, for SHR. In addition, Ferraretto et al. [10] demonstrated increased kernel processing using SHR

in comparison with conventional technology. The higher degree of processing of maize kernels could mitigate the negative effect of the protein envelope of starch grains [17], which should theoretically lead to an increase in starch digestibility.

**Table 2.** Quality parameters of chopped maize processed by conventional and innovative systems.

	Control	SHR	MAX	SEM	<i>p</i>
% starch passing through a 4.75 mm sieve	59.4 <sup>c</sup>	79.2 <sup>a</sup>	75.6 <sup>b</sup>	0.58	<0.001
Particle fractions by separator, %					
Above 19 mm	3.6 <sup>b</sup>	21.3 <sup>a</sup>	4.7 <sup>b</sup>	3.13	0.004
Above 8 mm	59.4 <sup>a</sup>	48.4 <sup>b</sup>	61.3 <sup>a</sup>	1.75	0.002
Above 4 mm	25.2 <sup>a</sup>	15.4 <sup>c</sup>	22.1 <sup>b</sup>	0.91	0.001
Below 4 mm	11.9	14.9	11.9	1.49	0.11
Above 8 mm, %	62.9	69.7	66.0	2.27	0.05
peNDF, %	33.2	37.2	33.4	1.63	0.07

SHR = Shredlage processing; MAX = processing using MCC MAX (MAX) crop cracker; peNDF = physically effective neutral detergent fibre. Means within rows with different superscript letters indicate a significant difference at  $p < 0.05$ .

Other monitored parameters of the quality of maize silage processing by the new methods, compared to the conventional method, included the particle size distribution of the chop, determined using PSPS. As expected, a higher proportion of particles above 19 mm was found for the SHR technology, where a higher length of cut was set (TLC 27). Compared to the control, no difference in the proportion of particles above 19 mm was found for the MAX treatment. A tendency towards significant differences between SHR and the control was found for particles above 8 mm. The control and MAX achieved similar values of peNDF content, but SHR tended to have the highest peNDF content. This difference may be related to the NDF content, which was numerically higher for the SHR, mainly in comparison to MAX. Thus, the slightly higher concentration of NDF and the slightly higher proportion of particles above 8 mm gave a higher peNDF content.

Dairy cattle have been shown to selectively consume (sort for) the shorter concentrate particles in their total mixed ration (TMR), while selectively refusing (sorting against) the longer forage particles [18]. The results of Miller-Cushon and DeVries [19] demonstrated that lactating dairy cattle increased their sorting for medium particles and against short particles as feeding amounts increased. We hypothesized that the SHR technology for maize silage in the TMR for dairy cows may result in selective consumption of particles. Results of the study by Greter and DeVries [20] clearly showed that cattle were sorting their ration, regardless of feeding amounts. Cows sorted against long particles (67.3%) and tended to sort for short particles (104.4%) in both treatments. In our opinion, this type of behavior may be reduced by more frequent mixing of the TMR in a feed bunk.

### 3.3. In Situ Rumen Disappearance

Approximate values for the rumen disappearance of maize silage processed by different technologies were determined by the in situ method and are given in Table 3. After 12 h of incubation in the rumen, the dry matter disappearance was lower for SHR in comparison with MAX. The 24 h dry matter disappearance was greater for MAX than for the control and SHR, which did not differ from each other, and after 48 h the dry-matter disappearance was lowest for the control and highest for MAX. Similar results were also obtained for the organic matter (OM) disappearance.

The NDF disappearance showed higher values for MAX compared to the control at 24 h incubation time. Both SHR and MAX had higher NDF disappearance after 48 h of incubation, in comparison with the control. The disappearance of NDF in the rumen was not affected by the theoretical length of cut in the study by Couderc et al. [21], suggesting that the higher NDF disappearance observed for the SHR and MAX technologies was achieved by greater stover disruption (called pulping), thus making nutrients more accessible to rumen microorganisms. Larger particle surface area and a decreased proportion of large

feed particles were also associated with greater rumen disappearance of the rations in the study by Cao et al. [22].

**Table 3.** Effect of maize silage processing on rumen disappearance of dry matter, organic matter, NDF and starch.

	Control	SHR	MAX	SEM	<i>p</i>
Disappearance, %					
Dry matter					
12 h	53.1 <sup>ab</sup>	49.2 <sup>b</sup>	55.2 <sup>a</sup>	2.98	0.003
24 h	63.5 <sup>b</sup>	64.8 <sup>b</sup>	70.6 <sup>a</sup>	2.07	<0.001
48 h	74.4 <sup>c</sup>	77.2 <sup>b</sup>	80.2 <sup>a</sup>	3.23	<0.001
Organic matter					
12 h	52.7 <sup>ab</sup>	48.7 <sup>b</sup>	54.6 <sup>a</sup>	3.06	0.004
24 h	63.4 <sup>b</sup>	64.4 <sup>b</sup>	70.3 <sup>a</sup>	2.08	<0.001
48 h	74.9 <sup>c</sup>	77.4 <sup>b</sup>	70.3 <sup>a</sup>	1.43	<0.001
NDF					
24 h	49.5 <sup>b</sup>	53.6 <sup>ab</sup>	56.4 <sup>a</sup>	3.38	0.003
48 h	65.3 <sup>b</sup>	71.8 <sup>a</sup>	70.6 <sup>a</sup>	2.45	0.003
Starch					
12 h	76.6 <sup>b</sup>	78.4 <sup>b</sup>	82.0 <sup>a</sup>	1.78	<0.001
24 h	91.6 <sup>b</sup>	95.4 <sup>a</sup>	95.3 <sup>a</sup>	0.95	<0.001

SHR = Shredlage processing; MAX = processing using MCC MAX (MAX) crop cracker. Means within rows with different superscript letters indicate a significant difference at  $p < 0.05$ .

Starch disappearance in the rumen was assessed after incubation for 12 h, when the highest values were achieved by MAX, and after 24 h, when both SHR and MAX had significantly higher starch disappearance than the control. No differences in starch disappearance were found between MAX and SHR. Dias et al. [23] compared the effect of different types of maize processing on starch disappearance and observed that a higher starch disappearance in the rumen was associated with a higher percentage of starch passing through a 4.75 mm sieve. In addition, Saylor et al. [11] postulated that more aggressive processing of kernels between rolls leads to increased starch digestibility. This corresponds to our results, where both SHR and MAX had higher kernel processing, leading to higher starch disappearance after 24 h incubation.

#### 4. Conclusions

The new SHR and MAX maize processing methods had a positive effect, especially on the degree of kernel processing, which was highest for SHR, lower for MAX and lowest for conventional rollers. Better kernel processing was especially important in view of the generally lower starch content of maize silages produced during the period of the study. A tendency towards higher peNDF content was achieved with the SHR technology. Due to the higher chop processing, higher values of rumen disappearance of DM, OM and NDF after 48 h of incubation and of starch after 24 h of incubation were found for SHR and MAX, compared to the control.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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